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AUDITORY AND AUDITORY-VISUAL PERFORMANCE OF NORMALLY HEARING ADULT AGE GROUPS ON THE REVISED SPIN SENTENCE MATERIALS

The Ohio State University

Ph.D. 1983

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AUDITORY AND AUDITORY-VISUAL PERFORMANCE
OF NORMALLY HEARING ADULT AGE GROUPS
ON THE REVISED SPIN SENTENCE MATERIALS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Richard Edward Gans, B.A., M.S.

* * * *

The Ohio State University

1983

Reading Committee:  Approved By:
Edward J. Hardick
Herbert J. Oyer
Lida G. Wall

Edward J. Hardick
Advisor
Department of Communication
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VITA

November 2, 1951 ........ Born, Newport, Rhode Island

1972 ................. B.A., Speech and Theatre
University of Tampa, Tampa, Florida.

1978 ................. M.S., Audiology
University of South Florida, Tampa, Florida.

1978-1980 ............ Instructor/Clinical Augiologist,
Northern Michigan University,
Marquette, Michigan.

1978-1980 ............ Audiologist,
Marquette General Hospital,
Marquette, Michigan.

1980-1983 ............ Audiology Supervisor, Speech and
Hearing Clinic, The Ohio State
University, Columbus, Ohio.

1982-1983 ............ Audiologist, Central Ohio Medical
Group, Columbus, Ohio.

1983 ................. Ph.D., Audiology, The Ohio State
University, Columbus, Ohio.

PUBLICATIONS and PRESENTATIONS

Hardick, E.J., and Gans, R.E. Rehabilitation Through

Psychological Impact - Individual and Community Support For
the Elderly Deaf. Paper presented at the Ohio State Medical
Center - Geriatric Medicine, Continuing Education, Columbus,
Ohio, November, 1981.

Test Retest Reliability of a New MCL-S Procedure. Paper
presented at the Ohio Speech-Language-Hearing Association
Annual Convention, Cincinnati, Ohio, April, 1981.

Reading Problems of the Deaf. Paper presented at the Upper
Penninsula Reading Association Annual Convention, Marquette,
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CHAPTER I
INTRODUCTION

Clinical experience and the scientific literature relevant to auditory-visual speech perception tells us that hearing-impaired as well as normally hearing individuals use visual cues to facilitate receptive communication (O'Neill, 1953; Sumby and Pollack, 1954; Erber, 1969; Sanders and Goodrich, 1971). It is also apparent that hearing-impaired individuals use visual cues to a greater extent than do their normally hearing counterparts.

Audiologists at the present time typically assess the hearing-impaired individual's speech perception ability in an auditory-only mode via monosyllabic word lists. A problem exists in relating these performance scores to the individual's everyday receptive communication functioning. Evaluation of receptive communication behavior and development of nonmedical management strategies cannot be optimal when assessment is exclusively unisensory in nature.

Speech perception in real-life is a complex process. The processing of acoustic, visual, and situational information combined with the listener's linguistic
abilities is occurring at simultaneous and parallel levels (O'Neill and Oyer, 1981). In conversation the receiver is provided with an abundance of cues to facilitate message understanding. Individuals vary in their ability to utilize non-auditory information. It is not unusual for hearing-impaired individuals with identical hearing loss to present quite different receptive communication problems. Therefore, it is important for clinicians to evaluate in a more global manner the hearing-impaired individuals' ability to use non-auditory information. Assessment of communication function may best be accomplished by measuring performance on a complex task that approximates real-life communication. This information would be invaluable in the development and implementation of realistic and individualized aural rehabilitation planning.

Although numerous tests of lipreading and auditory discrimination have been developed over the years, little attention has been directed toward the development of materials for assessing auditory-visual receptive communication. Currently available auditory speech materials are frequently utilized to assess auditory-visual performance. This documents the need for such an instrument.

In order to develop such an auditory-visual test of receptive communication the following steps should be taken:
1. selection of suitable materials
2. simultaneous audio and video taping of materials
3. establishment of list equivalence for auditory-only and auditory-visual conditions
4. collection of normative data based on normally hearing adults

Relative to the selection of stimulus materials the Speech Perception In Noise (SPIN) sentences (Kalikow, Stevens, and Elliott, 1977) appear to offer considerable face validity as a task representative of real-life communication. The sentences were developed to include syntactic, semantic, and prosodic cues. In addition the sentences are presented in a background of multi-speaker babble which simulates often encountered listening conditions. Although other sentence materials are readily available it is believed that the additional component of context makes the SPIN sentences a more robust instrument. The SPIN Sentences were recently revised (Nuetzel Rzeckowski, and Bilger, 1980) to enhance list equivalency. The revised SPIN (RSPIN) sentences (Appendix A) were selected for use in this investigation.

All eight RSPIN lists (50 sentences each) were video-taped and recorded in the television laboratory of the Department of Communication. A subsequent pilot study (Appendix B) provided preliminary list equivalence data for auditory-only and auditory-visual conditions for both high and low probability sentences.
Purpose of the Study

The primary focus of this investigation was the fourth step enumerated in the development of an auditory-visual test of receptive communication function; the collection of normative data from normally hearing adults, as a function of age, gender, and mode of presentation. Normative data was defined as mean performance, standard deviation, and range by age, gender, and condition. However, several hypotheses were also tested. The literature suggests that auditory-only and auditory-visual performance declines as a function of age, as does ability to make use of linguistic cues. Observation of clinic populations also suggests that females better utilize non-auditory cues than do men.

Therefore, the following hypotheses were posited and were tested by appropriate statistical analyses:

1. auditory-only performance scores decline as a function of age
2. auditory-visual performance scores decline as a function of age
3. the difference scores between high and low probability sentences decrease as a function of age
4. visual contribution (difference of auditory-only auditory-visual) is greater for females than males
Importance of the Study

At the present time the bisensory advantage is not traditionally assessed clinically, although its importance is recognized in the rehabilitation of hearing-impaired individuals. Likewise, there have been few attempts to develop acceptable assessment materials of auditory-visual speech perception. Therefore, prior to clinical use of such materials it is important that normative data be obtained on a normally hearing population due to greater homogeneity of perceptual behavior.

It is recognized that test standardization involves the collection of data on numerous subjects, but this has not been the practice in the initial standardization studies of speech tests. A review of the literature reveals that the following sample sizes were employed in the initial research of the following audiometric speech tests: (1) a monosyllabic word test, the CID Auditory Test W-22 (Hirsh, Davis, and Silverman, 1952) 15 subjects; (2) a monosyllabic word test, the N.U. Auditory Test No. 6 (Tillman and Carhart, 1966) 24 subjects; (3) in their evaluation of various forms of the CID sentences, Giolas and Duffy (1973) 30 subjects; (4) in his evaluation of the CID sentences, Sims (1975) approximately 14 subjects; and (5) in their development of the SPIN Sentence Test, Kalikow, Stevens, and Elliott (1977) 16 subjects. Such initial standardization studies were used to explore the utility of a specific test.
Therefore, prior to standardization of these materials for use with a sensorineural clinical population, their utility needs to be determined with a normally hearing population.
CHAPTER II

REVIEW OF THE LITERATURE

The purpose of the present investigation was to obtain normative data on a bisensory speech perception task utilizing an auditory-visual version of the Revised Speech Perception In Noise (RSPIN) Test. Specifically, age-related data pertaining to the use of visual and linguistic cues were examined. In this chapter, the relevant auditory-visual literature with relation to materials and presentation conditions were considered. In addition, studies concerning age and sensory performance were examined.

Auditory-Visual Speech Perception

It has been demonstrated that auditory-visual speech perception performance is better than expected from simple addition of auditory-only and visual-only scores for both normally hearing subjects (under degraded listening conditions) and hearing-impaired subjects. In auditory-visual listening conditions a bisensory interaction
can be observed between the auditory and visual perception of speech.

**Normally hearing subjects**

O'Neill (1954) was one of the first investigators to demonstrate the bisensory advantage with normally hearing subjects. Each subject was requested to lipread vowels, consonants, words and phrases under four S/N ratios (-20 dB, -10 dB, 0 dB, and +10 dB). Unfortunately, O'Neill did not directly compare the four types of stimuli. Further, O'Neill assumed that the -20 dB S/N was the equivalent of lipreading (visual-only) in noise. This assumption is consistent with the findings of Miller (1947) who found a -18 dB S/N to be the lowest ratio for which speech could be detected. Results indicated that the visual contribution became more substantial at poorer S/N ratios. Specifically, O'Neill found that the visual contribution was as great as 72% for consonants, 44.5% for vowels, 64.1% for words, and 25.9% for phrases in the most difficult listening condition (-20 dB S/N).

Sumby & Pollack (1954) substantiated the results of O'Neill, indicating that the visual complement to normally hearing subjects was greatest at the poorer S/N ratios. This study employed spondees as its stimuli and the effects of the size of the alternative response set were also examined. Under conditions of auditory-only presentation, speech intelligibility was found to decrease as the S/N was
decreased, and as the size of the vocabulary increased. The most significant finding was the high resistance to noise under the auditory-visual condition.

Erber (1969) presented spondees to his normally hearing subjects under auditory-only and auditory-visual conditions. Results were found to be consistent with those of O'Neill and Sumby and Pollack, again indicating improved bising sensory performance at poor S/N ratios. Erber also observed greater variability for auditory-visual scores at poor S/N ratios for his subjects. Erber attributed this finding to overall differences in lipreading skill among the subjects.

Also using normally hearing subjects, Sanders and Goodrich (1971) demonstrated the bising sensory advantage under three conditions of frequency distortion (400 Hz low-pass, 1800 Hz high-pass, and 400-2200 Hz band-pass). They presented W-22s to their subjects visual-only, auditory-only, and auditory-visual (however, visual-only, scores were not given). Results revealed that under the most adverse listening condition (400 Hz low-pass), the bising sensory advantage was greatest (+54%). In general terms, this finding supports those already reported above.

Binnie (1973) generated PI functions for NU #6 words for normally hearing subjects under auditory-only and auditory-visual conditions. Overall, results were consistent with those of other reported studies. Binnie demonstrated the visual contribution to be greatest at low sensation levels. Under the auditory-only condition,
however, Binnie revealed a PI slope of 4.8% versus the 5.6% obtained for the original recordings. Differences may be attributed to speaker and/or equipment differences for the auditory-visual findings, a difference of 57% was observed over the auditory-only results at 0 dB SL. At -20 dB SL (visual-only), the visual cues alone were minimal. As SL was increased, the relative contribution of visual cues diminished as would be expected.

Krug (1960) found similar results using PB-50s on both normally hearing and hearing-impaired subjects. While showing a significant bisensory advantage over auditory-only or visual-only, the amount of the visual contribution was not as great as that demonstrated by Binnie (1973). For example, at 0 dB S/N Binnie revealed an improvement of 57%, whereas Krug only showed about a 30% difference. For both hearing-impaired and normally hearing subjects. These difference can probably be attributed to differences in material, as well as speaker differences.

Steele, Binnie, and Cooper (1978) demonstrated a bisensory advantage for normally hearing subjects. Using the target scores of 29.3% and 70.7% for NU 06 words, they found the contribution of visual cues to be consistent. A mean lipreading score of 16.28% fell within the range found by Binnie (1970; 1973) and Krug (1960). In addition they reported greater auditory-visual performance variability at 29.3% than at 70.7%. This finding is consistent with Erber (1969), who found greater variability under more adverse
listening conditions due to differences in overall lipreading skills.

Most of the data in the above reviewed studies was derived from normally hearing subjects. Therefore, one can only generalize these results to the hearing-impaired population. Typically, these studies employed noise, frequency distortion, or low levels of speech signal intensity to approximate different degrees, configurations and types of hearing loss. However, it is not known how to simulate the perceptual effects of hearing loss. Erber (1975) suggested that hearing-impaired individuals probably do not perceive, process, or comprehend language stimuli, through listening or lipreading, in the same way as do normally hearing persons. Therefore, the studies to follow review the bisensory advantage with hearing-impaired subjects.

Hearing-impaired subjects

Numbers and Hudgins (1948) Prall (1957) and Ross et. al. (1972) have reported at least a 19% bisensory advantage in severely hearing-impaired children. Similarly, Craig (1964) and Erber (1972) found significant improvement in auditory-visual speech perception for severely and profoundly hearing-impaired children. These studies suggested that bisensory gains were most significant for the severely impaired group. The profoundly impaired scored lower due to the unavailability of acoustic information. Furthermore Erber (1972) found that with auditory-visual
presentation severely hearing-impaired children performed nearly as well as normally hearing children on consonant recognition.

Siegenthaler and Gruber (1969) demonstrated that the combined auditory-visual scores for hearing-impaired adults on PB-50s were higher than the sums of the separate visual-only and auditory-only scores. These results were substantiated clinically by Hutton (1959), and Hutton, Curry, and Armstrong (1959), also using word stimuli (Semi-Diagnostic Test). Similar results were found for sentences (Ewersen, Nielsen, and Nielsen, 1970). Walden, Prosek, and Worthington (1975) found that adults with noise induced hearing loss benefited from an auditory-visual presentation in their ability to detect place-of-articulation, friction, and duration features. These investigators had their subjects use their own amplification systems which led Erber (1975) to conclude that audiologists should consider amplification systems as both a hearing aid and a lipreading aid.

**Materials**

A variety of stimulus material have been utilized in the investigation of auditory-visual speech perception. Erber and McMahan (1976) presented 20 monosyllabic nouns (10 animate, 10 inanimate) in isolation and in three different positions in sentences to 15 profoundly deaf children in order to determine the effects of context on word intelligibility through lipreading. It was found that
isolated words were easier to lipread (80%) than were words in sentences (46%). This finding is contrary to that of Miller, Heise, and Lichten (1951), who found that for auditory-only conditions in noise, context facilitated word recognition. Their study also revealed that when used in the initial position of sentences, animate nouns were more intelligible (70%) than inanimate nouns (33%). Also, a correlation was made between teachers' ratings of these students' overall lipreading ability and each child's actual visual-only scores for isolated words and these words in sentences. Results indicated that there was higher correlation between teachers' ratings and a child's recognition of key words in sentences.

Erber and McMahan (1976) suggested that intelligibility can be improved by having difficult to perceive key words in sentences isolated and emphasized. Erber and McMahan indicated that sentence tests which are scored on a key word basis (e.g., CID everyday Speech Sentences), could be used to diagnose speech perception difficulties of deaf children.

Brannon (1961) found somewhat different results than Erber and McMahan. He found that sentences (Utley Lipreading test) were more intelligible (50%) than either PB-50s (35%) or spondees (30%) in a visual-only condition for normally hearing adults. These findings suggest that contextual cues afforded by sentence stimuli facilitates intelligibility in a manner similar to that found by Miller, Heise, and Lichten (1951).
The differences found by Brannon and by Erber and McMahan may be attributed to both differences in materials, and that Brannon did not use the same words in isolation as he did in sentences. Similarly, Lloyd and Price (1971) have shown that sentence familiarity improved lipreading performance of 85 severe to profound deaf college students. Each student was administered 60 sentences of a filmed lipreading test, and were asked to rate each sentence for familiarity on a five-point scale from most familiar (1) to least familiar (5). One month later, each student was re-administered the test, but this time requested to write down as much of the sentences as possible. Results revealed a low positive, but statistically significant correlation between those sentences most easy to lipread and those sentences which received highly familiar ratings. These authors recommend that familiarity of material be controlled when developing lipreading material.

Related to this study, Hull and Alpiner (1976) found a significant effect of syntactic word variations on the predictability of sentence content in lipreading for normally hearing subjects. They suggested that there is a "complement between the linguistic patterns of our language and the auditory and visual reception of sentences." These investigators employed a modified CLOZE procedure in order to systematically add word cues from stimulus sentences. Each cue word was presented (visual-only, auditory-only, and auditory-visual) individually in a predetermined order until
the words formed complete sentences. Results indicated that the visual-only condition yielded the poorest scores for all syntactic conditions. In other words, regardless of the syntactic combinations, there was no facilitating effect for predicting the test sentence. For the auditory-only condition, scores were slightly higher than visual-only, but again, no facilitating effects were observed. However, in the auditory-visual mode, sentence prediction scores were much higher. An average of only 2.13 auditorily presented cue words were necessary for prediction of sentences. It may be concluded that syntactic variations are a factor related to ease of lipreading. These authors also recommend an auditory-visual training approach based on the complementary (audition and vision) nature of our language.

It is apparent that use of different types of material for assessing auditory-visual performance yields varying results. Erber (1975) suggested the need to develop tests that could assess lipreading performance for syllables, words, sentences, and continuous discourse. Each type of test stimulus has both advantages and disadvantages. Erber stated that "whereas syllables and words allow precision in measurement, sentences and brief stories are more like the stimuli of daily conversation." The use of sentence materials as a more appropriate indicator of hearing-impaired individuals speech perception ability had been recommended earlier by Niemeyer (1965). Support for the sentence as a measure of perceptual performance is also
found in the work of Liberman et. al. (1967) and Stevens and House (1972) who suggested that sentences are the basis of speech perception.

**Linguistic Constraints**

Sanders (1971) discussed two linguistic constraints of interest to this review: (1) structural and (2) contextual. Structural constraints function at the level of a sentence and include phonemic, syntactic, and semantic rules. Contextual constraints are active between and among sentences. Each of these two linguistic constraints shall be reviewed separately.

Structural constraints refer to the rules which govern the manner in which phonemes and words may be arranged or sequenced within words and sentences respectively. Structural constraints are important to perception since a knowledge of them can assist one in predicting the nature of a message. Because of the influence of the various structural constraints, meaningful sentences are easier to perceive than single words, particularly under conditions of distortion or noise. This finding was shown by Miller, Heise, and Lichten (1951) who demonstrated that meaningful sentences provided an advantage in terms of the perception of words when those words were structured in sentences as opposed to presentation in isolation. Moreover, Miller and Isard (1963) found a difference in performance for meaningful (88.6%) as compared to meaningless (56.1%) sentence stimuli. Such evidence supports the use of
meaningful sentences for the measurement of perceptual skill because of their unique perceptual properties.

Contextual constraints are also important to the perceptual process. The context or the topic of a conversation provides cues to what a listener expects the words or sentences within the conversation to be.

Erber pointed out the need to assess auditory-visual intelligibility as a function of how well an individual maximizes contextual and situational cues. Pelson and Prather (1974) reported that contextual cues provided by relevant pictures, shown prior to presentation of sentence stimuli, facilitated lipreading performance.

This was supported by the findings of Garstecki (1976) and Garstecki and O'Neill (1980) who reported that appropriate visual and auditory cues increased auditory-visual performance while inappropriate cues had a deleterious effect.

More recently, Schow and Nerrbonne (1982) recommended using the Speech Perception In Noise (SPIN) Test (Kalikow, Stevens, and Elliott, 1977) in an auditory-only and auditory-visual paradigm with elderly clients to assess their bисensory and linguistic processing skills.

The Speech Perception In Noise (SPIN) Test

The SPIN test was developed (Kalikow, Stevens, and Elliott, 1977) to more accurately assess speech perception as it occurs in everyday listening conditions. This test is significantly different from the typical clinical
monosyllabic word lists used to assess speech discrimination. Traditional discrimination tests of words in isolation are poor predictors of performance in everyday speech in which phonologic, lexical, syntactic, and semantic cues are important in the perception of speech.

Kalikow and associates developed the materials to assess utilization of linguistic-situational cues as well as acoustic-phonetic cues as are measured in traditional monosyllabic word tests. Therefore, the required response is the final "key" word in each sentence which is a monosyllabic noun. The final word of each sentence was selected based on its low or high predictability. Low predictability (PL) sentences were constructed around neutral contexts which can be completed with practically any noun. The high predictability (PH) were developed by administering paper and pencil completion tests to 24 high-school students. The subjects were instructed to "fill in the word that you think is most likely to occur at the end," and they were told that the final words were all one syllable nouns. Intelligibility of the key word in PL sentences is heavily dependent on acoustic information. However, PH sentences provide contextual as well as acoustic cues to the final word. These sentences contain pointer words which provide a semantic clue to the key word in the final position. Therefore, accurate acoustic perception of the key word is not as critical as for the PL sentences.
Word familiarity has been demonstrated (Owens, 1961) to affect intelligibility and was controlled for in the development of the SPIN sentences. Key words were chosen based on moderate frequency of occurrence. Words which were common or unusual were eliminated. The key and pointer words were selected to be representative of the major phoneme groups in English. A total of 200 words were finally selected and placed in eight equivalent test forms containing 25 sentences of each predictability level randomized within each list. Further analysis of list equivalency has recently been conducted (Nuetzel, Rzeckowski, and Bilger, 1980; and eight new forms have been developed, which will be referred to hereafter as the Revised SPIN (RSPIN) sentences.

In order to more fully represent real-life communication situations the sentences are presented with a background of speech babble. As would be expected the addition of noise decreases discrimination scores and increases intersubject variability (Kalikow, Stevens and Elliott, 1977; Hutcherson, Dirks, and Morgan, 1979).

The SPIN test not only assesses acoustic and linguistic competency but offers the added dimension of speech discrimination in noise. Therefore, the addition of a visual mode to the SPIN test approximates a real-life communication situation.
Age and Sensory Performance

Birren (1964) defines aging as the deterioration of a mature organism resulting from time-dependent, essentially irreversible structural changes. According to Birren (1964) organisms as they advance in age become more susceptible to deleterious conditions and the self-repair ability of the organism is decreased. Oyer and Oyer (1976) also consider aging to be a slow but continuous process that results in the cessation of growth and in physical decline with a decreased bodily ability to regenerate or renew.

Peripheral and central changes in receptors and pathways have a direct effect on the performance of older adults. It has been well documented that older persons process information and behave differently than younger persons. The literature (Corso, 1971; Birren and Schaie, 1977; Botwinick, 1978) suggests that they are different while attending to, perceiving, encoding, and remembering information. Quite simply, older adults do not see, hear, or otherwise perceive as do younger persons.

Age related differences between young and older persons have been reported for all the sensory modalities. Vision and audition, however, are more easily and reliably investigated than the other senses. Changes in these two primary modalities have the greatest potential impact for affecting the behavior of the older adult. Therefore, it is not surprising that intact vision and hearing are ranked
first in importance by older adults themselves for a healthy old age (Rupp, 1977).

**Vision**

Changes in the aging eye primarily affect the lens ability to transmit and reflect light. Weales (1965) has estimated that only 1/3 of the energy incident on the retina of a young eye (20 years) reaches the retina of an old eye (85 years) due to yellowing of the lens and changes in pupil size with age. As reported by Botwinick (1978), Chapanis (1950) and Hirsch (1960) found little age-related change in visual acuity up to 40 to 50 years of age, but a marked decline thereafter. By age 70, poor vision is the rule rather than the exception. These changes also affect color vision as the yellowing lens filters out blues, greens, and violets making accurate color discrimination difficult.

Pastalan, Mantz, and Merrill, (1973) found that ordinary daily tasks require three times as much lighting for the average older adult than for the average 20 year old. Increased illumination however can cause increased glare. Wolf (1960) found 80 year olds to be hyper-sensitive to increased glare compared to 20 year olds.

Peripheral changes in visual acuity may not be the primary factor involved in the visual problems of older adults, nor may they be as simply resolved by refraction or lighting.

**Visual processing.** Numerous investigators have studied older adults ability to process relevant versus
irrelevant information. There is evidence indicating that older adults have greater difficulty ignoring irrelevant stimuli (Rabbitt, 1968). Layton (1975) has suggested the concept of "perceptual noise" to explain this masking phenomenon. The masking effect seems to be, at least in part, attributable to age changes in the central mechanisms concerned with perceptual processing which limit the rate at which stimuli can be "cleared" through the nervous system. In essence the problem is attributed to stimulus persistence within the nervous system of the older adult.

A primary means of investigating this phenomenon is via visual masking studies which examine the speed and quality of the visual sensory and perceptual process. Kline and Szafran (1975) found a significant decrease in the "stimulus clearing" speed of older adults (X = 68.2 years) compared to younger adults (X = 23.3 years). They also found that younger subjects had significantly faster recognition thresholds (2.1 msec) than did the older group (3.2 msec). They attributed their results to stimulus traces remaining in the older nervous systems.

Walsh (1976) found that older adults (X = 64.2 years) required a 24% longer interstimulus interval than did younger adults (X = 19.5 years) to escape the masking effect. In a subsequent study Walsh and Thompson (1978) investigated the perceived persistence of a single visual item in young (X = 24.5 years) and older (X = 67 years) adults. The letter 0 was flashed while interstimulus
interval and target duration were manipulated, the subjects reported when they perceived the 0 to be on continuously. Visual storage for the younger group was 15% greater than the older group. The investigators suggested that the results may be attributable to prolonged stimulus persistence in the older nervous system. This would suggest a decrease in the information holding capacity of the aging nervous system.

Kline and Orme-Rogers (1978) found supporting evidence for the stimulus-persistence phenomenon in aging adults. These researchers using half-words composed of lines reported that older subjects (X = 68 years) achieved higher word recognition scores than did younger subjects (X = 18.9 years) particularly as interstimulus interval was increased. Correct word recognition threshold was found to be an inverse function of both stimulus duration and interstimulus interval.

Recently, Wright and Elias (1979) suggested that older adults may, in fact, not be poorer at ignoring irrelevant stimuli, but rather may have difficulty discriminating between relevant and irrelevant items.

**Audition**

Estimates show that the incidence of hearing loss is approximately 10 times as great in the older adult than it is among those in early adulthood (Oyer and Oyer, 1976). The deterioration of the auditory system can have a significant effect on the extent to which the older person
remains in contact with others. Most gerontologists regard hearing loss as more important than loss of vision in terms of provoking emotional upset (Hendricks and Hendricks, 1977).

Age-related changes have been reported at all levels of the peripheral (Rosenwasser, 1964; Bredberg, 1964; Schknecht, 1964; and Johnsson and Hawkins, 1972) and central (Krmpotic-Nemanic, 1971; Brody, 1955; and Kent, 1976) auditory mechanism.

Presbycusis is a term labeling that hearing impairment occurring with age. It is most often characterized by a progressive loss of auditory sensitivity to high frequency pure tones, as well as a decreased ability to understand speech in everyday listening situations. Spoor (1967) reported presbycusic curves which combined data gained from eight different studies. Spoor's composite curve indicates that for frequencies up to 1000 Hz, the loss in hearing sensitivity is less than 5 dB for both males and females up to fifty years of age. For frequencies above 1000 Hz hearing impairment increases as frequency increases for all age groups. 

**Speech Discrimination**

Bergman (1971) views the gradual breakdown in the ability to understand speech as the major effect of presbycusis. It is his hypothesis that while the ability to hear soft sounds is important to lower animals, humans
utilize a more complex form of hearing to communicate through speech.

Auditory discrimination involves a number of factors and interacting processes which include parameters of the auditory stimulus, sensory organs, and the central or perceptual processes (Olsen, 1965). Sensation is commonly defined as the (reportable) conscious awareness of comparatively simple stimuli. Perception, however, is necessary in the process of understanding speech. Birren (1964) defines perception as the recognition of complex stimuli and the interpretation of, or meaning attached to the patterns of sensation, rather than to the mere awareness of sensation. Various investigators (Punch and McConnell, 1969; Willeford, 1977; Hull, 1977) have commented that the speech discrimination of older adults cannot always be predicted reliably from the pure-tone audiogram.

Studies that have investigated the speech discrimination abilities of older subjects have presented speech stimuli monotonically and dichotically in quiet or in noise. Speech stimuli have been intentionally distorted by filtering or by altering their normal temporal parameters.

Speech intelligibility in quiet. Gaeth (1948) was one of the first investigators to report a relationship between aging and monotic discrimination scores measured in quiet. Discrimination scores decreased as age increased. He termed this loss of speech discrimination ability in the older adult "phonemic regression."
Pestalozza and Shore (1955) found lower speech discrimination scores in older persons than in younger subjects despite similar pure-tone audiograms. In general, as the amount of hearing loss increased the problem of understanding speech also increased. In the group of older individuals, however, discrimination loss was independent of the slope of the audiogram. Blumenfeld, Bergman, and Millner (1969) reported similar results particularly for persons over the age of 60.

Although reduced speech discrimination ability is often noted among older persons, it is not a universal condition. Melrose, Welsh, and Luterman (1963) investigated the monotonic speech discrimination scores of 52 veterans of the Spanish American War. The mean age was 82 years. The older subjects all were experiencing mild sensorineural losses, and the majority had lowered discrimination scores. However, 30% had scores in the 19th percentile. The authors suggest than phonemic regression is not a consistent finding in presbycusis.

**Speech intelligibility in noise.** Olsen (1965) reported that a major cause of the older adult's auditory discrimination problems relates to a lack of attention, concentration, and flexibility necessary to cope effectively with constantly changing sound patterns. Interference with maximal auditory efficiency in practical everyday listening situations occurs most frequently as a result of conflicting
high ambient noise levels or the sound of other engaged in conversation.

A study conducted by Olsen (1965) investigated voice recognition ability of 50 young adults, age 17 to 26 years, and 50 subjects age 60 to 95 years, in a voice interference situation. The subjects were required to first become familiar with one voice, then to report messages relayed by that voice when masked by an interfering voice. Two versions were given, one normal, the other a low band pass version to discount any high frequency hearing losses.

The older subjects were less able to make use of minimal auditory cues in discriminating between the message sender and the interfering voice. They also could not store information in their auditory memory long enough to relay the information.

Olsen speculated that the older subjects performed poorer than the younger subjects because: (1) the older subjects were auditorily confused and they did not have the ability to selectively "filter" or "scan" the message; (2) the central integration functions of the aged become overloaded which caused confusion; and (3) The older subjects had more difficulty performing the complex task than did the younger subjects.

Blumenfeld, Bergman, and Miller, (1969) utilized the Rhyme Test of speech discrimination to study the relationship between speech discrimination scores and aging in 55 older adults. The scores tended to decrease as age
increased, particularly in the age group over 60 years for test situations both in noise and in quiet. The subjects' self-estimate of hearing handicap correlated with their speech discrimination scores.

Smith and Prather (1971) have studied the effects of signal-to-noise ratios on an older population. Ten subjects over 60 years old, all having pure-tone averages within normal limits, were compared with a group of younger subjects for phoneme discrimination. Speech tapes were passed through a low-bandpass filter to discount for high frequency hearing losses. As might be expected the discrimination scores of the older subjects were significantly poorer than those of the younger group.

In addition to the deleterious effects upon speech discrimination of external noise, Smith and Prather (1971) speculate that there is also an internal noise that may interfere with ability to understand speech. The authors suggest this is a definite variable as to why reduced discrimination is observed in older individuals whether they listen in quiet or in external noise.

This theory of internal or neural noise in older individuals was discussed earlier (Layton, 1975). The trains of nerve impulses convey signals against a background of random, ambient neural activity ("neural noise") in the nerve pathways and brain. Since the noise level, however, fluctuates, the signal must be sampled by the elderly person for a period of time if it is to be distinguished reliably
from the background "noise". The length of time needed to
sample the stimuli will depend on the signal-to-noise ratio.
The time needed will increase as the signal decreases, or if
the "noise" increases.

Bergman et al. (1976) conducted a 10 year study of
speech perception in a variety of altered conditions. This
study is the only one to date that has investigated a number
of altered listening conditions. Two Hundred and eighty two
persons ranging from 20 to 80 years old were subjects for
their extensive research. The recorded test material were
the CID Sentences (Davis and Silverman, 1970) spoken by five
different speakers, varying in age, sex, and accent.

The findings of Bergman et. al. (1976) suggest the
greatest changes in speech discrimination ability with age
are in the perception of distorted and competing speech.
The older patient will often tell the audiologist that he or
she can hear fine when only one person is speaking.

Rehabilitation methods offered to older patients and
their families will usually include the need for limited
background noise, one speaker at a time, and familiarity
with the subject under discussion. These compensatory
methods will afford the older adult a greater ease in the
perception of speech.

Auditory-Visual Performance

In view of the significant differences between young
and old individuals in the reception and processing of
auditory and visual information it is not surprising that
age-related bisensory performance has been noted to decline in older adults.

Goetzinger (1964) reported significantly better lipreading scores for subjects in the age range of 18 to 22 years. This supported the findings of Farrimand (1959) who found an 8% per decade decline in lipreading ability past the age of 30 years. Likewise, Ewertsen and Nielson (1971) and Pelson and Prather (1974) also found younger subjects to be superior lipreaders to older subjects.

Until recently, an obvious factor which may influence auditory-visual performance escaped critical review. The ability to lipread is dependent upon how well an individual sees. Hardick, Oyer, and Irion, (1970) investigated lipreading (visual-only) performance as it relates to measurements of vision. Out of a pool of 53 subjects, the 8 who scored the highest and the 8 who scored the lowest on the Utley Lipreading test were selected for this study. All 16 of these subjects had normal hearing and no formal lipreading training. Each subject then received complete optometric evaluations. Subjects who received the lipreading test with corrective lenses were evaluated optometrically with their lenses. In general, the results indicated that those subjects who were optometrically normal performed better on the lipreading test. Even those subjects with only a slight optometric abnormality performed inferior to those with normal vision.
In order to study auditory-visual speech perception under poor optical conditions, Erber (1979) varied the available optical cues to normally hearing and hearing-impaired subjects by placing a rough sheet of Plexiglas between talker and subject at different distances, and under visual-only and auditory-visual conditions. Erber indicated that varying the distance of the Plexiglas distorted the optical cues in a way analogous to masking or filtering acoustic cues. Subjects were presented live with words and sentences at different distances (optical distortion), and each was asked to identify the material. Under the visual-only condition, performance dropped to chance level as blurring was increased (beyond 20 cm = 10% or less). Auditory-visual performance was good at close viewing (less than 10 cm = 90% or more); however, scores dropped substantially as distance was increased. Results of this study closely parallel those of Sumby and Pollack (1954) and Sanders and Goodrich (1971), indicating the increased contribution of visual cues to audition under adverse listening conditions. However, in Erbers' study, the reciprocal was the case; i.e., the contribution of auditory cues to vision under adverse viewing conditions. Erber concluded that optical distortion techniques may have potential as an auditory training method for those hearing-impaired individuals who use audition as their nondominant modality.
These studies have particular importance to the auditory-visual capabilities of older adults due to age-related change in visual acuity and processing. Further difficulties are presented by the rapid rate and coarticulatory effects of normal conversational speech. Shepherd et. al. (1977) reported high negative correlations (-.90) between lipreading ability and visual neuronal firing. Their findings suggest that use of visual information may be physiologically based. Although this particular study did not investigate age effects, evoked potential studies of other sensory modalities have indicated age-related changes with increased transmission time of neuronal conduction.

One criticism of research to date examining differences between young and old individuals ability in the use of visual cues has been the lack of simultaneous auditory-visual presentation i.e. the bisensory advantage.

**Conditions for Auditory-Visual Presentation**

It has been documented that the conditions under which auditory-visual speech perception is assessed will affect the bisensory advantage. Those factors contributing to auditory-visual performance are 1) visual i.e. angle, distance, and illumination, and 2) auditory i.e. masking noise and presentation level.

**Angle, Distance and Illumination**

Neely (1956) investigated the effects of both angle and distance on lipreading performance for 35 subjects with
normal hearing and vision. Each subject was administered a multiple-choice intelligibility test at three distances (3, 6, and 9 feet), and three viewing angles (0°, 45° and 90°). Results indicated that lipreading performance deteriorated as viewing angle of the face changed from 0° to 90°. However, the effect of distance (3 to 9 feet) was not found to be significant.

Erber (1971b) also studied the effects of distance on lipreading performance of 240 common nouns (80 monosyllables, 80 trochees, 80 spondees) for six profoundly deaf children. Results revealed that under conditions of bright, shadow-free illumination, scores decreased from 75% correct at 5 feet to 11% correct at 100 feet. A systematic decrease for lipreading scores of 0.8%/foot was observed for the distance range of 5 to 70 feet, and about 0.5%/foot from 70 to 100 feet. While Neely observed only a negligible distance effect from 3 to 9 feet, the Erber study revealed a systematic variation within this same range. This may be attributable to the differences in lighting. Neely used standard illumination, while Erber employed special mouth level illumination which allowed observers to visualize certain tongue movements that are not normally perceivable. Erber also suggested that this difference may be attributed to the lack of lipreading skill for the untrained observers in Neely's study.
Another interesting finding in the Erber study was that vowel identification scores were less dependent on distance than were consonant identification scores.

In a more extensive study, Erber (1974) investigated the effects of angle, distance, and illumination on the lipreading scores of 240 nouns for 11 profoundly deaf children. Results indicated the following: (1) highest lipreading performance scores were obtained for 0° or 45° horizontal viewing angles; (2) average lipreading scores deteriorated from 14 to 22% when viewing angle was increased to 90°; (3) decreasing distance from 6 to 24 feet for the viewing angles of 0° to 45° increased intelligibility scores (0.8 to 1.6%/foot which compares favorably to Erber, 1971b); (4) varying the vertical viewing angle from -30° to +30° had a negligible effect on visual-only performance; (5) illumination conditions which shadowed the speaker's oral cavity (overhead lighting, +90°) for the horizontal viewing angles of 0° to 45°, resulted in a 3 to 12% decrease in lipreading performance compared to the 0° or +45° angles of light incidence; (6) with frontal illumination of the speaker, a reduction in facial luminance from 30 to 0.03 footlamberts, resulted in a 13% decrease in visual-only scores; (7) however, under conditions of high background illumination, a reduction in facial luminance from 30 to 3 footlamberts resulted in a mean decrement of 41%.

These findings have educational and clinical implications. Erber suggested that communication in the
classes for hearing-impaired students can be improved by positioning teachers so they face the windows when they speak, and by concentrating students' desks so that the viewing angle does not exceed 45%.

**Masking Noise**

Several studies with normally hearing adults (O'Neill, 1953; Sumby and Pollack, 1954; Erber, 1969; and Sanders and Goodrich, 1971) have demonstrated that as the signal-to-noise ratio is decreased speech discrimination decreased but the visual contribution increased. In other words, as the auditory signal becomes more degraded the visual contribution becomes more apparent.

In the only auditory-visual study to investigate masking stimuli, Binnie (1970) used normally hearing subjects to study the effects of different types of noise on four types of speech stimuli, and under visual-only auditory-only, and auditory-visual conditions. Overall, results revealed that the auditory-visual condition yielded the best results. The average visual-only scores for monosyllables, disyllables and sentences was about 30%, while the visual-only score for continuous discourse was much lower. It is apparent that the high redundancy of continuous discourse in the auditory-only condition is absent when only visual cues are afforded to the listener. Perhaps this is due to the difficulty tracking the quickly changing transitional movements during running speech (co-articulation).
Binnie (1973) also found that the auditory-visual advantage was improved over the auditory-only scores in all types of noise. However, single-speaker noise resulted in the highest intelligibility scores, whereas uniform white noise resulted in the poorest. Moreover, sentence intelligibility scores remained highest regardless of the noise type used.

**Presentation Level**

The intensity level at which speech materials are presented is an important factor in the assessment of an individual's speech perception ability. The findings of Krug (1960) and Binnie (1973) indicate that not only do listeners perform best with an auditory-visual presentation but that the visual contribution was greatest at low sensation levels. These results are consistent with the findings of studies employing varied signal-to-noise ratios indicating the greatest visual contribution in the most difficult listening conditions.

It has been recommended (Binnie, 1973; Giolas and Duffy, 1973; Kalikow, Stevens, and Elliott, 1977; Speaks et al., 1972) that if real-life communication situations are being investigated it would be most logical to present the test stimuli at a level consistent with real-life listening conditions.

**Summary**

The literature concerning auditory-visual speech perception and age-related sensory performance was reviewed
in this chapter. Previous investigators have found that normally hearing and hearing impaired individuals benefit significantly more from a bisensory message than can be explained by a simple addition of audition and vision alone.

A review of the literature revealed that the type of stimuli utilized will affect intelligibility. Although the principal rationale for auditory-visual testing is to assess everyday communication ability, very few studies have utilized sentence materials. Furthermore, at the present time there has been no attempt to standardize auditory-visual materials or to gather age-related normative data.

Sensory performance and age-related differences for the primary sense modalities of vision and audition have been reviewed. Age differences are obvious for both sensory reception and central processing. In addition several studies reported age-related decrements in auditory-visual speech perception. However, many of these studies examined only unisensory (visual-alone or auditory-alone) performance and are therefore limited. Based on the literature relevent to age-related sensory performance it is unreasonable to expect older adults to perform as well on visual-only or auditory-only tasks.

These scientific findings contributed to the formulation of the research questions in the present investigation. That is, does the relationship of visual contribution and linguistic cue use in real-life
communication change as a function of age? Specifically, auditory-visual speech perception was studied in normally hearing individuals ranging in age from 20 to 70 years. Administration of the RSPIN test with a signal-to-babble ratio (-8 dB) adjusted to maximize visual and linguistic information usage was utilized.
CHAPTER III

EXPERIMENTAL METHODS

The present study was designed to collect normative data on an auditory-visual task representative of everyday receptive communication, as a function of age, gender, and condition. This chapter includes a description of subjects, materials, instrumentation, and experimental procedures. In addition, statistical methods of data analysis are discussed.

The general procedures of this study involved the presentation of four lists of fifty sentences to each subject who in turn wrote down the final "key" word as perceived. Two stimulus conditions were employed: (1) auditory-only with a noise background, and (2) auditory-visual with a noise background.
Subjects

Subjects for this study were 90 normally hearing adults, ranging in age from 20 - 70 years. Fifteen males and 15 females were included in each of three age categories. The distribution within age categories is summarized in Table 1.

TABLE 1. Means, standard deviations and ranges of age by gender for 90 normally hearing adults in 3 age groups

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>20-30 years</th>
<th>40-50 years</th>
<th>60-70 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M F</td>
<td>M F</td>
<td>M F</td>
</tr>
<tr>
<td>Mean</td>
<td>22.5 23.9</td>
<td>43.8 45.07</td>
<td>64.13 63.80</td>
</tr>
<tr>
<td>S.D.</td>
<td>2.56 2.60</td>
<td>3.0 3.01</td>
<td>3.09 3.80</td>
</tr>
<tr>
<td>Range</td>
<td>20-27 21-29</td>
<td>40-50 40-50</td>
<td>60-70 60-70</td>
</tr>
</tbody>
</table>

Subjects were selected if they met the following criteria: (1) hearing within normal limits (for their respective age group) at 500, 1000, 2000, and 4000 Hz (ANSI, 1969); (2) at least 20/30 far vision (correction allowed) as determined by the Snellen chart; (3) at least a high school education or equivalent; (4) native speakers of English; and (5) no previous speechreading training. The subjects in the 20-30 and 40-50 age groups had thresholds no greater than 20 dB HL. The OSU Regression (Hardick, 1979) provided average thresholds for 60-70 year olds (Appendix C) as the criterion.
for that age group. Means, standard deviations and ranges of better ear thresholds in dB HL for all 90 subjects can be seen in Table 2.

Lists and mode of presentation were systematically controlled to minimize possible order-effects. This was accomplished by starting individuals of each group of 15 subjects randomly on a different list and mode of presentation. The results were, seven subjects started with auditory-only and the other eight with auditory-visual. With this method of ordering presentation, it was possible to minimize learning or practice effects.

Materials

The Speech Perception In Noise (SPIN) Sentences (Kalikow, Stevens, and Elliott, 1977) as revised by Nuetzel, Rcezokowski, and Bilger (1980) were used as the stimuli. The sentences were recorded on videotape in the television laboratory of the Department of Communication of The Ohio State University. The recording process and control of appropriate lighting conditions were conducted by the professional staff of the television laboratory. The speaker, a 30 year old male, was familiar with the task and the sentence materials, and had practiced reading these sentences orally so that he could produce each sentence in
Table 2. Means, standard deviations, and ranges of better ear thresholds in dB HL by frequency, sex, and age for 90 normally hearing adults.

<table>
<thead>
<tr>
<th></th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>Hz</th>
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<td></td>
<td>M</td>
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<td>F</td>
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<td>20-30 Years</td>
<td></td>
<td></td>
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<tr>
<td>X</td>
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<td>2.00</td>
<td>1.33</td>
<td>3.00</td>
<td>1.00</td>
</tr>
<tr>
<td>SD</td>
<td>3.20</td>
<td>2.53</td>
<td>2.30</td>
<td>4.55</td>
<td>2.07</td>
</tr>
<tr>
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<td>0-15</td>
<td>0-5</td>
</tr>
<tr>
<td>40-50 Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>1.00</td>
<td>2.66</td>
<td>1.70</td>
<td>4.33</td>
<td>3.67</td>
</tr>
<tr>
<td>SD</td>
<td>1.76</td>
<td>5.00</td>
<td>3.10</td>
<td>4.60</td>
<td>6.11</td>
</tr>
<tr>
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<td>0-20</td>
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<tr>
<td>60-70 Years</td>
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<tr>
<td>X</td>
<td>5.00</td>
<td>4.66</td>
<td>4.33</td>
<td>6.00</td>
<td>8.00</td>
</tr>
<tr>
<td>SD</td>
<td>6.00</td>
<td>6.11</td>
<td>5.00</td>
<td>4.31</td>
<td>5.61</td>
</tr>
<tr>
<td>Range</td>
<td>0-15</td>
<td>0-20</td>
<td>0-15</td>
<td>0-15</td>
<td>0-20</td>
</tr>
</tbody>
</table>
as natural a manner as possible with equal vocal effort.
The video-tape recording provided a 0° azimuth view of the speaker's upper torso and head.

**Instrumentation**

The instrumentation employed for the video-taping included:
1. Color camera (Hitachi, Model FP1010);
2. Videocassette recorder (Sony, Model VO2850);
3. Microphone (Sony, Model ECM-16);
4. Audio console (General Electric).

The master tape was edited with an automatic editing control unit (Sony-U-Matic), and each list copied onto a new tape (Scotch High Energy UCA 60 color video-tape) which served as the actual experimental tapes.

The auditory signal was analyzed to obtain an estimate of amplitude variation in VU units. The variation among the 50 sentences in each list was ± 3 dB VU units relative to the 1000 Hz calibration tone recorded at the beginning of the videotape. Sentences were recorded with an auditory sentence number cue as well as a visual number cue on the videotape superimposed in the corner of the screen in a contrasting color. There was a constant 20 second interval between the end and the beginning of adjacent sentences. After each sentence a 15 second interval was provided, followed by a 5 second interval in which the item number of the next sentence was provided. This sequence allowed
sufficient time for the subject to write a response and also provided a timing cue relative to stimulus presentation.

**Stimulus Presentation.**

Figure 1 is a block diagram of the instrumentation used for stimulus presentation. The auditory and visual signals were presented from a videocassette recorder (Wollensak, Model VR-210). Competing speech babble was presented from a stereo-cassette recorder (Sony, Model TC-117). The experimenter monitored the auditory and visual signals through a 19 inch color monitor (Panasonic). The auditory signal presented to the subjects was delivered from the video-tape recorder to an audiometer (Grason-Stadler, Model 1702) where it was mixed with the speech babble from the cassette recorder and controlled for presentation level. The combined auditory stimuli, including the competing speech babble were passed through a stereo amplifier (Harmon Kardon, Model Citation B) before transduction via a loudspeaker (Electro-Voice, Model SP8 B), mounted in a high-fidelity speaker enclosure.

The loudspeaker was situated in one corner of a single-walled sound room, (IAC, Model 402) in a horizontal position approximately one meter from the floor. The subject's 19 inch color monitor (Panasonic, Model CT-1920M) was located directly below the loudspeaker at the subject's eye level. Subjects were seated 4.5 feet from the loudspeaker and monitor. Communication between the examiner and the
Figure 1. Block Diagram of Instrumentation Used for Stimulus Presentation.
subjects and the examiner was possible at all times (talkforward and talkback).

The auditory signal was delivered at 65 dB SPL and the speech babble at 73 dB SPL. The VU meter of the audiometer was used to monitor: (1) the 1000 Hz calibration tone from the video-tape and (2) the calibration tone on the speech babble tape. The attenuators of the audiometer were adjusted to achieve the desired -8 dB signal-to-noise ratio.

Acoustical calibration was performed by introducing speech noise from a noise generator (Grason Stadler, Model 901A) through the respective channels of the audiometer. Measurements were performed with a sound level meter (Brüel and Kjær, Model 2204) and a condenser free-field microphone, (Brüel and Kjær, Model 4145) at the position of the listener's head which was 4.5 feet from the sound-field loudspeaker.

**Experimental Procedures**

Analysis of the pilot study data (Appendix B) indicated that lists 1, 3, 4, 6, 7, and 8 were the most homogeneous across all conditions for high and low probability. In order to develop multiple lists and avoid any duplication of "key" words, lists 1, 3, 6, and 8 were selected for use in this investigation.

All subjects were provided a "warm-up" practice session which included 5 sentences for auditory-only or
auditory-visual prior to the respective presentation mode at a +10 signal-to-noise ratio. Subjects were required to produce a written response for each of the items in a list (Appendix D). Twenty seconds were provided for each response, however additional time was available as necessary. The entire experimental task required approximately 1 hour, including the "warm-up" session. Subjects were provided with a written copy of the instructions (Appendix E) to read while they were presented verbally.

Two modes of stimulus presentation were used with all subjects. They were:

**Auditory-only in noise.**

Each of the subjects when receiving this condition was required to respond to an auditory presentation of each sentence with a constant competing noise background. The auditory stimulus and the competing speech babble noise were presented at a -8 dB signal-to-noise ratio (speech at 65 dB SPL; noise at a 73 dB SPL sound level).

**Auditory-visual in noise.**

Each of the subjects when receiving this condition was required to respond to a simultaneous presentation of auditory and visual signals with a constant competing noise background. A -8 dB signal-to-noise ratio was employed as noted above.
Scoring Procedures

The revised SPIN (RSPIN) Sentences (Nuetzel, Rzecowski, and Bilger, 1980) with key words underlined can be found in Appendix A. Certain exceptions to the scoring procedures advocated by the original authors was employed. Identifiable misspelled words (brews/brulse) and changes in number (thorn/thorns) were scored as correct.

Experimental Measures and Data Analysis

Four basic measures were obtained for each subject. They were percent correct score for the AVPH, AVPL, APH, and APL conditions. Each subject received 2 lists for each condition, auditory-only and auditory-visual. The 2 scores were averaged and recorded as the criterion value for the respective presentation condition. In addition, four difference scores were computed for each person. The difference scores indicated the relative visual and contextual contribution for each condition. These included: AVPH - APH, visual contribution - probability high; AVPL - APL, visual contribution - probability low; AVPH - AVPL, contextual - auditory-visual; APH - APL, contextual - auditory-only.

Equivalence of the four lists utilized in this study as a function of presentation condition was also investigated e.g. List 1 AVPH, List 1 AVPL, List 1 APH, and List 1 APL.
The data were analyzed at The Ohio State University Statistics Laboratory. The primary statistic used was a two factor randomized analysis of variance. The advantage of this statistic is that it offers the most robust examination of interval data involving two groups or more and subsequent interactions (Kennedy, 1978). A total of 12 ANOVA's were performed, one for each of the four basic measures, the four difference scores, and the four last examined list equivalence.
CHAPTER IV

RESULTS AND DISCUSSION

The data collected can be viewed in 2 different ways. First, the major purposes was to obtain normative data from normally hearing adults on a task of receptive communication function.

Second, several hypotheses concerning differences in performance as a function of age and gender were tested. The test of these hypotheses forms a second subdivision of the chapter. A general discussion of the results comprises the third part of the chapter, culminating in a summary of the findings.

Performance by Normally Hearing Adults

Auditory-visual

The normative data obtained at a \(-8\)dB signal-to-noise ratio provided valuable information on how normally hearing people performed on this bisensory task. The data allows direct comparison of the performance of hearing-impaired persons relative to normally hearing people.
Summary data, consisting of means, standard deviations, and ranges of auditory-visual performance by age and gender are presented in Table 3.

Table 3. Means, standard deviations, and ranges of percent correct scores for auditory-visual performance on the RSPIN sentences for 90 normally hearing adults by age, gender, and context.

<table>
<thead>
<tr>
<th></th>
<th>20-30 years</th>
<th>40-50 years</th>
<th>60-70 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Probability High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>93.60</td>
<td>93.50</td>
<td>85.73</td>
</tr>
<tr>
<td>SD</td>
<td>5.08</td>
<td>5.73</td>
<td>11.66</td>
</tr>
<tr>
<td>Range</td>
<td>84-100</td>
<td>76-100</td>
<td>54-100</td>
</tr>
<tr>
<td>Probability Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>66.07</td>
<td>63.20</td>
<td>51.60</td>
</tr>
<tr>
<td>SD</td>
<td>4.82</td>
<td>11.87</td>
<td>18.00</td>
</tr>
<tr>
<td>Range</td>
<td>56-74</td>
<td>42-76</td>
<td>6-72</td>
</tr>
</tbody>
</table>

The mean performance for the high probability sentences approached 100%. Actually, only 5 individuals or 5.5% of the total number of subjects obtained a perfect score. This suggests the -8dB signal-to-noise ratio was appropriate for the task. Three of these subjects were in the 20-30 year group and 2 were in the 40-50 year group. Twenty-two subjects, approximately 25% of the 90 subjects, scored 95%
or better. Of these 22, 14 were 20-30 years, 7 were 40-50 years, and 1 was 60-70 years. This distribution is indicative of changes with age.

Examination of the auditory-visual performance data suggests several trends. Mean performance was greater for high than low probability sentences for all 3 age groups. Improved auditory-visual performance as a function of context has been reported by several investigators (Pelsoon and Prather, 1974; Garstecki, 1976; and Garstecki and O'Neill, 1980). Standard deviations and ranges of scores increased as a function of increasing age and task difficulty. The younger group was more homogeneous than was that of the older age groups. Likewise, all age groups were more homogeneous on the easier, high probability sentences.

Auditory-visual mean performance and standard deviations as seen in Figure 2, can be useful in projecting realistic goals in rehabilitative programs for the hearing-impaired. Comparison of hearing-impaired individual's bisensory receptive communication performance with that of normally hearing age-matched peers may influence recommendations regarding further visual assessment. Clinically, this data could be utilized in hearing aid selection procedures. In the evaluation of several hearing aids, if auditory-only discrimination scores were equivalent then the aid providing the greatest bisensory gain would be the instrument of choice. Likewise, if amplification
Figure 2. Mean performance and standard deviations on auditory-visual RSPIN Sentences for 90 normally hearing adults as a function of age category and context.
improved bisensory performance into the upper performance range of normally hearing people, the prognosis for successful hearing aid use would be very good. Emphasis could then be placed on specific management strategies, which would allow for an individualized rehabilitation program.

Auditory-visual performance in the present investigation was assessed at a -8dB signal-to-noise ratio, and resulted in only 5.5% of the subjects obtaining a perfect score. Further investigation of the effects of signal-to-noise ratios on performance is necessary. It would be useful to know the range of ratios that would produce 100% for 50% of the subjects or the level at which 0% obtained 100%.

Auditory-only

Summary data, consisting of means, standard deviations and ranges of auditory-only performance by age and gender are presented in Table 4.
Table 4. Means, SDs, and ranges of percent correct scores for auditory-only performance on the RSPIN sentences for 90 normally hearing adults by age, gender, and context.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>20-30 years</th>
<th>40-50 years</th>
<th>60-70 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Probability High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>65.00</td>
<td>58.00</td>
<td>56.40</td>
</tr>
<tr>
<td>SD</td>
<td>12.58</td>
<td>13.86</td>
<td>22.35</td>
</tr>
<tr>
<td>Range</td>
<td>48-88</td>
<td>40-84</td>
<td>2-82</td>
</tr>
<tr>
<td>Probability Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>22.80</td>
<td>24.00</td>
<td>18.53</td>
</tr>
<tr>
<td>SD</td>
<td>7.44</td>
<td>10.17</td>
<td>12.57</td>
</tr>
<tr>
<td>Range</td>
<td>14-40</td>
<td>8-48</td>
<td>0-46</td>
</tr>
</tbody>
</table>

The auditory-only performance scores were relatively low for high and in particular low probability sentences. Although the ranges of scores indicates a 0% low end, only 4 subjects, or 4.5% scored this poorly. One subject was 40-50 and 3 were 60-70 years. A difficult listening condition (-8 dB S/N ratio) was necessary to obtain a clear measure of bisensory advantage. This was accomplished by computing the difference between auditory-visual and auditory-only performance, which was the primary purpose of the investigation. Several studies had already reported auditory-only performance on the SPIN sentences as a
function of age and signal-to-noise ratio (Kalikow, Stevens, and Elliott, 1977; Hutcherson, Dirks, and Morgan, 1979; and Nuetzel, Rzeckowski, and Bilger, 1980). Valid comparisons, however, of auditory-only scores obtained in this study and previous research cannot be made due to substantive procedural differences.

A review of the auditory-only raw data revealed several trends consistent with those observed for the auditory-visual scores. First, mean performance was greater for the high probability sentences. This supports numerous studies (Miller, Heise, and Lichten, 1951; Miller and Isard, 1963; Owens, 1961; and Duffy and Giolas, 1974) which have demonstrated improved auditory-only intelligibility as a function of context or word familiarity. Secondly, as shown in Figure 3, standard deviations and ranges of scores increased with increasing age and difficulty. Furthermore, the standard deviations and ranges were greater for all age groups on the auditory-only task than for the auditory-visual condition. The increased variability may be explained by any number or combination of factors such as difference in hearing thresholds especially at 3 and 4K Hz, and/or a fatigue effect. Subjects had reported the need for concentrated listening in this difficult presentation condition.

The -8dB signal-to-noise ratio was a good choice for the auditory-visual condition and could be used immediately with a hearing-impaired population. Auditory-only
Figure 3. Mean performance and standard deviations on auditory-only RSPIN Sentences for 90 normally hearing adults as a function of age category and context.
performance at this signal-to-noise ratio should not be considered as the most relevant normative data for hearing-impaired people. Additional studies need to be conducted assessing auditory-only performance under a number of signal-to-noise ratios, for normally hearing and hearing-impaired adults. As recommended by the authors of the SPIN sentences (Kalikow, Stevens, and Elliott, 1977) signal-to-noise ratios should be adjusted relative to the degree and configuration of the individual's hearing loss. It is difficult to predict receptive communication performance based on the degree and configuration of hearing loss. Therefore, an important subsequent study would be an investigation of the effects of various signal-to-noise ratios for this recording of the SPIN sentences on a hearing-impaired population.

**Hypothesis Testing**

In Chapter I, 4 hypotheses were presented as research questions. The testing of these hypotheses is presented here under the appropriate heading.

**Auditory-visual**

The following hypotheses were tested:

\[ H_{01} : \text{There is no significant difference in auditory-visual performance as a function of age.} \]

\[ H_{02} : \text{There is no significant difference in auditory-visual performance between males and females.} \]
The sets of raw data for high and low probability were each subjected to a two-factor, analysis of variance (Kennedy, 1978); the results are summarized in Tables 5 and 6.

Table 5. ANOVA summary table for AVPH performance on the RSPIN sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>1065.2667</td>
<td>532.6333</td>
<td>7.82*</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>49.8778</td>
<td>49.8778</td>
<td>.73</td>
</tr>
<tr>
<td>Age X Gender (AxB)</td>
<td>2</td>
<td>30.4222</td>
<td>15.2111</td>
<td>.22</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>5719.68</td>
<td>68.0873</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>6864.9000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P< .05 Significant F
Table 6. ANOVA summary table for AVPL performance on the RSPIN Sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>3099.2667</td>
<td>1549.6334</td>
<td>9.20*</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>227.2111</td>
<td>227.2111</td>
<td>1.35</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>612.6889</td>
<td>306.3444</td>
<td>1.82</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>14145.7333</td>
<td>168.4016</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>18084.9000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P ≤ .05 Significant F

The analyses indicated the main effect for age was significant for both high probability F(2,84) = 7.82, p<.05 and low probability, F(2,84) = 9.20, p<.05. No significance for the main effect of gender was observed. Likewise, an age x gender interaction was not significant.

A post hoc Tukey's HSD test (Kennedy, 1978) was performed to determine which age groups accounted for the age main effect. Tukey's HSD testing revealed significant differences (p<.05) between the 20-30 year olds and the 2 older age groups. The difference between the 40-50 year olds and the 60-70 year olds, however, was not significant.

Results indicated an age-related difference in auditory-visual performance. By rejecting H01, we must conclude that auditory-visual performance declines significantly between the age of 30 and 40. No significant
difference in auditory-visual performance was found between males and females. Assumptions based on clinical observation suggested that females might be more attentive to visual cues. This did not prove to be so as seen in Figure 4. Consequently, $H_2$ could not be rejected.

Further analysis of visual contribution to auditory-visual performance was accomplished by computing AVPH-APH and AVPL-APL mean difference scores as summarized in Table 7. The range of visual contribution was a minimum of 28% and as high as 43%.

Table 7. Mean difference scores in percent indicating relative visual contribution to performance on the RSPIN sentences for 90 normally hearing adults by age, gender, and sentence context.

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-30 years</td>
<td>28.67</td>
<td>35.50</td>
<td>29.33</td>
<td>28.67</td>
<td>33.07</td>
<td>29.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-50 years</td>
<td>43.27</td>
<td>39.20</td>
<td>33.07</td>
<td>30.13</td>
<td>27.87</td>
<td>33.87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4. Mean performance on auditory-visual and auditory-only high and low probability RSPIN Sentences for 90 normally hearing adults as a function of sex.
The difference scores for high and low probability were subjected to a two-factor analysis of variance (Kennedy, 1978); the results are summarized in Tables 8 and 9.

Table 8. ANOVA summary table for AVPH-APH performance difference on the RSPIN sentences for 90 normally hearing adults by age, gender, and context.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>168.2889</td>
<td>84.1444</td>
<td>.25</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>10.6778</td>
<td>10.6778</td>
<td>.03</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>463.4889</td>
<td>231.7444</td>
<td>.70</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>27768.0000</td>
<td>330.5714</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>.28410.4555</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9. ANOVA summary table for AVPL-APL performance difference on the RSPIN sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>2164.9555</td>
<td>1082.4777</td>
<td>4.68*</td>
</tr>
<tr>
<td>Gender(B)</td>
<td>1</td>
<td>.2778</td>
<td>.2778</td>
<td>.00</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>591.6222</td>
<td>295.8111</td>
<td>1.28</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>19449.4667</td>
<td>231.5413</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>22206.3222</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P< .05 Significant F
The analysis indicated that no main effects or interactions were significant for visual contribution for high probability sentences. However, a significant main effect for age was observed for visual contribution for low probability sentences, $F=(2,84) = 4.68, p<.05$. Post hoc analysis utilizing Tukey's HSD (Kennedy, 1978) was performed to determine which age groups accounted for the significance. The post hoc testing revealed significant differences ($p<.05$) between the 20-30 year olds and the 2 older age groups. As was found in the analyses of auditory-visual performance, no significant difference was found between the 40-50 and 60-70 year olds. This age-related difference in visual contribution for the low probability sentences can be seen in Figure 5. The significance for age main effects and lack of significance for gender main effects in consistent with the earlier rejection of $H_{01}$ and the failure to reject $H_{02}$.

**Auditory-only**

As previously discussed, auditory-only performance should not be considered as normative and may not be clinically useful at this time. However, the data was examined in the following hypothesis:

$H_{03}$: There is no significant difference in auditory-only performance scores as a function of age.
Figure 5. Mean AV-A performance differences in percent on the RSPIN Sentences for 90 normally hearing adults as a function of age category and context.
The raw data for high and low probability were subjected to a two-factor analysis of variance (Kennedy, 1978); the results are summarized in Tables 10 and 11.

Table 10. ANOVA summary table for APH performance on the RSPIN Sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>814.0222</td>
<td>407.0111</td>
<td>1.15</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>14.4000</td>
<td>14.4000</td>
<td>0.04</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>728.8667</td>
<td>364.4333</td>
<td>1.03</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>29640.2667</td>
<td>352.8603</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>31197.5555</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11. ANOVA summary table for APL performance on the RSPIN sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>85.6889</td>
<td>42.8444</td>
<td>.30</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>211.6000</td>
<td>211.6000</td>
<td>1.46</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>71.4667</td>
<td>35.7333</td>
<td>.25</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>12163.2000</td>
<td>144.8000</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
<td>12531.9555</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The analyses indicated no significant difference in auditory-only performance for high or low probability among the 3 age groups. Furthermore, as in the auditory-visual data analyses, no significant difference was found between males and females, nor was there an age x gender interaction, as was shown in Figure 4. Therefore, \( H_0 \) could not be rejected.

**Contextual Cue Use.**

Because of the nature of the task, a value could be extracted which can provide information relative to contextual cue use. Based on those values the following hypothesis was tested:

\[ H_0^4: \text{The difference scores between high and low probability sentences will decrease as a function of age.} \]

Use of contextual information was assessed by generating AVPH-AVPL and APH-APL mean difference scores as summarized in Table 12. The range of contextual contribution, 28-42% was almost identical to that of visual contribution (27-43%).
Table 12. Mean difference scores in percent indicating relative contextual contribution to performance on the RSPIN sentences for 90 normally hearing adults by age, gender, and visual condition.

<table>
<thead>
<tr>
<th></th>
<th>20-30 years</th>
<th>40-50 years</th>
<th>60-70 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>AVPH-AVPL</td>
<td>27.53</td>
<td>30.27</td>
<td>34.13</td>
</tr>
<tr>
<td>APH-APL</td>
<td>42.13</td>
<td>34.00</td>
<td>37.87</td>
</tr>
</tbody>
</table>

The difference scores for auditory-visual and auditory-only conditions were subjected to a two-factor analysis of variance (Kennedy, 1978); the results are summarized in Tables 13 and 14.

Table 13. ANOVA summary table for AVPH-AVPL performance difference on the RSPIN sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>Sums of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>531.8000</td>
<td>265.9000</td>
<td>3.11*</td>
</tr>
<tr>
<td>Gender (B)</td>
<td>1</td>
<td>64.1778</td>
<td>64.1778</td>
<td>.75</td>
</tr>
<tr>
<td>Age X Gender(AxB)</td>
<td>2</td>
<td>396.8333</td>
<td>198.4167</td>
<td>2.32</td>
</tr>
<tr>
<td>Error</td>
<td>84</td>
<td>7183.2000</td>
<td>85.5143</td>
<td>---</td>
</tr>
</tbody>
</table>

Total 89 8176.0000

*p < .05 Significant F
Table 14. ANOVA summary table for APH-APL performance difference on the RSPIN sentences for 90 normally hearing adults by age and gender.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Square</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (A)</td>
<td>2</td>
<td>456.9555</td>
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<td>1.58</td>
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The analysis for AVPH-AVPL difference scores indicated a significant age main effect $F(2,84) = 3.11$, $p<.05$. A post hoc Tukey's HSD test (Kennedy, 1978) was used to examine age group differences. Tukey's HSD test revealed that the 40-50 and 60-70 year olds utilized context, under auditory-visual conditions to a significantly greater degree than did the 20-30 year old group. Consistent with earlier analyses no significant group performance differences were found between the two older age groups, as can be seen in Figure 6. Therefore, based on the findings of increased contextual use with age $H_0^4$ was rejected.

However, no significant (APH-APL) group differences were found under auditory-only conditions. Likewise, no significant main gender effect or age x gender interactions were noted for contextual cue use in an auditory-only condition.
Figure 6. Mean PH-PL performance differences in percent on the RSPIN Sentences for 90 normally hearing adults as a function of age category and visual condition.
List Equivalency

To assess internal consistency, the equivalence of the 4 lists for AVPH, AVPL, APH, and APL conditions was analyzed by 4 separate two-factor analyses of variance (Appendix F). The results indicated significant list main effects, $F(3,87) = 15.92, p<.05$ and $F(3,87) = 5.52, p<.05$ for AVPH and APH respectively. No significant list main effects were apparent for AVPL and APL conditions.

In order to determine which list differences caused the significant main effects for the AVPH and APH conditions, post hoc testing employing Tukey's HSD (Kennedy, 1978) was utilized. The post hoc testing revealed the following: lists 1 and 3 were equivalent, but were significantly easier than lists 6 and 8. List 6 was significantly easier than list 8.

Therefore, only lists 1 and 3 were equivalent for all 4 conditions. All lists, however, were equivalent for the AVPL and APL conditions. A possible reason for this may be due to an age factor. List equivalence in the pilot study was determined on subjects under 30 years of age. Therefore, before lists 6 and 8 are used interchangeably in the clinic, further research is necessary.

List presentation was thoroughly counterbalanced, therefore, the effects of the lack of equivalence was distributed evenly throughout test groups. As a result, any effects should have no impact on the reported findings.
Discussion

This study was undertaken to obtain normative data on a bisensory receptive communication task which incorporates more cues than are available in an auditory-only task. The data would provide baseline information on normally hearing and seeing adults to be used as a basis of comparison with hearing-impaired people. In addition, several hypotheses regarding visual and contextual cue use as a function of age and gender were tested and then discussed.

Across age groups, mean scores consistently indicated the following receptive communication performance hierarchy, in order of declining performance: AVPH; APH; AVPL; and APL. These results are consistent with previous investigations demonstrating improved speech intelligibility for bisensory presentation (O'Neill, 1954; Sumby and Pollack, 1954; Erber, 1969; and Sanders and Goodrich, 1971). Likewise, improved intelligibility as a function of context or word familiarity has been demonstrated for auditory-only (Miller, Heise, Lichten, 1951; Miller and Isard 1963; Owens, 1961; and Duffy and Giolas, 1974) and auditory-visual (Peloson and Prather, 1974; Garstecki, 1976; and Garstecki and O'Neill, 1980) conditions.

In difficult listening conditions, as used in this investigation (-8 dB signal-to-noise), context enhanced speech intelligibility equal to or slightly more than did visual information. Across age groups, the range of
improved receptive communication ability for bisensory presentation and context was 28-43% and 27-42% respectively. It is apparent that the contribution of visual and contextual information to receptive communication is both similar and significant.

Consistent with the findings of earlier studies assessing bisensory advantage (O'Neill, 1954; Sumby and Pollack, 1954; Sanders and Goodrich, 1971; and Binnie, 1974) the greatest visual contribution (43%) was found to occur for the most difficult listening condition (low probability sentences). Likewise, the most significant contextual contribution (42%) also occurred in a more difficult auditory-only condition.

AVPH performance was the best for all age groups as it is the most redundant, offering visual and contextual information. As redundancy of information decreases so does receptive communication performance. However, a compensatory shift occurs, in that the listener relies more on the available information as the visual or contextual information is removed.

Effecting successful compensatory shift in difficult listening conditions was highly individual as evidenced by increased standard deviations and ranges of scores as redundancy was reduced. In other words, as the task became more difficult, individuals became more unalike in their receptive communication ability. The difference among individual performance was most clearly evidenced by the
considerably larger standard deviations found for the 2 older groups, particularly the 60-70 year olds. Heterogeneity among older adults is a consistent finding in age-related studies. Older adults may be more different from each other, as a group, than they are from young adults.

Auditory-visual performance did decline as a function of age. It appeared that the decline occurred between 30-40 years. Performance held steady over a 30 year period as evidenced by the similar scores of the 40-50 and 60-70 age groups. Performance beyond 70 years was not assessed and any predictions would be purely speculative. Younger adults scored significantly better than did the older age groups. This finding was further supported by the younger adults increased use of visual information under low probability conditions. These results were consistent with previous research (Farrimond, 1959; Goetzinger, 1964; Ewertsen and Nielsen, 1971; and Pelson and Prather, 1974) indicating age-related decrements in auditory-visual performance.

In order to better investigate at what age performance begins to decline, scores by year within each decade were graphically depicted. No declining trend was observed within the second decade. Likewise, no obvious decrements were noted for the fourth and sixth decades. Therefore, it is postulated that the decline in auditory-visual performance occurs during the third decade of life. This would support Farrimond's (1959) findings that decreased
auditory-visual performance can be observed in individuals as early as 40 years. This may indicate physiological limitations for visual cue utilization at 40 years and over.

Based on clinical experience, the natural predication was that females better utilize visual information. For auditory-visual conditions this was not found to be the case. The increased redundancy available in the auditory-visual condition over a visual-only lipreading task may account for the absence of a gender difference.

Auditory-only performance did not indicate significant age group differences. This finding differs from the literature reporting reduced speech intelligibility in normally hearing older adults in difficult listening conditions (Sticht and Gray, 1969 and Pelson and Smith, 1971). This may be explained by different experimental methods. Studies reporting age-related decrements have often used speeded or compressed speech materials. The findings of the present study are, however, consistent with those of other investigators (Orchick and Burgess, 1977) who found age differences in performance only at the most difficult signal-to-noise ratios.

Analysis of the data relevant to contextual cue use indicated significant age-related differences. The 40-50 and 60-70 year olds utilized contextual cues significantly better under auditory-visual (high probability) presentation than did the 20-30 year olds. This somewhat surprising finding may have several explanations. The AVPH condition
is the most redundant, as well as the condition in which younger adults perform best. Therefore, the 20-30 year olds because of their efficiency in using visual information may not need to rely on context to accurately receive the message as do older adults. An additional explanation could be the greater life experience of the older adults and therefore, greater linguistic competency. However, the former explanation, relevant to compensatory shift is probably the case.

The auditory-visual version of the RSPIN materials appears to be a good bisensory task which approximates real-life listening conditions. Auditory-only monosyllabic word lists such as the W-22's and NV-6's provide valuable diagnostic information, however, they are not as appropriate for rehabilitation purposes as is a bisensory task. Therefore, the auditory-visual RSPIN materials should be considered for inclusion in the rehabilitative audiological test battery.

Summary of Results

The following results are based on the collected data and statistical results presented in this chapter.

1. A receptive communication hierarchy was consistent for all 3 age groups. In order of declining performance it was as follows: AVPH; APH; AVPL; and APL.
2. Visual and contextual information improved receptive communication ability an average of 35% for all age groups.

3. Contextual cues provide an equal or slightly greater contribution to receptive communication than do visual cues. This may be due to individual differences in lipreading ability.

4. As receptive communication situations become more difficult (reduced redundancy) individual performance becomes more heterogeneous.

5. Auditory-visual performance declines with age. Young adults (20-30 years) utilize visual cues significantly better than 40-50 and 60-70 year olds.

6. Older adults' performance as a group is more heterogeneous than is younger adults performance. Individuals become more unalike with aging.

7. Males and females did not significantly differ in their use of visual or contextual cues.

8. Auditory-only performance did not decline as a function of age.

9. Performance of people over the age of 40, for auditory-visual and contextual conditions, was different than that of 20-30 year olds.

10. Under bisensory, high redundancy conditions, older adults utilize contextual information significantly better than do younger adults.
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11. Lists 1 and 3 were equivalent for all 4 presentation conditions. Lists 1, 3, 6, and 8 were equivalent only for AVPL and APL conditions.
CHAPTER V

SUMMARY AND CONCLUSIONS

The basic purpose of this research was to collect normative data on a bisensory task of receptive communication function utilizing the RSPAN Sentence Test. Research questions were raised concerning the effects of age and gender on auditory-visual and auditory-only performance. The relative contribution of visual and contextual information to receptive communication function was also considered.

Summary

The subjects were 90 normally hearing adults, 45 males and 45 females. They ranged in age from 20 to 70 years and had at least 20/30 vision (correction allowed), high school education, were native English speakers, and had no formal lipreading training.

Their performance on auditory-visual and auditory-only versions of the RSPAN Sentence test were obtained in percent correct scores. Four scores were obtained on each subject

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AVPH, AVPL, APH, and APL representative of four different presentation conditions.

The data were subjected to statistical analysis in order to examine the research questions that were originally posed. Eight, two-way analysis of variance tests were utilized to investigate age and gender effects across conditions. Likewise, analysis of variance procedures were used to consider difference in visual and contextual cue use as a function of age and gender. Post hoc testing when appropriate, utilized Tukey's HSD.

The results indicated that visual and contextual information enhanced receptive communication. Furthermore, in difficult listening conditions, context may be more helpful than vision. The ranges of performance increased as a function of increased difficulty of the task and increasing age.

Younger individuals performed significantly better than middle and older age adults on auditory-visual conditions. No age effects were demonstrated for the auditory-only conditions. Gender effects were not observed for any presentation condition.

Consistent with the above findings, the younger age group was more successful in utilizing visual cues in the most difficult listening condition to aid receptive communication. The 40-50 and 60-70 year olds did, however, use contextual information more advantageously under auditory-visual conditions than did the 20-30 year olds.
This was probably due to a compensatory shift effected by the limited aid of visual cues for the older age groups.

**Conclusions**

Based on the data collected and within the limitations of this study the following conclusions are offered:

1. Assessment of real-life communication function may best be accomplished by measuring performance on a complex bisensory task that approximates real-life communication.

2. Receptive communication is substantially enhanced with the addition of visual and contextual information.

3. As the difficulty of the listening condition increases so does the variability of individual differences.

4. Individuals become more heterogeneous in their receptive communication ability as a function of increasing age. Therefore, expectations based on age group norms may not be accurate in the assessment of older adults.

5. Age-related changes in receptive communication ability may occur as early as the 3rd decade of life.
6. Realistic rehabilitation goals should be set for the hearing-impaired client based on normal hearing individual's performance.

7. Individualized training in the use of visual and contextual information to enhance receptive communication function may be most effective when conducted in difficult listening conditions.

Recommendations for Future Research

Additional data collection toward the development of a standardized test of bisensory communication function is warranted. Age group categories should continue to be controlled to further investigate age-related differences in receptive communication performance. Furthermore, age differences should be investigated through 20-40 years of age.

The future collection of data on normally hearing individuals should include investigation of the effects of varied signal-to-noise ratios on auditory-visual and auditory-only performance. In addition, collection of data with hearing-impaired individuals grouped by hearing loss and duration of loss should be considered.

These measures could be incorporated into hearing aid evaluations to obtain a more global measure of aided versus unaided receptive communication ability. It has been apparent clinically that traditionally used auditory-only
word discrimination tasks do not provide adequate or realistic information relevant to rehabilitation. Therefore, the development of standardized bisensory test materials is long overdue.
# APPENDICES

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APPENDIX A

REVISED SPEECH PERCEPTION IN NOISE (RSPIN) SENTENCES
List 1

1. His plans meant taking a big RISK. (H)
2. Stir your coffee with a SPOON. (H)
3. Miss White won't think about the CRACK. (L)
4. He would think about the RAG. (L)
5. The plow was pulled by an OX. (H)
6. The old train was powered by STEAM. (H)
7. The old man talked about the LUNGS. (L)
8. I was considering the CROOK. (L)
9. Let's decide by tossing a COIN. (H)
10. The doctor prescribed the DRUG. (H)
11. Bill might discuss the FOAM. (L)
12. Nancy didn't discuss the SKIRT. (L)
13. Hold the baby on your LAP. (H)
14. Bob has discussed the SPLASH. (L)
15. The dog chewed on a BONE. (H)
16. Ruth hopes he heard about the HIPS. (L)
17. The war was fought with armored TANKS. (H)
18. She wants to talk about the CREW. (L)
19. They had a problem with the CLIFF. (L)
20. They drank a whole bottle of GIN. (H)
21. You heard Jane called about the VAN. (L)
22. The witness took a solemn OATH. (H)
23. We could consider the FEAST. (L)
24. Bill heard we asked about the HOST. (L)
25. They tracked the lion to his DEN. (H)
List 1 (Continued)

26. The cow gave birth to a **Calf**. (H)
27. I had not thought about the **growl**. (L)
28. The scarf was made of shiny **silk**. (H)
29. The super highway has six **lanes**. (H)
30. He should know about the **hut**. (L)
31. For dessert he had apple **pie**. (H)
32. The beer drinkers raised their **mugs**. (H)
33. I'm glad you heard about the **bend**. (L)
34. You're talking about the **pond**. (L)
35. The rude remark made her **blush**. (H)
36. Nancy had considered the **sleeves**. (L)
37. We heard the ticking of the **clock**. (H)
38. He can't consider the **crib**. (L)
39. He killed the dragon with his **sword**. (H)
40. Tom discussed the **hay**. (L)
41. Mary wore her hair in **braids**. (H)
42. She's glad Jane asked about the **drain**. (L)
43. Bill hopes Paul heard about the **mist**. (L)
44. We're lost so let's look at the **map**. (H)
45. No one was injured in the **crash**. (H)
46. We're speaking about the **toll**. (L)
47. My son has a dog for a **pet**. (H)
48. He was scared out of his **wits**. (H)
49. We spoke about the **knob**. (L)
50. I've spoken about the **pile**. (L)
List 2

1. Miss Black thought about the LAP. (L)
2. The baby slept in his CRIB. (H)
3. The watchdog gave a warning GROWL. (H)
4. Miss Black would consider the BONE. (L)
5. The natives built a wooden HUT. (H)
6. Bob could have known about the SPOON. (L)
7. Unlock the door and turn the KNOB. (H)
8. He wants to talk about the RISK. (L)
9. He heard they called about the LANES. (L)
10. Wipe your greasy hands on that RAG. (H)
11. She has known about the DRUG. (L)
12. I want to speak about the CRASH. (L)
13. The wedding banquet was a FEAST. (H)
14. I should have considered the MAP. (L)
15. Paul hit the water with a SPLASH. (H)
16. The ducks swam around on the POND. (H)
17. Ruth must have known about the PIE. (L)
18. The man should discuss the OX. (L)
19. Bob stood with his hands on his HIPS. (H)
20. The cigarette smoke filled his LUNGS. (H)
21. They heard I called about the PET. (L)
22. The cushion was filled with FOAM. (H)
23. Ruth poured the water down the DRAIN. (H)
24. Bill cannot consider the DEN. (L)
25. This nozzle sprays a fine MIST. (H)
List 2 (Continued)

26. The sport shirt has short SLEEVES. (H)
27. She hopes Jane called about the CALF. (L)
28. Jane has a problem with the COIN. (L)
29. She shortened the hem of her SKIRT. (H)
30. Paul hopes she called about the TANKS. (L)
31. The girl talked about the GIN. (L)
32. The guests were welcomed by the HOST. (H)
33. Mary should think about the SWORD. (L)
34. Ruth could have discussed the WITS. (L)
35. The ship's Captain summoned his CREW. (H)
36. You had a problem with a BLUSH. (L)
37. The flood took a heavy TOLL. (H)
38. The car drove off the steep CLIFF. (H)
39. We have not discussed the STEAM. (L)
40. The policeman captured the CROOK. (H)
41. The door was opened just a CRACK. (H)
42. Tom is considering the CLOCK. (L)
43. The sand was heaped in a PILE. (H)
44. You should not speak about the BRAIDS. (L)
45. Peter should speak about the MUGS. (L)
46. Household goods are moved in a VAN. (H)
47. He has a problem with the OATH. (L)
48. Follow this road around the BEND. (H)
49. Tom won't consider the SILK. (L)
50. The farmer baled the HAY. (H)
List 3

1. Kill the bugs with this **spray**. (H)
2. Mr. White discussed the **cruise**. (L)
3. How much can I buy for a **dime**? (H)
4. Miss White thinks about the **tea**. (L)
5. We shipped the furniture by **truck**. (H)
6. He is thinking about the **roar**. (L)
7. She's spoken about the **bomb**. (L)
8. My T.V. has a twelve-inch **screen**. (H)
9. That accident gave me a **scare**. (H)
10. You want to talk about the **ditch**. (L)
11. The king wore a golden **crown**. (H)
12. The girl swept the floor with a **broom**. (H)
13. We're discussing the **sheets**. (L)
14. The nurse gave him first **aid**. (H)
15. She faced them with a foolish **grin**. (H)
16. Betty has considered the **bark**. (L)
17. Watermelons have lots of **seeds**. (H)
18. Use this spray to kill the **bugs**. (H)
19. Tom will discuss the **swan**. (L)
20. The teacher sat on a sharp **tack**. (H)
21. You'd been considering the **gee-see**. (L)
22. The sailor swabbed the **deck**. (H)
23. They were interested in the **strap**. (L)
24. He could discuss the **bread**. (L)
25. He tossed the drowning man a **rope**. (H)
List 3 (Continued)

26. Jane hopes Ruth asked about the **stripes**. (L)
27. Paul spoke about the **pork**. (L)
28. The boy gave the football a **kick**. (H)
29. The storm broke the sailboat's **mast**. (H)
30. Mr. Smith thinks about the **cap**. (L)
31. We are speaking about the **prize**. (L)
32. Mr. Brown carved the roast **beef**. (H)
33. The glass had a chip on the **rim**. (H)
34. Harry had thought about the **logs**. (L)
35. Bob could consider the **pole**. (L)
36. Her cigarette had a long **ash**. (H)
37. Ruth has a problem with the **joints**. (L)
38. He is considering the **throat**. (L)
39. The soup was served in a **bowl**. (H)
40. We can't consider the **wheat**. (L)
41. The man spoke about the **clue**. (L)
42. The lonely bird searched for its **mate**. (H)
43. Please wipe your feet on the **mat**. (H)
44. David has discussed the **dent**. (L)
45. The pond was full of croaking **frogs**. (H)
46. He hit me with a clenched **fist**. (H)
47. Bill heard Tom called about the **coach**. (L)
48. A bicycle has two **wheels**. (H)
49. Jane has spoken about the **chest**. (L)
50. Mr. White spoke about the **firm**. (L)
List 4

1. The doctor X-rayed his **CHEST**. (H)
2. Mary had considered the **SPRAY**. (L)
3. The woman talked about the **FROGS**. (L)
4. The workers are digging a **DITCH**. (H)
5. Miss Brown will speak about the **GRIN**. (L)
6. Bill can't have considered the **WHEELS**. (L)
7. The duck swam with the white **SWAN**. (H)
8. Your knees and your elbows are **JOINTS**. (H)
9. Mr. Smith spoke about the **AID**. (L)
10. He hears she asked about the **DECK**. (L)
11. Raise the flag up the **POLE**. (H)
12. You want to think about the **DIME**. (L)
13. You've considered the **SEEDS**. (L)
14. The detectives searched for a **CLUE**. (H)
15. Ruth's Grandmother discussed the **BROOM**. (L)
16. The steamship left on a **CRUISE**. (H)
17. Miss Smith considered the **SCARE**. (L)
18. Peter has considered the **MAT**. (L)
19. Tree trunks are covered with **BARK**. (H)
20. The meat from a pig is called **PORK**. (H)
21. The old man considered the **KICK**. (L)
22. Ruth poured herself a cup of **TEA**. (H)
23. We saw a flock of wild **GEESE**. (H)
24. Paul could not consider the **RIM**. (L)
25. How did your car get that **DENT**. (H)
List 4 (Continued)

26. She made the bed with clean **SHEETS**.  (H)
27. I've been considering the **CROWN**.  (L)
28. The team was trained by their **COACH**.  (H)
29. I've got a cold and a sore **THROAT**.  (H)
30. We've spoken about the **TRUCK**.  (L)
31. She wore a feather in her **CAP**.  (H)
32. The bread was made from whole **WHEAT**.  (H)
33. Mary could not discuss the **TACK**.  (L)
34. Spread some butter on your **BREAD**.  (H)
35. The cabin was made of **LOGS**.  (H)
36. Harry might consider the **BEEF**.  (L)
37. We're glad Bill heard about the **ASH**.  (L)
38. The lion gave an angry **ROAR**.  (H)
39. The sandal has a broken **STRAP**.  (H)
40. Nancy should consider the **FIST**.  (L)
41. He's employed by a large **FIRM**.  (H)
42. They did not discuss the **SCREEN**.  (L)
43. Her entry should win first **PRIZE**.  (H)
44. The old man thinks about the **MAST**.  (L)
45. Paul wants to speak about the **BUGS**.  (L)
46. The airplane dropped a **BOMB**.  (H)
47. You're glad she called about the **BOWL**.  (L)
48. A zebra has black and white **STRIPES**.  (H)
49. Miss Black could have discussed the **ROPE**.  (L)
50. I hope Paul asked about the **MATE**.  (L)
List 5

1. Betty knew about the NAP. (L)
2. The girl should consider the FLAME. (L)
3. It's getting dark, so light the LAMP. (H)
4. To store his wood he built a SHED. (H)
5. They heard I asked about the BET. (L)
6. The mouse was caught in the TRAP. (H)
7. Mary knows about the RUG. (L)
8. The airplane went into a DIVE. (H)
9. The firemen heard her frightened SCREAM. (H)
10. He was interested in the HEDGE. (L)
11. He wiped the sink with a SPONGE. (H)
12. Jane did not speak about the SLICE. (L)
13. Mr. Brown can't discuss the SLOT. (L)
14. The papers were held by a CLIP. (H)
15. Paul can't discuss the WAX. (L)
16. Miss Brown shouldn't discuss the SAND. (L)
17. The chicks followed the mother HEN. (H)
18. David might consider the FUN. (L)
19. She wants to speak about the ANT. (L)
20. The fur coat was made of MINK. (H)
21. The boy took shelter in a CAVE. (H)
22. He hasn't considered the DART. (L)
23. Eve was made from Adam's RIB (H)
24. The boat sailed along the COAST. (H)
25. We've been discussing the CRATES. (L)
List 5 (Continued)

26. The judge is sitting on the **BENCH**. (H)
27. We've been thinking about the **FAN**. (L)
28. Jane didn't think about the **BROOK**. (L)
29. Cut a piece of meat from the **ROAST**. (H)
30. Betty can't consider the **GRIEF**. (L)
31. The heavy rains caused a **FLOOD**. (H)
32. The swimmer dove into the **POOL**. (H)
33. Harry will consider the **TRAIL**. (L)
34. Let's invite the whole **GANG**. (H)
35. The house was robbed by a **THIEF**. (H)
36. Tom is talking about the **FEE**. (L)
37. Bob wore a watch on his **WRIST**. (H)
38. Tom had spoken about the **PILL**. (L)
39. Tom has been discussing the **BEADS**. (L)
40. The secret agent was a **SPY**. (H)
41. The rancher rounded up his **HERD**. (H)
42. Tom could have thought about the **SPORT**. (L)
43. Mary can't consider the **TIDE**. (L)
44. Ann works in the bank as a **CLERK**. (H)
45. A chimpanzee is an **APE**. (H)
46. He hopes Tom asked about the **BAR**. (L)
47. We could discuss the **DUST**. (L)
48. The bandits escaped from **JAIL**. (H)
49. Paul hopes we heard about the **LOOT**. (L)
50. The landlord raised the **RENT**. (H)
List 6

1. You were considering the **GANG**. (L)
2. The boy had considered the **MINK**. (L)
3. Playing checkers can be **FUN**. (H)
4. The doctor charged a low **FEE**. (H)
5. He wants to know about the **RIB**. (L)
6. The gambler lost the **BET**. (H)
7. Get the bread and cut me a **SLICE**. (H)
8. She might have discussed the **APE**. (L)
9. The sleepy child took a **NAP**. (H)
10. Instead of a fence, plant a **HEDGE**. (H)
11. The old woman discussed the **THIEF**. (L)
12. Drop the coin through the **SLOT**. (H)
13. They fished in the babbling **BROOK**. (H)
14. You were interested in the **SCREAM**. (L)
15. We hear they asked about the **SHED**. (L)
16. The widow's sob expressed her **GRIEF**. (H)
17. The candle flame melted the **WAX**. (H)
18. I haven't discussed the **SPONGE**. (L)
19. He was hit by a poisoned **DART**. (H)
20. Ruth had a necklace of glass **BEADS**. (H)
21. Ruth will consider the **HERD**. (L)
22. The singer was mobbed by her **FANS**. (H)
23. The old man discussed the **DIVE**. (L)
24. The class should consider the **FLOOD**. (L)
25. The fruit was shipped in wooden **CRATES**. (H)
List 6 (Continued)

26. I'm talking about the **BENCH**. (L)
27. Paul has discussed the **LAMP**. (L)
28. The candle burned with a bright **FLAME**. (H)
29. You knew about the **CLIP**. (L)
30. She might consider the **POOL**. (L)
31. We swam at the beach at high **TIDE**. (H)
32. Bob was considering the **CLERK**. (L)
33. He got drunk in the local **BAR**. (H)
34. A termite looks like an **ANT**. (H)
35. The man knew about the **SPY**. (L)
36. The sick child swallowed the **PILL**. (H)
37. The class is discussing the **WRIST**. (L)
38. The burglar escaped with the **LOOT**. (H)
39. They hope he heard about the **RENT**. (L)
40. Mr. White spoke about the **JAIL**. (L)
41. He rode off in a cloud of **DUST**. (H)
42. Miss Brown might consider the **COAST**. (L)
43. Bill didn't discuss the **HEN**. (L)
44. The bloodhound followed the **TRAIL**. (H)
45. The boy might consider the **TRAP**. (L)
46. On the beach we play in the **SAND**.
47. He should consider the **ROAST**. (L)
48. Miss Brown spoke about the **CAVE**. (L)
49. She hated to vacuum the **RUG**. (H)
50. Football is a dangerous **SPORT**. (H)
List 7

1. We're considering the BROW. (L)
2. You cut the wood against the GRAIN. (H)
3. I am thinking about the KNIFE. (L)
4. They've considered the SHEEP. (L)
5. The cop wore a bullet-proof VEST. (H)
6. He's glad we heard about the SKUNK. (L)
7. His pants were held up by a BELT. (H)
8. Paul took a bath in the TUB. (H)
9. The girl should not discuss the GOWN. (L)
10. Maple syrup is made from SAP. (H)
11. Mr. Smith knew about the BAY. (L)
12. They played a game of cat and MOUSE. (H)
13. The thread was wound on a SPOOL. (H)
14. We did not discuss the SHOCK. (L)
15. The crook entered a guilty PLEA. (H)
16. Mr. Black has discussed the CARDS. (L)
17. A bear has a thick coat of FUR. (H)
18. Mr. Black considered the FLEET. (L)
19. To open the jar, twist the LID. (H)
20. We are considering the CHEERS. (L)
21. Sue was interested in the BRUISE. (L)
22. Tighten the belt by a NOTCH. (H)
23. The cookies were kept in a JAR. (H)
24. Miss Smith couldn't discuss the ROW. (L)
25. I am discussing the TASK. (L)
List 7 (Continued)

26. The marksman took careful **AIM**. (H)
27. I ate a piece of chocolate **FUDGE**. (H)
28. Paul should know about the **NET**. (L)
29. Miss Smith might consider the **SHELL**. (L)
30. John's front tooth has a **CHIP**. (H)
31. At breakfast he drank some **JUICE**. (H)
32. You cannot have discussed the **GREASE**. (L)
33. I did not know about the **CHUNKS** (L)
34. Our cat is good at catching **MICE**. (H)
35. I should have known about the **GUM**. (L)
36. Mary hasn't discussed the **BLADE**. (L)
37. The stale bread was covered with **MOLD**. (H)
38. Ruth has discussed the **PEG**. (L)
39. How long can you hold your breath? (H)
40. His boss made him work like a **SLAVE**. (H)
41. We have not thought about the **HINT**. (L)
42. Air mail requires a special **STAMP**. (H)
43. The bottle was sealed with a **CORK**. (H)
44. The old man discussed the **YELL**. (L)
45. They're glad we heard about the **TRACK**. (L)
46. Cut the bacon into **STRIPS**. (H)
47. Throw out all this useless **JUNK**. (H)
48. The boy can't talk about the **THORNS**. (L)
49. Bill won't consider the **BRAT**. (L)
50. The shipwrecked sailors built a **RAFT**. (H)
List 8

1. Bob heard Paul called about the **STRIPS**. (L)
2. My turtle went into its **SHELL**. (H)
3. Paul has a problem with the **BELT**. (L)
4. I cut my finger with a **KNIFE**. (H)
5. They knew about the **FUR**. (L)
6. We're glad Ann asked about the **FUDGE**. (L)
7. Greet the heroes with loud **CHEERS**. (H)
8. Jane was interested in the **STAMP**. (L)
9. That animal stinks like a **SKUNK**. (H)
10. A round hole won't take a square **PEG**. (H)
11. Miss White would consider the **MOLD**. (L)
12. They want to know about the **AIM**. (L)
13. The Admiral commands the **FLEET**. (H)
14. The bride wore a white **GOWN**. (H)
15. The woman discussed the **GRAIN**. (L)
16. You hope they asked about the **VEST**. (L)
17. I can't guess so give me a **HINT**. (H)
18. Our seats were in the second **ROW**. (H)
19. We should have considered the **JUICE**. (L)
20. The boat sailed across the **BAY**. (H)
21. The woman considered the **NOTCH**. (L)
22. That job was an easy **TASK**. (H)
23. The woman knew about the **LID**. (L)
24. Jane wants to speak about the **CHIP**. (L)
25. The shepherd watched his flock of **SHEEP**. (H)
List 8 (Continued)

26. Bob should not consider the MICE. (L)
27. David wiped the sweat from his BROW. (H)
28. Ruth hopes she called about the JUNK. (L)
29. I can't consider the PLEA. (L)
30. The bad news came as a SHOCK. (H)
31. A spoiled child is a BRAT. (H)
32. Paul was interested in the SAP. (L)
33. The drowning man let out a YELL. (H)
34. A rose bush has prickly THORNS. (H)
35. He's glad you called about the JAR. (L)
36. The dealer shuffled the CARDS. (H)
37. Miss Smith knows about the TUB. (L)
38. The man would not discuss the MOUSE. (L)
39. The railroad train ran off the TRACK. (H)
40. My jaw aches when I chew GUM. (H)
41. Ann was interested in the BREATH. (L)
42. You're glad they heard about the SLAVE. (L)
43. He caught the fish in his NET. (H)
44. Bob was cut by the jacknife's BLADE. (H)
45. The man could consider the SPOOL. (L)
46. Tom fell down and got a bad BRUISE. (H)
47. Lubricate the car with GREASE. (H)
48. Peter knows about the RAFT. (L)
49. Cut the meat into small CHUNKS. (H)
50. She hears Bob asked about the CORK. (L)
APPENDIX B

PILOT STUDY OF LIST EQUIVALENCY
FOR AUDITORY-ONLY AND AUDITORY-VISUAL
RSPIN SENTENCES
Twenty normally hearing young adult females were used as subjects during this pilot study. Subjects were randomly assigned to auditory-only or auditory-visual treatment groups. List presentation was counter-balanced to minimize possible order effects.

Examination of the data (Tables 15 and 16) revealed that the most equivalent lists under all conditions for high and low probability sentences were lists 1, 3, 4, 6, 7, and 8.
Table 15. Mean performance of 20 normally hearing adults on RSPIN Sentences presented auditory-only and auditory-visual, by list and condition.

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Table 16. Comparison of list mean differences for auditory-visual and auditory-only conditions.

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APPENDIX C

AGE CORRECTION FOR 60-70 YEAR OLD MALES AND FEMALES

BY THE OSU-SELECTED REGRESSION
AGE CORRECTIONS FOR 60-70 YEAR OLD MALES AND FEMALES AS DERIVED BY THE OSU-SELECTED REGRESSION

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APPENDIX D

SUBJECT RESPONSE FORM
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APPENDIX E

SUBJECT INSTRUCTIONS
YOU ARE GOING TO HEAR (AND/SEE) 200 SENTENCES. THE SENTENCES ARE ARRANGED IN FOUR LISTS OF 50 SENTENCES PER LIST. THESE SENTENCES WILL BE PRESENTED IN A BACKGROUND OF NOISE WHICH SOUNDS LIKE A LOT OF PEOPLE TALKING. EACH SENTENCE WILL BE PRECEDED BY A NUMBER. YOU ARE TO WRITE ONLY THE LAST WORD OF EACH SENTENCE, AND YOU ARE ENCOURAGED TO GUESS. YOU HAVE 15 SECONDS BETWEEN ITEMS. THIS IS GENERALLY ENOUGH TIME TO WRITE DOWN YOUR RESPONSE; HOWEVER, SHOULD YOU NEED MORE TIME, IT WILL BE PROVIDED UPON YOUR REQUEST.

BEFORE WE BEGIN, YOU WILL HEAR (AND/SEE) FIVE PRACTICE SENTENCES. THE BACKGROUND NOISE WILL NOT BE AS LOUD FOR THE PRACTICE SENTENCES AS IT WILL BE FOR THE TEST SENTENCES. YOU NEED NOT WRITE ANYTHING FOR THE PRACTICE ITEMS. ARE THERE ANY QUESTIONS?
APPENDIX F

MAJOR STUDY OF LIST EQUIVALENCY
FOR AUDITORY-ONLY AND AUDITORY-VISUAL
RSPIN SENTENCES
Table 17. ANOVA summary table of list equivalence for the AVPH condition.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>List</td>
<td>3</td>
<td>3005.5256</td>
<td>1001.8418</td>
<td>15.92*</td>
</tr>
<tr>
<td>Error</td>
<td>87</td>
<td>5476.4743</td>
<td>62.9480</td>
<td>---</td>
</tr>
</tbody>
</table>

Total 90 8481.8999

*p<.05 Significant F

Table 18. ANOVA summary table of list equivalence for the AVPL condition.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>List</td>
<td>3</td>
<td>419.3078</td>
<td>139.7692</td>
<td>1.26</td>
</tr>
<tr>
<td>Error</td>
<td>87</td>
<td>9678.6921</td>
<td>111.2493</td>
<td>---</td>
</tr>
</tbody>
</table>

Total 90 10098.000
Table 19. ANOVA summary table of list equivalence for the APH condition.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>List</td>
<td>3</td>
<td>64336.000</td>
<td>21445.333</td>
<td>5.52*</td>
</tr>
<tr>
<td>Error</td>
<td>87</td>
<td>17988.0555</td>
<td>206.7593</td>
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<tr>
<td>Total</td>
<td>90</td>
<td>82324.06</td>
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<td></td>
</tr>
</tbody>
</table>

*p<.05 Significant F

Table 20. ANOVA summary table of list equivalence for the APL condition.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>Sums of Squares</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>List</td>
<td>3</td>
<td>25063.9111</td>
<td>8354.6370</td>
<td>2.07</td>
</tr>
<tr>
<td>Error</td>
<td>87</td>
<td>8670.1141</td>
<td>99.5665</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
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LIST OF REFERENCES

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