Speech Discrimination by Hearing Impaired Children

ABSTRACT

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Auditory and Visual Speech Discrimination by Hearing-Impaired Children

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Summary

Discrimination of consonant vowel syllables by eight hearing-impaired children was studied. Each child was tested over twelve sessions under each of the following conditions: vision, audition, vision supplemented by optimal audition, and vision supplemented by suboptimal audition. Speech material was presented by videotape and subjects responded by operating a same-different response device. Discrimination was better under bisensory conditions than under either unisensory condition. Vision supplemented by optimal audition was superior to vision supplemented by suboptimal audition. There was no significant difference between visual and auditory conditions. Dental consonants were visually discriminable when contrasted with alveolar consonants, and the vowels /a/ and /i/ had a more positive

influence on consonant discrimination than /u/. Subjects' discrimination improved, and their response times decreased over training sessions. Pre- and post-tests of word recognition indicated that experimental subjects, compared to a control group, did not generalize from learning over the training program.

AUDITORY AND VISUAL SPEECH DISCRIMINATION BY HEARING-IMPAIRED CHILDREN

by

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INTRODUCTION

Speechreading has long enjoyed a position of prominence over audition in the traditional oral approach to teaching hearing-impaired children. Surprisingly, there have been few definitive experimental studies of the speechreading process. Report and opinion abound but in general contribute little worthwhile scientific knowledge. The majority of studies undertaken have usually involved normal hearing adults, and the relation of such studies to speechreading by hearing-impaired children is tenuous. The acquisition of speechreading skill by children is accompanied by cognitive, perceptual and social development. It serves as a means of learning language. Among adults who become hearing impaired, speechreading, in contrast, is acquired when personal-social behavior is highly developed and when language is established.

The development of more sophisticated auditory aids has placed greater emphasis on utilising the deaf child's residual hearing. Studies which examine auditory perception and decoding by deaf children are not abundant. However, there is a growing body of research aimed at defining and exploring the acoustic parameters that are critical to the hearing-impaired child.

The combining of audition and vision for greater communication efficiency for the hearing impaired is now widely advocated. It seems, however, that more information is required concerning the relative contributions of the auditory and visual channels for speech reception.

The purpose of the present study was to evaluate the discriminability of phonemically identical and minimally different pairs of nonsense syllables under four conditions:

1) vision,
2) audition,
3) vision supplemented by optimal audition, and
4) vision supplemented by suboptimal audition.

Under each condition the following aspects were studied:

1) Influence of the vowel on the discriminability of the consonant,
2) improvement in discrimination with repeated testing,
3) response time, particularly as a means to determine the rate of information transfer, and
4) the extent to which improvement in the discrimination of nonsense syllables influences the child's ability to recognize words.

CHAPTER 1

LITERATURE REVIEW

Speechreading

Visibility

The limitations of speechreading imposed by reduced visual cues and similarity of lip movements for phonemes has long been recognized. Bell (DeLand, 1938) is quoted as saying,

> "Spoken language I would have used by the pupil from the commencement of his education to the end of it; but spoken language I would not have as a means of communication with the pupil in the earliest stages of communication because it is not clear to the eye, and requires a knowledge of language to unravel the ambiguities."

Heider & Heider (1940) investigated the visibility of phonemes to hearing-impaired children. They found less confusion among vowels than among consonants. The authors also noted that consonant confusions were clustered in groups (e.g., m, p and b) while confusions of vowels showed no such pattern. They concluded that while vowels could be learned in speechreading, consonants could not. In contrast, O'Neill (1954), with a group of normally-hearing adults, found that vision contributed less to the recognition of vowels (29.5%) than to the recognition of consonants (57%). His visual recognition scores for individual vowels and consonants did not agree with those obtained by Heider & Heider. Such discrepancies could be attributed to speaker variability, population differences and nonsense syllable structure.

Brannon and Kodman (1959) compared the ability of skilled and unskilled speechreaders to recognize monosyllabic words. They found for both groups that the place of articulation of phonemes was related to their visual identification. Sounds articulated at the front of the mouth were most visible and those articulated at the back least visible.

Groups of consonants which are visually similar have been variously termed contrastive units (Woodward & Barber, 1960), kinemes (Alich, 1961) and visemes (Fisher, 1968). From sets of consonant vowel nonsense syllable pairs, Woodward and Barber's normal-hearing subjects judged whether the pairs were the same or different. Four distinct units were identified, which were categorized according to place of articulation as bilabial, rounded labial, labiodental and non-labial. The non-labial group contained all but eight of the 24 initial consonants tested. These findings were the first to challenge the traditional classifications of the visibility of lip movements.

More recently, Fisher (1968), using a method of forced error for mono- and poly-syllabic words, described five groupings for initial consonants. In addition to the Woodward and Barber classification, he found that the velars /k/ and /g/ formed an independent unit. For final consonants, Fisher showed that a further independent group was formed by the palato-alveolars /ʃ, ʒ, tʃ, dʒ/.

Commenting on the influence of the consonant on the shaping movement of the vowel, Hudgins (1951) suggested that the consonant releasing the syllable affects the vowel movement in a manner different from that of the consonant arresting it. Bel'Tiukov (Quigley, 1966) reports that, in Russian, /i/ and /u/ exert a more negative influence on the visual recognition of consonants than /a/. Velars before /i/ and alveolars in general were the most difficult consonants to recognize. No other studies have been undertaken that systematically evaluate vowel-consonant influences on visibility.

Speechreading and Language

The extent to which the hearing-impaired child utilizes visual sensory cues depends on his ability to incorporate such information into a receptive language system. Pauls (1965) stated that,

> "Speechreading assumes that the person has language facility (the mind's reflexive use of verbal symbols) as well as an adequate vocabulary. Thus if one's language is limited, one cannot hope to speechread no matter how attentively he observes."

Although speechreading relies heavily on a knowledge of the linguistic probabilities of language, Pauls' view, that speechreading with limited language is impossible is, perhaps, extreme. Avery (1967) suggests that the child first develops "situational lipreading" and later, because of direct teaching, "specific lipreading". She states that speechreading (the perception of visual language symbols) requires, "intelligent interpretation of the speaker's language, facial expression, the environmental situation that speaker and lipreading share, their previous common experience and any other concrete objects or actions in view."

As information on the lips is incomplete and ambiguous, some educators of the deaf have proposed a system of cues to assist the speechreader. Forchhammer (Holm, 1960) introduced a mouth-hand system whereby different movements of the fingers and wrist supplement those lip movements which are difficult to speechread. More recently, Cornett (1967) advocated the use of twelve hand cues which give additional information when used in conjunction with the lips. To date, no research has been reported that examines the efficacy of cuing systems.

Factors Related to Speechreading Skill

Although verbal language is a prerequisite for efficient speechreading, it does not necessarily follow that a person with good language will be a successful speechreader. The skills and abilities required for competency in speechreading are not clearly defined, but the ability to synthesize (Kitson, 1915; Kitchen & Oyer, 1969; Sanders & Coscorelli, 1970), speed of perception (Costello, 1957; Kitchen & Oyer, 1969), and visual sequential memory (Simmons, 1959; Neyhus & Myklebust, 1969), may be associated with competency.

The interrelationships among several variables may be important to success in speechreading. Evans (1965) found that children with substantial residual hearing, above average intelligence and high visual recognition scores were good speechreaders. In an endeavor to determine the reason for speechreading failure in children, Neyhus & Myklebust (1969), indicated that children who developed good speechreading ability demonstrate "superior intellectual functioning, are more highly differentiated in terms of visual perceptual ability, may have or are using their residual hearing to advantage and have developed superior verbal symbolic skills." Both studies indicated improvement in speechreading with increased age. Evans, whose experimental population ranged from 8 to 16 years of age compared to a 4 to 9 age range for the Neyhus & Myklebust group, found the most rapid increase in speechreading scores was from 8 to 11 years. The most rapid period of growth for Neyhus & Myklebust's good speechreaders was between 5 and 7 years. Their poor speechreaders were 2 years retarded, though for more complex material presented at a faster rate they were 4 years retarded.

Environment and Speaker Influences on Speechreading

Distance is generally considered to be related to speechreading performance. However, studies to date have not indicated that distance is a critical variable. Mulligan, (O'Neill, 1961) testing at 5, 10, 15 and 20 feet, and Neely (1956) testing at 3, 6 and 9 feet found no difference in speechreading ability related to range.

The influence of illumination on speechreading ability has been examined by Thomas (Oyer, 1964), who showed that speechreading performance did not decrease until the light level on the speaker's face was one foot candle or almost darkness.

Speaker rate has been examined by several investigators. Mulligan (O'Neill, 1961) indicated that speech presented by film at 16 frames per second (fps) was recognized more correctly than when projected at 24 fps. Neyhus and Myklebust (1969) used three rates of presentation. Besides normal conversational rate, the speaker was filmed speaking at a slower rate used for teaching the deaf. This slower rate was then projected at 18 and 24 fps. The most suitable speed was the slow 18 fps rate. In contrast, Byers and Lieberman (1959) found no significant difference in speechreading performance when speaking rate was varied from normal to 2/3, 1/2 and 1/3 that rate. Frisina and Bernero (Frisina, 1964) similarly found no significant differences for presentation rates of 16, 20, 24 and 28 fps.

Stone (1957) evaluated the effects of facial exposure, facial expression and lip mobility of the speaker on speechreading performance. The best results were obtained when the speaker used normal lip movement compared to tight lip movement; when the speaker's expression was plainly set compared to smiling; and when the full torso rather than only the mouth was exposed. Greenberg & Bode (1968) found that, for consonant discrimination in nonsense syllables, full face presentation yielded more accurate results than when only the lips were viewed.

Hearing

Recent developments in psychoacoustics and acoustic phonetics have provided valuable information to those interested in the auditory habilitation of the deaf. Greater understanding of the speech code in relation to the hearing-impaired should result in more enlightened approaches to auditory training. Improvements in electronic equipment have played an important role in promoting research into the acoustics of speech.

It is well established that vowels are distinguished from each other on the basis of their formant frequencies, particularly the first two formants (Fairbanks & Grubb, 1961; Morton and Carpenter, 1963). The frequency range of the first formant varies from 250-800 Hz while the second formant varies from about 700-2,500 Hz. Children who show typical residual hearing for low-frequency tones are unable to hear most of the second formants but usually can hear the first formant. With extended low-frequency amplification they can discriminate vowel differences more accurately (Ling, 1966).

Because many consonants have predominantly high-frequency energy, consonant discrimination is generally difficult for hearing-impaired children.. The energy level for consonants is approximately 30 dB less than for vowels (Hirsh, 1964). Studies at the Haskins Laboratories, reviewed by Liberman, Cooper, Shankweiler and Studdert-Kennedy (1967) indicated that temporal cues, intensity differences, and second formant transitions are also important for the discrimination of consonants.

Hirsh (1967) points out that there appear to be many kinds of acoustic cues available to the listener, one or more of which may be used for a particular speech sound discrimination in a particular context. Fry (1964) indicates that many of the normal acoustic cues are still available to the deaf child, and that he should be given the opportunity to "organize the available cues into a system which will form an adequate basis both for the reception of speech and for its production."

Combining Vision and Audition

The contribution of vision to the understanding of speech in a high-intensity noise environment has been noted for normal-hearing adults (O'Neill, 1954; Sumby & Pollack, 1954; Neely, 1956; Erber, 1969). As the ratio of noise to speech increases, visual cues become increasingly more important for the comprehension of speech. Erber (1969) suggests that, in quiet surroundings, audition and vision provide redundant information, and visual cues are superfluous for normal-hearing individuals. However, when the speech-to-noise ratio is not ideal, weaker phonemes are masked, and even the normal listener must rely more on visual cues for satisfactory message reception.

The Ewings (1938, 1944) were among the first investigators to demonstrate the advantages of a bisensory approach to deafness. In North America, Heider (1943) and Albright (1944) also advocated combining hearing and speechreading for teaching the hearing-impaired. The latter demonstrated that "of 6,750 possible correct responses, 5,912 were correctly recognized by the eyes, 4,692 by the ears and 6,303 were recognized by combination of the two sensory modalities."

The superiority of bisensory, as compared with unisensory presentation of speech for the hearing-impaired has received considerable experimental support (Hudgins, 1951; Clarke, 1957; Prall, 1957; Hutton, 1959). Krug (1960) more clearly defined the hearing level of subjects than previous investigators. With an adult population, he reported that all subjects showed significantly better bisensory than unisensory scores. Similarly, Beggs (1968) evaluated the supplementary contribution of audition to speechreading for hearing-impaired children. She divided her subjects into groups according to three audiometric configurations (after Huizing, 1959) and compared the results obtained over eight individual speechreading sessions. The stimuli used were 8 mm auto-instructional films of noun series. Her results substantiate previous findings that visual-auditory presentation is superior to visual-only presentation. No relationship was found between the three audiometric patterns and the visual-auditory scores.

Comparative studies evaluating auditory, visual and auditory-visual performance with hearing-impaired children have on the whole, been poorly conducted or controlled. Variables which have received little attention include speaker, presentation mode, response mode, speech material, and more importantly, visual training, auditory training, and past experience

Other Related Studies

A series of studies on sense modality in relation to the learning of paired-associate words was conducted by Graunke (1959) and by Gaeth (1960, 1966). In these studies, the visual mode was a printed word and the auditory mode was speech. For neither normal nor hearing-impaired children were results for combined audio-visual presentation superior to those for the better of the two single-channel presentations. Graunke, in fact, found that for hearing-impaired subjects, audio-visual presentation yielded poorer results than visual presentation. Examining this finding further in relation to the hearing handicapped, Gaeth (1966) ascertained that the visual channel was either superior, or equivalent to an audio-visual channel of learning for most tasks. With bimodal simultaneous stimulation, learning appeared to occur more rapidly when the visual modality contained the more meaningful element. The processes involved in paired-associate learning are different from those in most speech perception studies. Results from studies of paired-associate learning nevertheless show that bisensory superiority does not extend to all verbal recognition tasks.

Pfau (1967), in an extensive study of programmed learning, found that for hearing-impaired children the percentage of incorrect responses was significantly decreased by increasing the number of input modalities. The modalities included printed words, pictures, audition, speechreading and fingerspelling. When auditory information was added during programmed learning, severely hearing-impaired children made fewer error responses. However, audition had less of an effect on performance than did speechreading or fingerspelling.

Some Theoretical Implications

In understanding the result of combining sensory modalities when one sensory input is limited, Pickett (1963) indicates two ways in which the added information can improve communication.

> "First if the added information conveys dimension of the source code that is poorly transmitted by the existing sensory channel, then the total channel capacity is increased. Secondly, even if added information is partially or totally redundant... the added redundancy will improve the resistance of the link."

An extension of Pickett's concept is suggested by Severin's (1967) theoretical approach. Using the cue summation principle of learning, he proposes that multisensory channels are superior to single channels when relevant cues are summated across channels, are equal when redundant features exist between channels, and inferior when irrelevant cues are combined because of the expectancy that irrelevant cues will result in interference.

Pickett's second point is supported by Brown & Hopkins (1967), who found that redundant bisensory information presented through noisy channels produces improved signal detection performance when compared to single-channel performance. It appears that the increased detectability of the signal resulted from simple probabilistic adding of the response of the two sensory systems.

It cannot, however, be assumed that auditory and visual cues associated with speech sounds are necessarily perceived by deaf children as relevant or related. With multichannel presentation of unrelated stimuli, Broadbent and Gregory (1961) have shown that there is often a loss of information. Broadbent's (1958) sequential processing hypothesis offers an explanation in terms of the difficulty of the observer to alternate successfully between channels, although Talving and Lindsay (1967) indicate results compatible with the view that a person cannot attend or respond to two events at the same time. They found no evidence for Broadbent's sequential processing hypothesis. Two alternatives are suggested, either that information from the non-attended source is only 'attenuated' (Broadbent & Gregory, 1963) or that the switching from one channel to another is instantaneous (Kristofferson, 1967).

Test and Program Media

The advantages of film for the presentation of speechreading material were first recognized by Nitchie (1913). Since then a number of films of speechreading tests have been produced (Utley, 1946; Mason, 1943; Reid, 1947; Heider & Heider, 1940; Lowell, 1957; Moser, Oyer, O'Neill, Gardner (O'Neill & Oyer, 1961); and Evans, 1965). Film has also been introduced for teaching speechreading (Morkovin, 1947; Pauls, 1965), although its applicability has been limited because of film production costs, bulkiness, and operational difficulties. More recently, speechreading programmes have been introduced using auto-instructional techniques and programmed instruction principles (Brehman, 1965). Eight mm films have been found to be feasible for individual speechreading instruction (Stepp, 1966; Withrow, 1965; Neyhus, 1966) and can, moreover, be operated by young children (Forsdale, 1966).

The greater flexibility of videotape over film makes it a more suitable media for the presentation of speechreading material. Investigations have indicated that there is no significant difference between speechreading scores for television presentation compared to live presentation (Strain, 1960) or to color film presentation (Donnelly, 1969).

Same-Different Responses and Reaction Time

A discussion of the literature pertaining to same-different decision task and related response time measurement is included because of its direct relevance to the present experimental design.

Studies of reaction time for same-different judgments have indicated that "same" and "different" latencies have different characteristics. However, the parameters which determine these differences are not entirely clear. Bindra, Donderi & Nishisato (1968) report that both codability and discriminability are important factors related to latency differences. Where stimuli are codable the latency of the decision "same" tends to be shorter than for the decision "different" and for non-codable stimuli the relation is reversed. The expectation with regard to discrimination difficulty is not as clear cut. These authors report a relative decrease in "same" latencies with increased discrimination difficulty; whereas other studies (Bindra, Williams & Wise, 1965; Corballis, Lieberman & Bindra, 1968) indicate an increase in latency for "same" judgments. Decision latencies for "same" and "different" are not, however, dependent upon stimulus modality or whether the stimuli are presented simultaneously or successively.

Chananie & Tikofsky (1969) used the same-different paradigm to examine choice reaction time (CRT) in speech discrimination. They found that the mean CRT's for identical pairs of initial consonants were significantly higher than for contrasting pairs. However, response bias was not adequately controlled and could have contributed to this difference. Analysis of errors revealed that consonants that differed by only one Miller-Nicely distinctive feature were more difficult to discriminate than consonants differing by 2, 3 or 4 distinctive features.

In an experiment designed to determine whether paired visual and auditory stimuli yielded faster response times than either modality alone, Costa, Rapin and Mandel (1964) found that normal children responded more rapidly to combined stimulation. Moreover, response times to auditory stimulation were found to be shorter than to visual stimulation. This pattern has also been reported for adults (Teichner, 1954; Morrell, 1968). Costa, Rapin and Mandel also noted that as stimuli intensity was decreased response time increased. Their results suggest that reaction time for auditory stimuli might be slower than for visual stimuli among hearing-impaired subjects.

CHAPTER II

METHOD

Experimental Design

This study was designed to evaluate the discriminability of consonant-vowel syllable pairs by hearing-impaired children under the following conditions: vision, audition, vision supplemented by optimal audition, and vision supplemented by suboptimal audition. Videotape was the medium used to present the speech material to the experimental subjects.

Since there are considerable individual differences for relevant variables among hearing-impaired children, a repeated measures design was used to assess subjects' performance. Thus, each subject served as his own control and participated under all conditions.

To permit subjects to learn to discriminate between stimuli each subject was trained over twelve trials under each condition. The repeated measures constituted the training program. Pre- and post-tests of word-recognition were administered to determine whether learning over the training program would improve subjects' ability to recognize words. A second group of control subjects, who did not participate in the training task, were given the word-recognition tests at the same time as the experimental subjects.

With this experimental design, learning under one condition may affect learning under the other conditions. The hearing-impaired child learns through both his main distance senses, sometimes in combination, often in isolation and even occasionally in combination with his close senses. Thus, the design reflects the subjects' everyday experience.

Subjects

Sixteen subjects were selected from the children attending the Montreal Oral School for the Deaf.

Subjects were selected on the basis of the following criteria:

1) Chronological age from 7.0 to 14.0 years.
2) Congenital deafness.

3) Sensori-neural hearing impairment with no known additional central nervous system involvement.

4) Teachers' ratings of at least average ability to achieve.

5) Normal or corrected vision.

6) Ability to respond on the pre-test.

With the exception of item 6, the above information was taken from the school files.

All subjects had been audiometrically assessed within the previous six months by the School audiologist. The subjects selected were matched in pairs according to pre-test scores for the auditory and visual condition, hearing level, teacher rating and age in that order. The subjects of each pair were then assigned at random to either the control or experimental group.

Relevant background data on each subject are given in Tables 2.1 and 2.2.

Table 2.1

Age, Sex, Teacher's Rating, Years of Special Schooling, Years of Hearing Aid Use and Hearing Levels for Experimental Subjects

Subject	Age	Sex	Teacher's Rating *	Yrs. of Spec. Schooling	Yrs. Aid Worn		Hearing Levels (ISO) 125	250	500	1000	2000	4000
1	13-6	F	B-	6	6	R	75	90	110	-	-	-
						L	55	80	100	110	90	85
2	13-4	F	C	10	6	R	70	85	90	-	-	-
						L	70	90	110	-	-	-
3	11-9	M	B-	8	10	R	60	70	90	105	-	-
						L	70	75	90	110	-	-
4	8-0	F	B	1	6	R	35	60	90	95	95	95
						L	40	65	85	95	-	-
5	7-4	F	B+	1	3	R	65	80	85	95	-	-
						L	80	90	110	-	-	-
6	9-0	F	C	6	6	R	80	80	100	-	-	105
						L	75	90	100	-	110	100
7	12-1	F	A	5	5	R	80	85	100	105	100	-
						L	75	80	95	-	110	100
8	8-10	F	C	4	4	R	80	90	-	-	-	-
						L	90	95	-	-	-	-

* A - Superior, B - above average and C - Average ability to achieve
\- Denotes no response at 110 dB

Table 2.2

Age, Sex, Teacher's Rating, Years of Special Schooling, Years of Hearing Aid Use and Hearing Levels for Control Subjects

Subject	Age	Sex	Teacher's Rating*	Yrs. of Spec. Schooling	Yrs. Aid Worn		Hearing Levels (ISO) 125	250	500	1000	2000	4000
1	13-10	M	B-	8	6	R	65	85	105	110	-	-
						L	80	85	100	110	-	-
2	13-1	F	B-	7	6	R	70	75	100	-	-	-
						L	70	70	95	105	90	85
3	12-8	M	B+	8	6	R	65	75	90	95	100	-
						L	60	75	95	100	-	-
4	12-7	M	B-	7	6	R	-	-	-	-	-	-
						L	50	50	65	70	85	75
5	7-9	F	B+	5	6	R	65	85	95	110	-	-
						L	65	90	-	-	-	-
6	9-0	M	B-	6	6	R	65	80	100	-	-	-
						L	70	85	95	110	-	-
7	10-11	M	A	5	5	R	65	85	100	105	90	100
						L	70	90	105	-	-	-
8	8-6	M	B-	4	4	R	60	80	90	100	90	80
						L	80	85	-	-	-	-

* A - Superior, B - Above Average and C - Average ability to achieve

\- Denotes no response at 110 dB

Materials and Apparatus

Training Program

Training stimuli consisted of consonant-vowel (CV) syllable pairs in which only the consonant was varied. The syllables were constructed by combining the six consonants /t/, /d/, /l/, /s/, /θ/, /ð/ with the three vowels /i/, /a/ and /u/. The six consonants were drawn from the large non-contrastive nonlabial group specified by Woodward and Barber (1960). Each syllable was paired with each other syllable in only one order to make 45 "different" comparisons. An equal number of "same" comparisons from the eighteen possible combinations were added to the "different" items. With the 90 items, eight series using all items in different random orders were constructed. The procedure proposed by Fellows (1967) which controls for four common strategies of response in a two-choice discrimination task was employed for randomizing the "same" and "different" sequences.

Speech tests were videotaped at the Instructional Communication Center of McGill University. The videotape was produced in the Center's studio by professional staff using a Marconi Mark IV Image Orthicon camera and associated equipment. The tape was filmed with the speaker directly facing the camera and the picture included the speaker's head and shoulders. Direct lighting was arranged to exclude shadows and no attempt was made to emphasize any facial features. The speaker was a 22 year-old Canadian-born female.

An Ampex 7500 videotape playback was used for presenting the test material. The video output was linked with a 21-inch Motorola television receiver. Dimensions of the facial image displayed on the television receiver approximated the speaker's actual facial proportions. The audio 1 output track from the video playback was channelled into a Linco auditory training unit equipped with TDH-39 earphones. Output levels were controlled independently for each ear. A VU meter was used to calibrate the correct setting of the audio output from the video playback, and this was checked from time to time to determine any variation or deterioration of the audio track. Calibration of the auditory training unit was taken from a 1000 Hz pure tone recorded on the videotapes at the time of production. For calibration of the video setting, a grey scale was placed at the beginning of each tape so that contrast and brightness could be set prior to each session.

Signals from the audio 2 (cue) track of the video playback operated a logic circuit controlling both a response device and a Standard centisecond clock used to measure reaction times. The first syllable of each pair activated a modified Uher 220 Aukustomat relay which was linked to the logic circuit, constructed with DigiBits solid state programming modules. The audio signals were the same as the syllables presented on the audio 1 track except that for "same" comparisons the second syllable was deleted at the time of recording. A same-different response device with two response buttons and two sets of two corresponding amber lights was connected with the logic circuit so that the presentation of one signal from the video playback would close one switch/light circuit and two signals would close the other circuit. When the response button was operated the corresponding light would illuminate to indicate correctness of response and stop the clock. The sequence of events could be monitored by the experimenter using headphones from the monitor output of the video playback.

Pre- and Post-Tests

Sixty four pictures of basic nouns (Ling & Ling, 1968) were pasted on to individual cards and arranged in sets of four. Vowels within sets were held constant. To ensure homogeneity, each word was phonetically transcribed by two speech therapists, and only those words for which there was complete agreement were included.

Four series of sixteen words were constructed as shown in Table 2.3. The order of the words in each series was randomly arranged.

Procedure

Testing Conditions

All testing was undertaken in a partitioned section of a classroom in the Montreal Oral School for the Deaf. Subjects were seated behind a low desk nine feet from the television receiver. The experimenter was positioned to one side and slightly behind the subject so that he could unobtrusively operate the video recorder and logic circuit as well as record subjects' responses and response times.

Table 2.3

The Sixteen Sets of Nouns from which the Four Pre- and Post-Tests were Constructed

Set	Stimuli			
1	horse	four	corn	door
2	hen	leg	bell	bed
3	ring	fish	pig	mit
4	bird	purse	girl	shirt
5	nut	sun	duck	cup
6	wolf	cook	wool	book
7	car	barn	star	card
8	clown	house	mouse	cow
9	cat	flag	man	pan
10	box	frog	doll	dog
11	rake	cake	train	rain
12	moon	shoe	two	spoon
13	leaf	sheep	meat	peas
14	fly	kite	pie	tie
15	chair	pear	hair	bear
16	boat	coat	goat	comb

Audio Settings

The importance of determining optimum listening levels for hearing impaired children has been emphasized by Harold (Ewing, 1964). There is no established technique to determine an appropriate level, hence the following procedure was employed in this study: A selection of consonant/vowel syllables was presented to each subject by earphones. Speech detection thresholds (SDT) were determined for each ear using the method of limits (Reger, 1965). Using SDT plus 20 dB as the minimal level, the setting at which each subject was able to repeat most syllables was also determined by using the method of limits. This setting was used as the subject's Optimal Auditory Level. Suboptimal Auditory Level was arbitrarily defined as 10 dB above SDT.

Training Program

For the training program the response device was placed on the desk in front of the subject. Subjects were instructed to watch and/or listen for two words and to decide whether they were the "same" or "different". The operation of the response buttons was then explained, and the subject was told which button was for "same" judgments and which was for "different" judgments. The purpose of the light to indicate correct responses was demonstrated. Subjects were encouraged to "Listen", "Look" and "Try to make the light come on every time". These instructions were accompanied with pantomine, and several syllables were presented live by the experimenter with appropriate reinforcing light prior to the actual presentation of the videotape series. Instructions were repeated before each series until the subject showed an understanding of the response device.

To counterbalance for a possible right-button bias (noted in previous studies, Bindra, Donderi & Nishisato, 1968; Ling, 1970) half of the subjects responded to "same" with the right button and half with the left. A modified form of a hand preference test, reported by Belmont & Birch (1963), indicated that all subjects were predominantly right handed.

Syllable pairs were recorded on the videotape at a rate of one pair every five seconds. The mean interval from onset to onset of syllables within pairs was 0.95 seconds. When a subject took longer to respond, the tape was stopped until a response had been made. The time taken for each series was approximately seven minutes. Initially two series of syllables were presented per session, however, this proved to be too fatiguing, and after the second session only one series was presented.

All subjects were seen two or three times a day, which allowed the 48 training sessions to be completed within a period of four weeks. To prevent bias due to order effects, the 48 sessions for each subject were arranged in 12 groups of four. Within each group, the four conditions were presented in accordance with predetermined random schedules. A different random schedule was arranged for each child. The eight series were systematically distributed over the 48 session in such a way that no subject received the same series more than twice under any condition.

An additional reinforcement procedure was introduced following the fourth session. Subjects who succeeded in equalling or exceeding their previous score for a given condition were rewarded with a piece of candy. Subjects were made aware of the criteria for reward by being shown their previous score prior to the test presentation.

Pre- and Post-Tests

Each subject was tested under each of the four conditions in a counterbalanced order. Subjects were told which type of test presentation to expect. Before each trial a set of four picture cards was placed in random order in front of the subject who was requested to name the picture. If the subject used a name other than that assigned or failed to respond, the correct name was given by the experimenter. Thus subjects were not penalized for limited vocabulary. The word was then presented by videotape and the subject responded by pointing to the chosen picture.

The post-test was administered one week after the completion of the training program. The break was necessitated by the Easter holiday session. Procedure for the post-test, including presentation order, was the same as for the pre-test.

CHAPTER III

RESULTS

Results are presented for the training program and the pre- and post-tests. Data for the training program included the number of correct responses and the response times for correct items. Data for the pre- and post-tests were error scores.

Trends in Subjects' Performance Under Each Condition

The number of correct responses and means for each subject over twelve sessions for each of the four conditions, vision (V), audition (A), vision supplemented by optimal audition (VOA), and vision supplemented by suboptimal audition (VSA) appear in Tables 3.1 - 3.4.

A four way analysis of variance for repeated measures was applied to the data and a summary of the results is shown in Table 3.5a. The difference between

Table 3.1

Number of Correct Responses and Means for Subjects
over Sessions under the Auditory Condition
(N presentations per series = 90)

	Session												
	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Subject													
1	48	65	60	71	77	73	70	77	71	70	67	71	68.3
2	45	46	54	52	42	53	50	54	55	62	56	58	52.3
3	54	47	57	57	60	56	51	51	74	66	48	54	56.3
4	56	61	65	51	53	68	72	53	67	59	61	51	59.8
5	44	40	51	56	49	48	44	49	54	60	43	44	48.5
6	53	55	59	66	61	55	70	65	73	66	73	61	63.1
7	72	78	72	83	78	88	80	75	73	71	78	81	77.4
8	49	51	50	48	49	45	57	58	58	54	45	58	51.8
Mean	52.6	55.3	58.5	60.6	58.6	60.7	61.7	60.2	65.6	63.5	58.8	59.7	59.6

Table 3.2

Number of Correct Responses and Means for Subjects over Sessions Under the Visual Condition (N presentations per series = 90)

	Session												
Subject	1	2	3	4	5	6	7	8	9	10	11	12	Mean
1	50	64	65	70	80	75	69	75	71	74	69	58	68.3
2	59	64	67	74	68	74	71	67	68	72	73	71	69.0
3	65	59	58	60	66	64	63	57	55	57	66	52	60.2
4	43	62	51	50	55	52	51	53	60	57	61	57	54.3
5	33	43	42	49	46	44	41	46	47	45	56	54	45.5
6	65	54	61	60	55	68	67	68	67	69	60	59	63.6
7	61	73	71	75	68	71	71	76	74	72	72	70	71.2
8	54	45	51	56	45	49	46	58	49	53	56	57	51.6
Mean	53.7	58.0	58.2	61.7	60.4	62.1	59.9	63.8	61.4	62.4	64.1	59.8	60.45

Table 3.3

Number of Correct Responses and Means for Subjects over Sessions Under the Visual Supplemented by Optimal Audition Condition
(N presentations per series = 90)

	Sessions												
Subject	1	2	3	4	5	6	7	8	9	10	11	12	Mean
1	53	74	76	80	82	79	84	73	83	76	79	83	76.8
2	72	65	75	74	74	71	69	62	68	71	74	74	70.8
3	68	65	71	63	60	68	60	60	74	64	59	59	64.3
4	70	71	45	66	77	71	61	61	75	68	65	60	65.8
5	41	47	58	57	41	57	53	49	57	37	52	40	49.1
6	76	74	86	73	77	73	81	86	83	84	81	77	79.3
7	82	79	81	85	90	88	85	84	89	85	81	86	84.6
8	44	45	54	47	52	45	53	52	54	52	60	53	50.9
Mean	63.3	65.0	68.2	68.1	69.1	69.0	68.3	65.9	72.8	67.0	68.9	66.5	67.7

Table 3.4

Number of Correct Responses and Means for Subjects over Sessions Under the Visual Supplemented by Suboptimal Audition Condition
(N presentations per series = 90)

	Sessions												
	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Subject													
1	53	72	77	72	82	77	75	75	75	76	84	80	74.8
2	63	66	67	59	71	72	72	70	75	71	73	73	69.3
3	59	67	73	70	59	69	53	64	68	67	65	60	64.5
4	61	67	65	69	72	60	64	64	75	62	69	61	65.7
5	52	55	56	53	50	53	46	51	47	50	48	42	50.3
6	68	72	78	63	60	73	78	74	78	80	69	75	72.3
7	68	71	76	82	82	83	82	81	80	79	72	79	78.0
8	46	39	59	58	51	44	39	53	47	60	50	47	49.4
Mean	58.8	63.6	68.9	65.8	65.9	66.4	63.6	66.5	68.1	68.1	66.3	64.6	65.5

Table 3.5A

Four Factor Analysis of Variance with Rēpeated Measures for Number of Correct Responses as Shown in Tables 3.1 - 3.4

Source of Variation		SS	df	MS	F
A	Subjects	17143.3	7	2449.04	
B	Conditions	2182.5	3	727.5	7.34 **
AB		2080.0	21	99.04	
C	Sessions	1099.4	11	99.95	3.71 **
AC		2073.0	77	26.92	
D	Response (Same/diff)	1549.8	1	1549.8	2.88 N.S.
AD		3762.1	7	537.44	
BC		355.5	33	10.77	
ABC		2894.4	231	12.53	
BD		384.5	3	128.17	4.54 **
ABD		930.4	33	28.19	
CD		245.2	11	22.29	7.73 **
ACD		222.1	77	2.88	
BCD		263.6	21	12.55	
ABCD		4093.8	231	17.72	

** Significant beyond the .01 level

Table 3.5B

Results of Neuman-Keuls Procedure to Examine Differences Among Total Scores for the Four Conditions

	A	V	VSA	VOA
Auditory	-	75	563 **	769 **
Visual		-	488 **	694 **
Visual Suboptimal-Auditory			-	206 **
Visual Optimal-Auditory				-

** Differences significant at .01 level

conditions was found to be significant at the .01 level ($F_{(3,21)} = 7.34$). A higher mean score was achieved under VOA (67.7) and VSA (65.5) conditions than for V (60.5) or A (59.6) conditions. To examine the differences among conditions, the Newman-Keuls procedure (Winer, 1962) was employed. Results, shown in Table 3.5b, indicate that performance under VOA was significantly superior to that under VSA. The VOA and VSA scores were significantly higher than either of the unisensory scores ($p < .01$). The A and V scores were not significantly different from each other.

Subjects' performance tended to improve with each successive session, and differences among sessions were significant at the .01 level of confidence ($F_{(11,77)} = 3.71$). Analysis of the trend of the scores indicated a significant linear component ($F_{(1,77)} = 16.31$, $p < .01$). Figure 1 shows subjects' mean scores pooled for each session under each of the four conditions. Both the improvement in subjects' performances and the relative superiority of the bisensory conditions is illustrated.

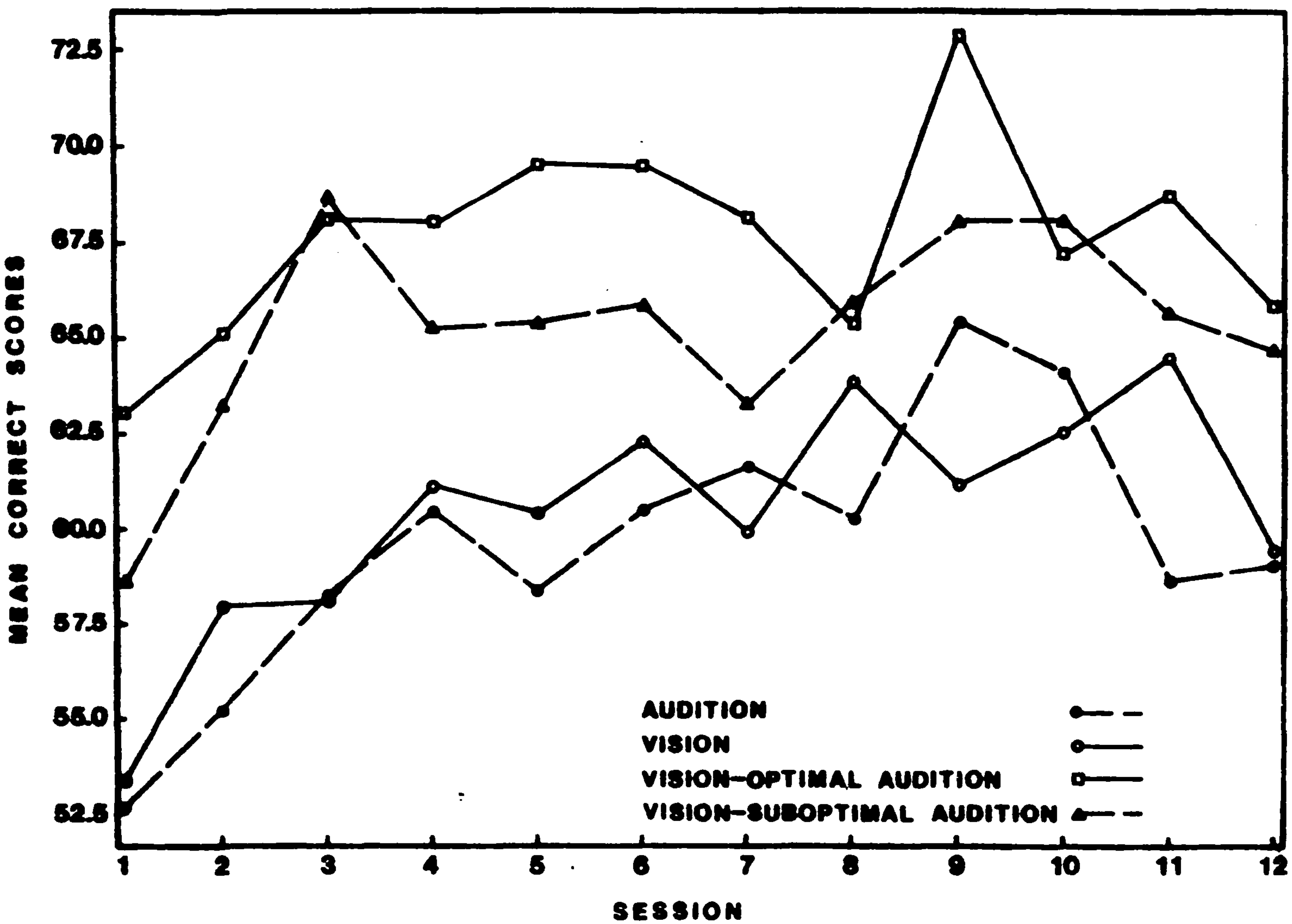

Figure 1. Subjects' Mean Scores Pooled for Each Session Under Each of the Four Conditions. Maximum possible score = 90.

Although there were more correct responses to "same" than to "different" trials, this main effect was not found to be significant ($F\ (1,7) = 2.88$). However, there was a significant interaction between conditions and same-different responses ($F\ (3,33) = 4.54,\ p < .01$). The interaction can be accounted for by the fact that proportionally fewer different judgments were correct for the A and V conditions than for the VSA and VSO conditions (see Table 3.6).

The analysis also indicated a significant interaction between sessions and same-different responses ($F\ (11,77) = 7.73,\ p < .01$). An explanation of this interaction is that subjects initially obtained proportionally more correct "same" judgments (see Table 3.7). However, from Session 5 to Session 10 a relatively larger proportion of "different" responses was correct. For Session 11 and 12 the relation between "same" and "different" scores was similar to the ratio for initial sessions. The peak point indicated at Session 9 for the VOA condition is the result of high scores by three subjects for that session. As

Table 3.6

Mean Correct Responses to Same and Different Trials under the Four Conditions

Condition	Response SAME	Response DIFFERENT
A	64.6	54.7
V	63.7	57.3
VOA	68.9	66.4
VSA	67.5	63.6

Table 3.7

Mean Correct Responses to Same and Different Trials in Relation to Sessions

Responses	Sessions											
	1	2	3	4	5	6	7	8	9	10	11	12
Same	61.3	63.8	68.3	67.6	65.7	66.0	65.6	64.9	69.8	67.1	68.2	65.8
Different	57.2	57.8	58.6	60.4	61.3	63.1	61.1	63.3	64.2	63.5	60.9	59.5

training sessions occurred on different days, this variation may be due to chance.

There were considerable differences between subjects' performance (see Tables 3.1 - 3.4). Scores achieved by Subject 5 were generally not significantly better than chance. (A binomial expansion indicates that scores better than 54 are required to exceed a 5% level of confidence). Subject 8 also responded at a chance level for the V, VOA and VSA conditions. Although all other subjects responded at a level above chance, Subject 3 showed no improvement over sessions under any condition, and Subject 4 only showed improvement for the V condition.

Consonant-Vowel Discrimination in Relation to Conditions

A further analysis of variance was applied to the data of correct responses to determine the discriminability of consonant/vowel combinations under the four conditions. The results of this analysis are summarized in Table 3.8.

Table 3.8

Summary of Analysis of Variance of Correct Responses for Vowels, Consonants and Conditions

Source of Variation		SS	df	MS	F
A	Subjects	137628.4	7		
B	Condition	60498.8	3	20166.27	5.763 **
AB		73488.7	21	3499.46	
C	Consonants	133559.1	20	6677.95	6.2291**
AC		150087.2	140	1072.05	
D	Vowels	1803.43	2	901.71	3.288 N.S.
AD		3839.13	14	274.22	
BC		100012.0	60	1666.86	6.119 **
ABC		114409.2	420	272.40	
BD		2762.91	6	460.48	3.334 *
ABD		5800.52	42	138.10	
CD		21879.13	40	546.97	2.724 **
ACD		56212.49	280	200.76	
BCD		28386.65	120	236.56	1.983 **
ABCD		100197.7	840	119.28	

** Significant beyond the .01 level
* Significant beyond the .05 level

As indicated in the previous analysis, a significant difference existed between the condition scores. The only other significant main effect was for consonants ($F\ (20,140) = 6.2291$, $p < .01$). Inspection of the percentage of correct responses for the consonants (see Table 3.9) showed that a higher percentage was obtained for all comparisons between the alveolars /t,d,s,l/ and the dentals /θ - ð/. Most comparisons between consonants within the alveolar and dental groups received low mean scores, with the cognate pairs /θ - ð, t - d/ receiving the least number of correct responses.

There was a significant consonant-condition interaction ($F\ (60,420) = 6.119$, $p < .01$). Table 3.10 shows that, under all but the A condition, high scores were obtained for comparisons between alveolars and dentals. Dispersion of scores among consonant-vowel combinations was not so marked for the A as for the V condition (54%-69% A, 31%-80% V). The A scores did not differ according to the number of distinctive feature differences (Wickelgren, 1966) between consonants of each pair. The

Table 3.9

Percentage of Correct Responses for Consonant Comparisons in Rank Order

Order	Consonant Pair	%	Order	Consonant Pair	%	Order	Consonant Pair	%
1	s - ð	- 77.3	8	l - ð	- 72.3	15	ð - ð	- 66.6
2	l - θ	- 77.0	9	s - s	- 71.8	16	t - t	- 66.5
3	t - θ	- 75.6	10	θ - θ	- 70.4	17	d - l	- 63.4
4	s - θ	- 75.1	11	d - d	- 68.8	18	t - s	- 58.6
5.5	t - ð	- 73.5	12	l - l	- 68.4	19	d - s	- 57.0
5.5	d - θ	- 73.5	13	t - l	- 68.3	20	t - d	- 55.0
7	d - ð	- 73.2	14	l - s	- 67.8	21	ð - θ	- 43.9

Table 3.10

Percentage of Correct Responses According to Consonant under the Four Conditions

Consonant Pair	Condition V	A	VOA	VSA
d - θ	80	56	79	80
l - θ	79	67	85	77
s - θ	79	59	84	79
t - θ	77	63	82	81
θ - θ	76	52	75	78
s - ð	76	69	83	81
d - ð	76	54	83	80
l - ð	75	55	80	79
ð - ð	73	48	74	72
t - ð	72	60	82	80
s - s	71	57	79	80
d - d	70	54	74	77
l - l	68	56	76	75
t - t	67	55	75	68
l - s	62	65	74	71
t - l	54	65	77	76
d - l	48	65	72	68
t - s	46	68	62	58
t - d	46	68	56	49
d - s	41	66	61	59
ð - θ	31	62	43	39

discrimination trend under the VOA condition was similar to that under the V condition. The lowest scores under the VSA condition were obtained for "different" comparisons between /t,d,s,l/. Under the VOA condition scores were, in most instances, higher than those obtained for either unisensory condition. The four exceptions to this trend were the comparisons, /ð - θ, d - s, t - d and t - s/. The higher of the unisensory scores for these four comparisons was obtained for the A condition. Their corresponding scores were the four lowest under the V condition. The results for the VSA condition were similar to those recorded under VOA, except that scores for /l - θ, s - θ/ and /t - t/ were equal, rather than superior, to the better of the unisensory scores.

The interaction between vowels and conditions was found to be significant at the .05 level ($F\ (6,42) = 3.334$). It was noted that for the V condition subjects made fewer correct responses to the syllables containing the vowel /u/ (62%) than to those containing either /a/ (68%) or /i/ (66%). Under the VOA condition the lowest scores were associated with /u/. For the A and VSA conditions differences between scores obtained for the different vowels were minimal.

Consonant by vowel interaction was significant at the .01 level of confidence (F (40,280) = 2.724). This indicates that several consonant pairs were more readily discriminated when presented with certain vowels than with others, e.g. scores for /ð-ð, l - s, d - l/ were higher with /a/ than with /i/ or /u/ and /ð- θ/ was discriminated the best with /u/, while for /l -ð/ highest scores were achieved with /i/.

Table 3.11 presents the percentage correct for consonant/vowel pairs under the four conditions. A significant second order interaction was found between these factors (F (120,840) = 1.983, p$<$.01). For the A condition /s -ð/ was discriminated correctly more often with /i/, but low scores were associated with /l -ð, d - ð/ in combination with /a/, whereas higher scores were achieved for /d - s/ with /u/. Under the V condition, discrimination of /t - d/ was best with /i/, and /t - l, t - s, d - l/ with /a/. The consonant pairs /t - s, t - l, l - θ, l -ð/ were discriminated less well with /u/ but /ð - θ/ more successfully. For the VOA condition,

Table 3.11

Percentage of Correct Responses for Each Syllable Pair According to Condition, Vowel and Consonant

Consonant Pairs	V i	V a	V u	A i	A a	A u	VOA i	VOA a	VOA u	VSA i	VSA a	VSA u
l - ð	85	80	61	57	43	66	86	86	68	91	76	71
l - θ	84	82	71	68	66	68	89	85	81	74	80	76
s - θ	83	77	75	54	66	56	91	84	77	79	84	75
d - θ	81	86	74	54	52	60	78	78	79	87	77	75
d - ð	81	72	75	58	46	58	84	82	81	86	80	73
t - θ	79	79	72	65	62	60	86	82	78	85	75	82
ð - ð	73	78	67	42	54	47	73	84	67	74	70	69
θ - θ	73	80	75	50	54	53	77	79	71	81	77	77
t - ð	71	69	75	59	70	52	88	79	78	83	79	78
s - ð	70	80	78	81	56	70	75	84	89	76	80	88
l - l	69	73	62	58	58	51	77	72	79	71	84	68
t - t	69	65	68	56	56	54	78	78	75	72	62	71
d - d	65	72	71	57	54	52	72	77	72	78	78	76
l - s	65	66	55	60	69	65	72	80	69	57	77	78
s - s	64	75	74	57	59	56	73	81	83	79	81	80
t - d	60	38	42	64	69	71	54	55	60	47	48	53
t - l	55	68	42	66	65	67	75	78	78	71	80	76
t - s	46	57	34	66	72	68	74	60	53	63	80	76
d - s	43	44	38	64	59	76	59	62	63	52	57	68
d - l	41	59	46	56	70	68	68	81	66	58	81	65
ð - θ	28	26	39	62	60	63	39	40	52	39	30	49

/t - s/ was discriminated more often with /i/, whereas /d - l, ð - ð/ were discriminated best with /a/ and /ð - θ/ with /u/, for /l - θ/ comparison a low scores was associated with /u/. Under the VSA condition subjects obtained low scores for /l - s/ combined with /i/, whereas /l - ð/ was discriminated correctly more often with this vowel. The consonant pairs /d - l, l - l/ were discriminated best with /a/, and /ð - θ/ best with /u/.

Age and Hearing

The relationship between condition scores and the variables of age and hearing were examined and a series of correlations calculated. The results are presented in Table 3.12. Only under the V condition was the correlation between age and scores significant, beyond the .05 level. No significant relationship was noted between average hearing level (500 Hz - 4000 Hz) and scores for the four conditions.

Table 3.12

Correlation Coefficients Showing Relationship of Chronological Age and Hearing Level, to the Four Experimental Conditions

	Conditions			
	V	A	VOA	VSA
Chronological Age	.86 *	.69	.64	.69
Hearing Level	-.23	-.07	-.30	-.12

* $R_{.99} = .86$

Response Time

A four-factor analysis of variance of the reciprocals of the mean response times (Edwards, 1968) was performed and a summary of the results is presented in Table 3.13. Subjects showed faster response times for successive sessions under each condition (see Table 3.14) and this main effect was found to be significant at the .01 level ($F\ (11,77) = 4.07$). Trend analysis indicated a significant linear component ($F\ (1,77) = 43.45$, $p < .01$). No other main effects or interactions were found to be significant.

The mean response time for all correct responses to each syllable are given in Table 3.15. No clear pattern for response time emerged except that the /ð - θ/ comparisons consistently yielded the slowest response times under all conditions.

Table 3.13

Summary of Four Factor Analysis of Variance with Repeated Measures for Reciprocals of Response Time for Correct Items

Source of Variation		SS	df	MS	F
A	Subjects	4548318.3	7		
B	Conditions	9957.2	3	3319.0	
AB		116345.6	21	5540.2	
C	Sessions	694003.3	11	63091.2	4.07 **
AC		1191208.1	77	15470.2	
D	Response	3807.2	1	3807.2	
AD		30768.7	7	4395.5	
BC		78966.3	33	2393.9	
ABC		1550829.9	231	6713.5	
BD		10831.2	3	3610.4	
ABD		170382.3	33	5163.1	
CD		7039.1	11	639.9	
ACD		1315646.9	77	17086.3	
BCD		113898.3	21	5423.7	
ABCD		2110889.2	231	9138.1	

** Significant beyond the .01 level

Table 3.14

Mean Reciprocals of Response Time for Conditions over Sessions

Condition	Session 1	2	3	4	5	6	7	8	9	10	11	12	Mean
A	.522	.563	.580	.560	.576	.576	.581	.588	.604	.644	.630	.616	.587
V	.537	.550	.533	.576	.578	.588	.581	.581	.615	.619	.616	.630	.583
VOA	.551	.561	.560	.575	.570	.593	.599	.609	.608	.628	.633	.639	.593
VSA	.519	.528	.583	.577	.579	.583	.582	.604	.610	.615	.639	.637	.588

Table 3.15

Mean Response Time in Seconds for Correct Responses Made to Each Syllable Pair According to Presentation Condition, Vowel and Consonant

Consonant	V			A			VOA			VSA		
Pairs	i	a	u	i	a	u	i	a	u	i	a	u
s - s	.50	.63	.78	.84	.75	.75	.71	.75	.68	.76	.75	.75
l - l	.62	.84	.92	.79	.82	.80	.91	.87	.88	.81	.92	1.14
θ - θ	.65	.69	.71	.76	.86	.77	.72	.79	.65	.59	.86	.84
t - t	.68	.80	.92	.73	.78	.73	.75	.74	.78	.80	.85	.78
s - ð	.69	.71	.78	.72	.74	.76	.72	.65	.82	.76	.62	.90
d - d	.71	.86	.62	.96	.76	.89	.83	.84	.85	.86	.87	.88
t - d	.75	.92	.97	1.19	.86	.65	1.01	.88	.91	.92	.92	.76
l - θ	.77	1.01	.99	.66	.87	.82	.74	.84	.81	.80	.78	.78
l - ð	.78	.88	.71	1.03	.92	.91	.75	.87	1.04	.79	.82	.87
t - l	.80	.87	1.18	.78	.88	.80	.82	.80	.63	.87	.90	.87
l - s	.82	.88	.83	.85	.92	.90	.81	.92	.90	.84	.93	.90
d - θ	.84	.83	.82	.94	.99	.96	.72	.70	.73	.79	.79	.87
d - l	.84	.91	.81	.89	.82	.92	.85	.83	.93	1.01	.83	.99
t - θ	.85	.90	.81	.87	.86	.80	.72	.75	.76	.75	.75	.81
s - θ	.85	.97	.70	.81	.96	.83	.79	.78	.67	.78	.77	.78
t - ð	.86	.74	.84	.80	.73	.96	.79	.73	.73	.80	.74	.93
d - ð	.90	.82	1.05	.95	.78	.70	.75	.76	.89	.85	.75	.91
t - s	.95	.93	1.18	.73	.78	.83	.73	.80	.87	.89	.96	.79
ð - ð	.98	.69	.86	1.03	.83	.85	.87	.79	.87	.88	.90	.59
d - s	1.04	1.00	.85	.91	.79	.79	.83	.79	.87	.97	.88	.95
ð - θ	1.20	1.19	1.04	1.07	.95	1.02	1.19	1.08	.99	1.06	.96	.99

Rate of Information Transfer

The transmission rate for each syllable pair was calculated from the following equation, given by Pierce (1961, p 155).

$$R = H(x) - H_y(x),$$

where R is the rate in bits per second, H(x) is the amount of information in the stimulus divided by response time, and $H_y(x)$ is the average uncertainty of the receiver as to what was actually presented, which is determined by the proportion of errors made in the discrimination task. The results are presented in Table 3.16.

Consonant pairs discriminated most accurately were not necessarily those processed most rapidly, and rate of information transfer was therefore poorer than error scores alone would indicate. The reverse was also true.

Pre- and Post-Tests

The purpose of the pre- and post-tests was to determine whether learning over the training program would

Table 3.16

Rate of Information Transmission in Bits per Second
For Syllables Under the Four Experimental Conditions

Consonant	V			A			VOA			VSA		
Pairs	i	a	u	i	a	u	i	a	u	i	a	u
s - s	1.28	1.18	.95	.68	.78	.74	1.01	1.08	1.22	1.04	1.08	1.06
l - l	1.11	.87	.68	.74	.70	.64	.85	.83	.90	.87	.92	.58
θ - θ	1.10	1.15	1.06	.66	.63	.69	1.07	1.01	1.09	1.37	.89	.92
l - ð	1.09	.91	.86	.55	.47	.73	1.14	.99	.65	1.16	.93	.82
l - θ	1.09	.81	.72	1.03	.76	.95	1.20	1.01	1.00	.92	1.02	.96
s - ð	1.01	1.13	1.00	1.13	.76	.92	1.04	1.29	1.09	1.00	1.29	.87
t - t	1.01	.81	.74	.77	.72	.74	1.04	.99	.96	.90	.73	.91
s - θ	.98	.80	1.07	.67	.69	.67	1.16	1.07	1.15	1.01	1.09	.96
d - θ	.93	1.03	.90	.57	.53	.62	1.08	1.11	1.08	1.10	.98	.88
t - θ	.91	.88	1.00	.75	.72	.75	1.20	1.09	1.03	1.13	1.00	1.01
d - d	.91	.84	1.14	.59	.71	.58	.86	.92	.85	.90	.90	.86
d - ð	.90	.88	.71	.61	.51	.83	1.12	1.09	.91	1.01	1.06	.80
t - ð	.83	.93	.89	.76	.96	.54	1.12	1.08	1.07	1.04	1.07	.84
l - s	.80	.75	.66	.70	.75	.73	.89	.87	.77	.68	.83	.87
t - d	.80	.42	.43	.54	.80	1.09	.53	.63	.88	.52	.52	.70
ð - ð	.75	1.13	.78	.41	.65	.55	.84	1.07	.77	.84	.78	1.17
t - l	.69	.78	.35	.82	.74	.84	.91	.97	1.24	.82	.89	.87
d - l	.49	.65	.57	.63	.86	.74	.80	.98	.71	.57	.99	.66
t - s	.48	.62	.29	.90	.92	.82	1.01	.75	.61	.71	.83	.94
d - s	.42	.44	.45	.80	.75	.94	.71	.79	.72	.54	.64	.71
ð - θ	.23	.22	.37	.59	.63	.62	.33	.37	.53	.37	.31	.50

improve subjects' ability to recognize words.

Error scores for the experimental and control subjects for the four conditions are presented in Table 3.17. An analysis of variance (Table 3.18) revealed no significant difference between groups for the post-test. Thus, the training program did not improve subjects' ability to recognize words. Results for both groups on the post-test were superior to those for the pre-test.

Subjects could not be matched under the two bisensory conditions and a greater number of errors was initially made by the experimental group. However, since the pre- and post- tests by condition interaction was not significant, this disparity was not likely to have influenced the post-test comparison.

There was a significant difference between the mean error scores for conditions ($F\ (3,42) = 74.81,\ p < .01$). Most error scores occurred for the A condition, and to a lesser extent for the V condition. Total error scores for the VSA and VSO conditions were similar.

Table 3.17

Error Scores for Each Subject on Pre- and Post-Tests for the Four Conditions

		Pre-Test					Post-Test				
	Subject	V	A	VOA	VSA	Sum	V	A	VOA	VSA	Sum
Exp. Group	1	1	9	2	3	15	2	6	1	0	9
	2	2	4	3	6	15	6	8	3	3	20
	3	4	4	4	5	17	4	5	0	2	11
	4	3	1	0	0	4	1	2	0	0	3
	5	8	12	6	9	35	6	12	6	3	27
	6	5	8	0	1	14	2	3	0	0	5
	7	1	6	2	2	11	1	5	0	1	7
	8	4	11	7	7	29	4	13	5	4	26
Sum		28	55	24	33	140	26	54	15	13	108
Control Group	1	3	11	4	1	19	3	12	5	1	21
	2	2	8	2	0	12	3	8	2	0	13
	3	3	1	0	2	6	3	1	0	2	6
	4	4	1	0	1	6	2	3	0	0	5
	5	7	6	2	6	21	4	9	0	2	15
	6	2	13	3	3	21	2	12	4	3	21
	7	1	2	0	2	5	1	4	0	1	6
	8	8	9	4	2	23	6	8	4	3	21
Sum		30	51	15	17	118	24	57	15	12	108

Table 3.18

Summary of the Analysis of Variance for Pre- and Post-Test Data

Source of Variation	SS	df	MS	F
Between Subjects	505.93	15		
A Groups	5.69	1	5.69	
Subject within groups (error a)	500.24	14	35.73	
Within Subjects	879.62	112		
B Pre- and Post-Test	10.69	1	10.69	6.52 *
AB	5.7	1	5.7	3.48 N.S.
B x Subjects within groups (error b)	22.98	14	1.64	
C Conditions	442.14	3	147.38	74.81 **
AC	5.91	3	1.97	
C x Subjects within groups (error c)	280.07	42	6.67	
BC	14.16	3	4.72	2.15 N.S.
ABC	5.88	3	1.96	
BC x Subjects within groups (error bc)	92.09	42	2.19	

* Significant at .05 level
** Significant beyond .01 level

CHAPTER IV

DISCUSSION

Performance in Relation to Conditions

The main purpose of this study was to examine the discriminability of consonant-vowel syllables by hearing-impaired children under the conditions of vision (V), audition (A), vision supplemented by optimal audition (VOA), and vision supplemented by suboptimal audition (VSA). Results for the bisensory conditions were significantly superior to those for the unisensory conditions. VOA was superior to VSA, but there was no significant difference between the results obtained under the two unisensory conditions. The finding of bisensory superiority is consistent with the results of previous research (Hudgins, 1951; Clarke, 1957; Prall, 1957; Hutton, 1959; Krug, 1960; Beggs, 1968), and is evidently related to subjects' ability to discriminate the differences between syllables more readily than when cues from only one sensory channel are available.

The superiority of bisensory speech discrimination suggests that the hearing-impaired child should be afforded information from both sensory channels for speech reception. While minimal auditory input supplements vision for speech discrimination as shown by VSA performance, to establish the most efficient communication link for the deaf child it is clearly important to determine individual optimal listening levels.

Two studies have shown vision to be superior to audition for the reception of speech (Numbers & Hudgins, 1957; Hudgins, 1951). In contrast, the A and V conditions were not significantly different in the present study. However, the nonsense syllables selected for the present study were of minimal visual difference. A random, rather than a selected set of phonemes based on visual difficulty, may have yielded higher visual than auditory scores.

Under all conditions subjects' performance improved over the first three or four sessions. A slower rate of learning was present for subsequent sessions. It is suggested that as the slow improvement was associated with judgments of difference, subjects were able to make increasingly finer discrimination of less discernable cues.

Consonant Discrimination

The results of individual consonant-vowel syllable pairs indicated that differences between some consonants were more visually discriminable than others and that vowels influenced their discriminability. The dentals, /ð/ and / θ /, were clearly differentiated when compared with the alveolars /t, d, l, s/ but consonants within these two groups were not discriminable from each other. The visual difference between the dental and the alveolar consonants is most likely associated with the visibility of the tongue movement during the production of the dentals. These findings apparently disagree with those of Woodward and Barber (1960) who classified dentals and alveolars as non-contrastive. Direct comparison between studies is complicated by procedural differences and different scoring criteria. Fisher (1968) pointed out that the actual interdentalness of /ð/ and / θ / in conversational speech is questionable, and suggests that for rapid speech the dental position may be undershot with the result that the movement is placed among the less discriminable post dental group. Nevertheless, there are potential cues available to the speechreader for the discrimination of this movement, though their visibility may vary according to the linguistic environment.

Consonants were more difficult to discriminate under the V condition with the vowel /u/ than with either /i/ or /a/. This finding agrees in part with the results of Bel'Tuikov (Quigley, 1966) though he reported that /i/ had a greater negative influence on the consonant. The wide opening of the lips in the production of /a/ evidently enables some cues, such as tongue position associated with the preceding consonant, to be discriminated. In comparison, the production of /u/ involves more liprounding and allows for fewer visible post labial cues. For /i/ the lips are spread and this position also restricts the number of visible targets available to the speechreader, though in the present study the percentage of correct responses with /i/ was only slightly less than with /a/. Vowel influences could be an important factor in accounting for discrepancies among results of previous research where different vowels were used to examine consonant discrimination. Woodward and Barber (1960), for example, combined consonants with /a/, whereas O'Neill (1954) used /i/ for his consonant vowel combinations and Heider and Heider (1940) used /ɔi/ and /i/ but in a consonant vowel consonant environment.

Results for the discrimination of syllables under the A condition indicate that "different" comparisons were more correctly discriminated than "same" comparisons. Under the V condition there were fewer correct "same" comparisons than under the A condition, and under the A condition "different" pairs did not show as large a range of scores. Thus visual speech patterns were more consistently discriminated than auditory patterns. Since hearing levels and auditory discrimination ability vary considerably between subjects, no clearly defined overall auditory pattern emerged.

The auditory results were examined according to distinctive feature theory with reference to Wickelgren (1966). Studies with normal-hearing subjects have indicated less errors for contrasts that differ by more than one distinctive feature (Tikofsky & McInish, 1968; Chananie & Tikofsky, 1969). Ling (1969) showed that hearing-impaired children did not recognize syllable pairs differing by only one distinctive feature as readily as those differing by more than one feature. However, no relationship appeared between the number of distinctive feature differences between syllables and their discriminability in the present study.

The three vowels had equal influence on the auditory discriminability of the consonant. A number of studies with normal hearing subjects (Sherman, 1952; Sadler, 1961; Wang & Fillmore, 1961) and deaf children (Ling, 1970) have indicated that some vowels influence the discriminability of adjacent consonants more than others. No differences were apparent in this study.

Discussed in Severin's (1967) terms, the pattern of scores for the VOA condition suggests that, for most comparisons, cues from the two sensory channels are relevant and therefore additive. For three comparisons the information from the A and V channels is redundant and the combined score is no better than the higher unisensory score. For several comparisons, cues from either sense channel are irrelevant (unrelated) and the combined score was less than the better unisensory result. Lower combined scores were noted for the four combinations which received the lowest visual scores. A similar result may occur when auditory scores are low though this was not shown in the present study.

With the VOA condition lower scores were recorded for consonants combined with the vowel /u/ compared to the scores obtained with the other two vowels. This pattern which is similar to that for the same vowel under the V condition, suggests that attention was paid predominately to the visual stimuli. However, a similar pattern was not recorded for the VSA condition. Under reduced auditory input, VSA condition, the syllables /l - θ, s - θ, t - t/ yielded scores which were equal, rather than superior, to the better unisensory score. Thus some relevant auditory cues were lost when input was reduced.

The A and V scores for a number of syllables do not support the popular notion expressed by Pauls (1965) that many sounds which are difficult to hear are easy to see on the lips, and likewise those which are difficult to see are easier to hear. The ease of hearing certain phonemes varies considerably depending on the degree and nature of the hearing impairment. Such untested statements often lead to misconceptions regarding the child's reception of speech.

In brief, the main findings in this study were, first, that bisensory discrimination was superior to unisensory discrimination, even when auditory input was less than optimal. Secondly, that within the selection of consonants studied, previously categorized as non-contrastive, two distinct contrastive groups emerged, the dentals and alveolars. Thirdly, that under the visual condition, consonants combined with /u/ were least discriminable.

Subject Differences

The number of correct responses per session by two subjects was rarely above a chance level. Subject 5 was the youngest subject and Subject 8 was rated as having poor academic achievement. Both subjects had difficulty in following the program though at the commencement of sessions, they were able to make consistent responses to live presentations of syllable pairs. Templin (1957) suggested that making same-different judgments to nonsense syllables demands considerable intellectual development. The discrimination of a large number of consonants appears to be too difficult for some children, in particular young children and poor achievers. A preferable procedure would be to introduce fewer comparisons initially so that subjects could be more successful and consequently receive greater positive reinforcement. The training procedure could be programmed to enable the subject to proceed according to his ability to manage an increasing number of different discriminations.

Although Subjects 3 and 4 could follow the program and use the response device appropriately, they did not improve over sessions under most conditions. Hence some children were not able to make increasingly finer discriminations in this type of training situation.

Variables of Hearing and Age

Correlations between age and training scores indicated a significant relationship with the visual condition and a positive though not significant trend for the other three conditions. Evans (1965) and Neyhus & Myklebust (1969) have also shown a significant relationship between speechreading ability and age for the group they studied. Templin (1957), assessing auditory discrimination indicated that the ability of normal-hearing children to discriminate between elements of speech increases with age. Tikofsky and McInish (1968), like Templin, found that by age 7 most normal-hearing children can discriminate among consonants. For the hearing-impaired child development of auditory discrimination is likely to take much longer. The positive correlation between age and scores may be related to the influence of several factors including language level and previous training.

No relationship was found between hearing level and any of the conditions. Beggs (1968) also failed to find a relationship between speechreading ability and hearing level, though studies by Evans (1965) and Neyhus & Myklebust (1969) have both shown a small but significant relationship. The lack of a significant correlation between hearing level and auditory scores is interesting and is consistent with the view that auditory discrimination involves a number of factors besides average hearing level.

Response Time

A significant decrease in response time was found over sessions. Thus not only did accuracy of response improve but decision time also decreased. As speech is a temporal event, latency of decision would appear to be an important parameter in speech discrimination ability.

There was no clearly defined pattern of response time in relation to syllable pairs. The only notable feature was that the /ð - θ/ comparison consistently showed a slower response time under all conditions.

Response time as an index of decision latency lost some of its value in the present study as it was difficult to control a standard distance between response finger and response button. This was particularly the case with the younger subjects. Hence the portion of time involved in motor activity tended to vary.

Information Transfer

Information rates and scores correct for dental-to-alveolar comparisons under the V and VOA conditions (Tables 3.16 and 3.11) yielded similar patterns. However, while information rate for "same" comparisons under these two conditions were similar, correct scores were not. Thus performance can be viewed differently by taking both response time and correct scores into account.

Effective speech reception requires the processing of the flow of information in time, a task in which both accuracy and speed are essential components. To assess one aspect without the other is to ignore an important parameter. The attempt to explore the time parameter yielded results which suggest that the use of information rate as a measure of speech transmission may prove to be a valuable tool in further research on speech discrimination performance.

Pre- and Post-Tests

The results of the post-program test indicate no significant difference between the performance of the experimental and control groups. Thus discrimination learning of consonant vowel syllables by the experimental group was not generalized to the recognition of words as measured by these tests. Compared to pre-test results, both groups showed improvement on the post-test. Improvement was probably related to practice effects, including familiarity of the subjects with the material, procedures and the experimenter. A direct relationship between the discrimination of isolated syllables and the recognition of words or larger speech units cannot be assumed, but in view of the importance of developing suitable testing and training procedures, possible relationships should be explored.

Suggestions for Further Research

1) In the present study the training procedure was too difficult for several subjects. Further studies could examine more elaborate programming of stimuli, geared to different levels of ability to manage test material.

2) Similar studies are required to examine the discriminability of other speech sounds.

3) The development of auditory and visual discrimination skills in the hearing-impaired child needs to be clarified by additional research.

4) This study needs to be replicated using more than one speaker.

5) The improvement of subjects' performance over sessions indicates the importance of multiple assessments to obtain reliable results of discrimination ability. For experiments using repeated measures, responses could be recorded for computation by a digital computer.

6) Further studies could examine response times for various types of speech material, particularly as a means to measure rate of information transfer.

7) The relationship between discrimination learning of syllable pairs and different speech recognition tests requires further investigation.

CHAPTER V

SUMMARY

Speech discrimination by hearing-impaired children was assessed under four conditions: vision, audition, vision supplemented by optimal audition, and vision supplemented by suboptimal audition. Eight experimental subjects, aged between 7 and 14, were evaluated over twelve sessions under each of the four conditions. The speech stimuli were identical and minimally different consonant vowel syllable pairs which were selected on the basis of their visual discriminability. The speech materials were presented by videotape and subjects responded by operating a same-different response device. Response times were recorded.

Results were as follows:

1) Discrimination was better under the two bisensory conditions than under either unisensory condition. Vision supplemented by optimal audition was superior

to vision supplemented by suboptimal audition. There was no significant difference between the visual and auditory conditions.

2) Dental consonants were visually discriminable when contrasted with alveolar consonants. The vowel environment influenced the visual discriminability of consonants, with the vowels /a/ and /i/ having a more positive influence on consonant discrimination than /u/.

3) Subjects' discrimination improved over training sessions.

4) Response latencies decreased over sessions.

5) Pre- and post-tests of word recognition, administered to the experimental group and to a matched control group showed that subjects did not generalize from the training program.

REFERENCES

Albright, M.A. Ear, Eye, or Both, Volta Review 46, 1944, 11-15.

Alich, G. New Investigations in Speechreading, from 20th Convention of Assoc. of German Teachers of the Deaf in dsh Abstracts 2, 1965, 149.

Avery, C.B. The Education of Children with Impaired Hearing: in Education of Exceptional Children and Youth, (W. Cruickshank & G. Johnson Eds.) 2nd Edition, New Jersey: Prentice Hall, 1967, 343-388.

Beggs, B.A. The Role of Audition in Bisensory Processing of Oral Information Transmitted Through the Medium of 8 mm Film to Hearing Impaired Children. Ph.D. Thesis, Teachers College, Columbia University, 1968.

Belmont, L. and Birch, H.G. Lateral Dominance and Right-Left Awareness in Normal Children, Child Develop.34, 1963, 257-270.

Bindra, D., Donderi, D. and Nishisato, S. Decision Latencies and Same and Different Judgements. Percep. and Psychophysics. 3(2B), 1968, 121-130.

Bindra, D., Williams, J.A. and Wise, J.S. Judgements of Sameness and Difference: Experiments on Decision Time. Science 150, 1965, 1625-1627.

Brannon, J.B. and Kodman, F. The Perceptual Process in Speechreading. Arch. Otolaryngol. 70, 1959, 124-129.

Brehman, G.E. Programmed Discrimination Training for Lipreaders. Amer. Annals of the Deaf 110, 1965, 553-562.

Broadbent, D.E. Perception and Communication. London: Pergamon, 1958.

Broadbent, D.E. and Gregory, M. On the Recall of Stimuli Presented Alternately to Two Sense Organs. Quart. J. Exp. Psychol. 13, 1961, 103-109.

Broadbent, D.E. and Gregory, M. Division of Attention and the Decision Theory of Signal Detection Proc. Royal Soc. 158, 1963, 222-231.

Brown, A.E. and Hopkins, H.K. Interaction of the Auditory and Visual Sensory Modalities. J. Acoust. Soc. Amer. 41, 1967, 1-6.

Byers, V.W. and Lieberman, L. Lipreading Performance and the Rate of the Speaker, J. Speech and Hearing Res. 2, 1959, 271-276

Chananie, J.D., Tikofsky, R.S. Choice Response Time and Distinctive Features in Speech Discrimination. J. of Exp. Psychol. 81, 1969, 161-163.

Clarke, B.R. Use of a Group Aid by Profoundly Deaf Children: in Educational Guidance and the Deaf Child. (A.W.G. Ewing, Ed) Manchester University Press, 1957.

Corballis, M.C., Lieberman, W., and Bindra, D. Discriminability and Central Intermittency in Same-Different Judgement. Quart. J. of Exp. Psychol. 20(1), 1968, 51-61.

Cornett, R.O. Cued Speech. Amer. Annals of the Deaf, 112, 1967, 3-13.

Costa, L.D., Rapin, I. and Mandel, I.J. Two Experiments in Visual and Auditory Reaction Time in Children at a School for the Deaf. Percep. and Motor Skills . 19. 1964, 971-981.

Costello, M.R. A Study of Speech Reading as a Developing Language Process in Deaf and Hard of Hearing Children. Ph.D. Thesis, Northwestern University, 1957.

DeLand, F. An Ever-Continuing Memorial. Volta Review 25, 1923, 37.

Donnelly, K.G. Analysis of Factors that Contribute to Lipreading Ability. Final Report, Project Number RD-2746-S, Speech and Hearing Laboratory, University of Cincinnati, Ohio, 1969.

Edwards, A.L. Experimental Design in Psychological Research. 3rd Edition, Holt, Rinehard & Winston Inc., 1968.

Erber, N. Interaction of Audition and Vision in the Recognition of Oral Speech Stimuli. J. Speech and Hearing Res. 12, 1969, 423-425.

Evans, L. Psychological Factors Related to Lipreading. Teacher of the Deaf. 63, 1965, 131-136.

Ewing, I.R. Lipreading and Hearing Aids. Manchester University Press, 1944.

Ewing, I.R. and Ewing, A.W.G. The Handicap of Deafness. New York: Longmans, Green and Co., 1938, 223-241.

Ewing, A.W.G. and Ewing, E. Teaching Deaf Children to Talk. Manchester University Press, 1964.

Fairbanks, G. and Grubb, P.M. A Psychophysical Investigation of Vowel Formants. J. Speech and Hearing Res. 4, 1961, 203-220.

Fellows, B.J. Chance Stimulus Sequence for Discrimination Tasks. Psychol. Bulletin. 67, 1967, 87-92.

Fisher, C.G. Confusions Among Visually Perceived Consonants, J. Speech and Hearing Res. 11, 1968, 796-804.

Forsdale, J.R. 8 mm Film in the Education of Handicapped Children. Amer. Annals of the Deaf 111, 1966, 622-625.

Frisina, R.D. Speechreading. Report of Proceedings of the International Congress of the Deaf. Washington, D.C. U.S. Government Printing Office, 1964, 191-207.

Fry, D.B. Speech. Report of Proceedings of the International Congress of the Deaf. Washington, D.C. U.S. Government Printing Office, 1964, 183-191.

Gaeth, J.H. Verbal Learning Among Children with Reduced Hearing Acuity. Final report Project No. 1001, Wayne State University, 1960.

Gaeth, J.H. Verbal and Nonverbal Learning in Children Including Those with Hearing Losses. Part II Final Report, Project No. 2207, Wayne State University, 1966.

Graunke, W.L. Effects of Visual Auditory Presentation of Memorization by Children with Hearing Impairments. Ph.D. Thesis, Northwestern University, 1959.

Greenburg, H.J. and Bode, D.L. Visual Discrimination of Consonants. J. Speech and Hearing Res. 11, 1968, 869-874.

Heider, F. Acoustic Training Helps Lipreading. Volta Review 45, 1943, 135.

Heider, F.K. and Heider, G.M. An Experimental Investigation of Lipreading. Psychol. Monogr. 52, 1940, 124-153.

Hirsh, I.J. Communication for the Deaf. Report of Proceedings of the International Congress on Education of the Deaf, Washington, D.C.: U.S. Government Printing Office, 1964, 164-183.

Hirsh, I.J. Perception of Speech: in Sensori Neural Processes and Disorders. (B. Graham, Ed) Boston: Little, Brown and Co., 1967, 129-137.

Holm, A. The Educational Treatment of Deafness in Denmark: in The Modern Educational Treatment of Deafness, (A.W.G. Ewing, Ed) Manchester University Press, 1960, 32/1-32/6.

Hudgins, C.V. Problems of Speech Comprehension in Deaf Children. Nervous Child 9, 1951, 57-63.

Huizing, H. Deaf-Mutism: Modern Trends in Treatment and Prevention. Advances in Oto-Rhino-Laryngology 5, 1959, 74-106.

Hutton, C. Combining Auditory and Visual Stimuli in Aural Rehabilitation. Volta Review, 61, 1959, 316-319.

Kitchen, D.W. and Oyer, H.J. The Relationship of Visual Synthesis to Lipreading Performance. Paper presented at American Speech and Hearing Assoc. Convention, Chicago, 1969.

Kristofferson, A.B. Attention and Psychophysical Time. Acta Psychologica 27, 1967, 93-100.

Krug, R. Effects and Interactions of Visual and Auditory Cues in Oral Communication. Ph.D. Thesis, The University of Oklahoma, 1960.

Liberman, A.M., Cooper, F.S., Shankweiler, D.P., and Studdert-Kennedy, M. Perception of the Speech Code. Psychological Review 74, 1967, 431-461

Ling, D. The Use of Low Frequency Residual Hearing in Profoundly Deaf Children. MSc Thesis, School of Human Communication Disorders, McGill University, 1966.

Ling, D. Deaf Children's Audition of Distinctive Features within Frequency Shifted Speech. Proc. 2nd Louisville Conference on Rate and Frequency Controlled Speech, October 22-24, 1969.

Ling, D. Auditory Discrimination of Speech Transposed by a Sample-and-Hold Process. Paper to be presented at the Scientific Symposium on Speech Communication Ability and Profound Deafness, Stockholm, August 12-14, 1970.

Ling, D. and Ling, A. Basic Vocabulary and Language Thesaurus for Deaf Children. Institute of Otolaryngology Monograph, McGill University, 1968.

Lowell, E.L. A Film of Lipreading. John Tracy Research Paper II , John Tracy Clinic, Los Angeles, California, 1957.

Mason, M.K. A Cinematographic Technique for Testing Visual Speech Comprehension. J. Speech Disorders. 8, 1943, 271-278.

Morkovin, B.V. Rehabilitation of the Aurally Handicapped Through the Study of Speech Reading in Life Situations. J. Speech and Hearing Dis. 12, 1947, 363-368.

Morrell, L.K. Corss Modality Effects Upon Choice Reaction Time. Psychn. Science 11, 1968, 129-130.

Morton, J. and Carpenter, A. Experiments Relating to the Perception of Formants. J. Acoust. Soc. Amer. 35, 1963, 475-480.

Neely, K.K. Effects of Visual Factors on Intelligibility of Speech. J. Acoust. Soc. Amer. 28, 1956, 1275-1277.

Neyhus, A.I. Self Teaching in the Development of Speech-reading in Deaf Children. Final Report, Grant No. OEG 32-23-0790-5002.: U.S. Department of Health, Education and Welfare, 1966.

Neyhus, A.I. and Myklebust, H.R. Speechreading Failure in Deaf Children. Final Report, Grant No. OEG-3-7-062582-2084.: U.S. Department of Health, Education and Welfare, 1969.

Nitchie, E.G. Moving Pictures Applied to Lipreading, Volta Review 15, 1913, 117-125.

Numbers, M.E. and Hudgins, C.V. Speech Perception in Present Day Education of the Deaf. Summary Report of the Group Hearing Aid Project. Washington, D.C. Volta Bureau, 1957.

O'Neill, J.J. Contributions of the Visual Components of Oral Symbols to Speech Comprehension. J. Speech and Hearing Dis. 19, 1954, 429-439.

O'Neill, J.J. and Oyer, H.J. Visual Communication for the Hard of Hearing: History, Research and Methods. New Jersey: Prentice Hall. 1961.

Oyer, H.J. An Experimental Approach to the Study of Lipreading, Report of the Proceedings of the International Congress on the Education of the Deaf. Washington, D.C.: U.S. Government Printing Office, 1964, 322-326.

Pauls, M.D. Speechreading: in Hearing and Deafness. (Davis, H. & Silverman, S.R. Eds.) New York: Holt, Rinehart and Winston Revised Ed. 1965, 353-367.

Pfau, G. The Influence of Modality of Presentation, Response Confirmation Modes and Types of Immediate Reinforcement Upon Programmed Learning by Hearing Impaired Children, Ph.D. Thesis, Ohio State University, 1967.

Pierce, J.R. Symbols, Signals and Noise: The Nature and Process of Communication. New York: Harper Torchbooks, Harper and Row, 1961.

Pickett, J.M. Tactual Communication of Speech Sounds to the Deaf: Comparison with Lipreading. J. Speech and Hearing Dis. 28, 1963, 315-330.

Prall, J. Lipreading and Hearing Aids Combine for Better Comprehension. Volta Review 59, 1957, 64-65.

Quigley, S.P. Language Research in Countries Other Than the United States. Volta Review, 68, 1966, 70.

Reger, S.N. Pure-Tone Audiometry: in Audiometry: Principles and Practices. (A. Glorig, Ed.) Baltimore: Williams & Wilkins, 1965, 108-150.

Reid, G. A Preliminary Investigation in the Testing of Lipreading Achievement. J. Speech and Hearing Dis. 12, 1947, 77-82.

Sadler, V. Effect of Succeeding Vowel on Consonant Recognition in Noise. Language and Speech. 4, 1961, 133-138.

Sanders, J.W. and Coscarelli, J.E. The Relationship of Visual Synthesis Skill to Lipreading. Amer. Annals of the Deaf. 115, 1970, 23-26.

Severin, W.J. Pictures as Relevant Cues in Multi-Channel Communication. Journalism Quart. 59, 1967, 17-22.

Sherman, D. The Influence of Vowels on Recognition of Adjacent Consonants. J. Speech and Hearing Dis. 17, 1952, 198-212.

Simmons, A.A. Factors Related to Lipreading. J. Speech and Hearing Res. 2, 1959, 340-352.

Stepp, R.E. A Speechreading Laboratory for Deaf Children, Volta Review, 68, 1966, 408-415.

Stone, L. Facial Cues of Context in Lipreading. John Tracy Clinic Research Papers V, John Tracy Clinic, Los Angeles, California, 1957.

Strain, B.J. A Comparative Study of the Effectiveness of Lipreading Instruction in a Face to Face Situation and by Closed Circuit Television. Master Thesis, Ohio State University, 1960.

Sumby, W.H. and Pollach, I.J. Visual Contribution to Speech Intelligibility. J. Acoust. Soc. Amer. 26, 1954, 212-215.

Talving, E. and Lindsay, P.H. Identification of Simultaneously Presented Simple Visual and Auditory Stimuli. Acta Psychologica 27, 1967, 101-109.

Teichner, W.H. Recent Studies of Simple Reaction Time. Psychol. Bulletin 51, 1954, 128-149.

Templin, M. Certain Language Skills in Children. University of Minnesota Press, 1957.

Tikofsky, R.S. and McInish, J.R. Consonant Discrimination by Seven Year Olds: A Pilot Study. Psychon. Science 10, 1968, 61-62.

Utley, J. Factors Involved in the Teaching and Testing of Lipreading Ability Through the Use of Motion Pictures. Volta Review 48, 1946, 657-659.

Wang, W. and Fillmore, C. Intrinsic Cues and Consonant Perception. J. Speech and Hearing Res. 14, 1961, 130-136

Wickelgren, W.A. Distinctive Features and Errors in Short Term Memory for English Consonants. J. Acoust. Soc. Amer. 39, 1966, 388-398.

Winer, B.J. *Statistical Principles in Experimental Design*, New York: McGraw Hill, 1962.

Withrow, F.B. The Use of Audiovisual Techniques to Expand Lipreading and Auditory Experiences of Young Deaf Children. *Amer. Annals of the Deaf* 110, 1965, 523-527.

Woodward, M.F. and Barber, C.G. Phoneme Perception in Lipreading. *J. Speech and Hearing Res*. 3, 1960, 213-222.