OPERANT AUDIOMETRY WITH TWO YEAR OLDS

by 6791

MARSHA MARLENE NOWELS

B.A., Western Washington State College, 1969

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Speech

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

APPROVED BY:

Bruce C. Flanagan

Major Professor

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

ACKNOWLEDGEMENTS

The writer wishes to express her sincere appreciation to Dr. Bruce C. Flanagan, major advisor, for his guidance and assistance in the preparation and completion of the present investigation. The author expresses her gratitude also to Dorothy Wallace for her support throughout the project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION AND RATIONALE

The purpose of this research was to assay operant audiometry procedures for obtaining threshold estimates for two year olds. Currently available methods of hearing evaluation, while reasonably reliable for a majority of subjects, have yielded unsatisfactory results for young children (Cody, Bickford, 1965; O'Neill, 1969). Eagles and Wishik (1961) concluded that conventional audiometric procedures are not effective with children under the age of three years. Nevertheless, it is essential that procedures be developed for assessment for the hearing potential of the young child in order that appropriate habilitation procedures may be instituted. Several investigators (Mykelbust 1956), Goldstein 1963, Fulton & Lloyd 1969) have discussed the problem of testing young children as being analagous with the problem of testing the retarded child. Based on this assumption, it seems reasonable to look to investigations using operant methods for hearing assessment in the mentally retarded population.

Myerson and Michael (1961) first proposed the assessment of hearing by operant conditioning procedures. They reported the need for a procedure that would be: (1) Simple enough to use with a two-year-old child and "other hard to test" subjects' (2) required no verbal bebavior on the part of the audiologist or the subject; (3) created a positively reinforcing environment in which a subject would be exposed for a long period of time; and (4) was automatic in the sense that once the subject was placed at an automated audiometer, he would plot his own audiogram without further intervention by an audiologist. They proposed the automat, an operant conditioning audiometric procedure using food and other unconditioned reinforcers. One of the most extensive sutides using operant conditioning similar to those described by Myerson and Michael was first reported by Spradlin and Lloyd (1965). Further reference and revisions of this procedure have been reported by Lloyd, Spradlin and Reid (1966), 1968), Spradlin, Locke and Fulton (1969), Fulton and Spradlin (1968), Lloyd (1968). Though this procedure was initially designed for the testing of retarded children, Lloyd, Spradlin and Reid (1966) suggested that the operant principles used in testing profoundly retarded, difficult-to-test children should be equally applicable to the testing of infants and young children.

Operant audiometry is based on selecting appropriate reinforcers and the structuring of contingencies. Initially a reinforcer of the edible type is determined. This reinforcement is delivered when the child responds to the S^D, the interval when the tone is present. Once a response is established, the subject is considered under stimulus control if he responds 90 percent of the time to the S^D and no more than 10 percent of the time to the S^Δ (the interval at which the tone is not present). If the subject responds to the S^Δ the tone is delayed for 5 seconds (a time out is instituted). When the child is under stimulus control he is then given a free field screening test and a pure tone threshold test. For these the S^D is presented at VI 6 seconds. Threshold testing was done at seven frequencies, 250, 500, 750, 1000, 2000, 3000, 4000, 6000, and 8000 Hz (250 and 3000 Hz are used only for generalization training).

Fulton and Spradlin (1968) reported test-retest data. Five out of 6 subjects showed test-retest reliability of ± 5 dB in at least 5 out of 6 sessions and in no case was the difference greater than ± 10 dB. Also Lloyd (1968) reported that 84 percent of the subjects tested did establish tone control. The author hypothesized that the failure of the other 16 percent was due to ineffective reinforcers.

The success of these procedures with a population that has been termed untestable both in terms of standard audiometric techniques and in terms of I.Q. tests (WISC, Standford Binet), warrants systematic investigation of the effectiveness of operant audiological procedures on hearing assessment of 2 year old children. It should be noted that Spradlin, Lloyd, and Reid (1966) reported anecdotal data on the applicability of this procedure to children under three years of age.

These reports establish four criteria which seem applicable to other methodological approaches to hearing assessment of the young child. First, a stimulus control should be established in terms of both the control of the stimulus and the response to the stimulus. In the above studies the physical dimensions of the stimulus were controlled by presenting the tone through calibrated apparatus by earphone, as opposed to free field or other less specific procedures. Adequate control of the response to the stimulus was empirically established by the 90 percent response to S^D and not more than a 10 percent probability of response to S^Δ criteria. Secondly, reliability as described by Fulton and Spradlin (1968) should be demonstrated by ± 5 dB test-retest results. Thirdly, the relevance of the test for the target population should be determined by the percentage of subjects performing the required psychophysical task. In the previously cited studies 84 percent of the subjects met this criterion. Fourthly, the validity of a test should be considered. As Lloyd (1968) reported, the test procedure should be compared with other accepted threshold procedures.

Other methodological approaches presently used to alleviate the problem of threshold testing in young children may be divided between play audiometry and electrophysical audiometry.

Play audiometry was devised to determine if, by making the testing situation "pleasurable" for the child, it would increase his attention to the stimulus and also induce more accurate responding. An initial attempt in this area was made by Dix and Hallpike (1947) who introduced the peepshow technique. In terms of criteria established previously, this procedure was deficient in all four areas. The stimulus was presented in a free field situation, without retest data, without comparison made to other tests and with no results given for one subject under three years of age. The authors concluded that this was an effective procedure for children from three to five years of age.

Several variations of the peepshow technique have been reported (Statten and Wishart, 1956; Guilford and Haug, 1960). Basically, with these modifications, one of the criterion that was previously stated was met; that the stimulus was presented through earphones, allowing control over the parameters of intensity and frequency. Again, the lack of relevance in these studies is demonstrated by the low percentage of successes within the age group of three years of age and under. None of these studies reported more than 50 percent success with the age group in question. The majority of failure occurred with subjects below three years of age (Frisina 1963).

Another type of play audiometry that presented the stimulus through earphones but changed the response required from pushing a button to moving a block, stacking rings or dropping marbles in a box has been reported by Barr (1955), and by Mykelbust (1954). Though Barr's study did report meeting the criterion of ± 5 dB for threshold by retest procedures, reliable thresholds were established with less than 40 percent of the cases tested. Also, for children under 2 ½ years of age, play audiometric procedures were successful in only 2 out of 10 subjects (20 percent).

Electrophysical audiometry, the major procedure utilized with children, was developed to make response criteria more objective. Most audiometric studies using electrophysiological equipment have employed in some measure either automatic function or the on-going electrical activity of the nervous system. The most common indicator of transient autonomic activity is some change in the electrically recorded activity of the sweat gland (Goldstein, 1963). This procedure has been referred to as galvanic skin response (GSR), psychogalvanic skin response (PGSR), or electral dermal response (EDR) audiometry. For the purposes of this review these procedures will be referred to as electral dermal response (EDR) audiometry. As a technique for the evaluation of hearing loss in young children the EDR method was first described by Bordley et. al. (1958, 1949). In the initial investigations by Bordley and Hardy (1949) several of the established criteria were not met. The stimulus was presented through a single earphone held to the child's ear, with no retest data reported. The test results were not compared to other tests and, though results were reported for three children under the age of three years, the authors concluded that one of the subjects' data did not "represent threshold testing" and stated that they had experienced serious problems in the behavioral control of the children. Barr (1955) reported in his study that control of the frequency and intensity parameters of the stimulus and a criterion of ± 5 dB between test and retest data was established. Further Barr reported that EDR audiometry was successful in 11 out of 20 cases (55 percent) under 2½ years of age. Statten and Wishart (1956) reported that they were successful with 19 of 44 (or 43 percent) of the 2 year olds tested using EDR conditioning. This procedure showed its greatest weakness in that less than 60 percent of the subjects it was intended to test did not perform the required psychophysical task. Other negative characteristics were reported as well. It was an unpleasant experience for the child, required specially trained teams and variability in basic skin resistance created problems in identifying the electral dermal response. O'Neill (1961) evaluated EDR audiometry and concluded that in no case was electrodermal audiometry found to be successful when play audiometry failed.

Marcus, Gibbs and Gibbs (1949) were one of the first investigating teams to introduce electroencephalography (EEG) audiometry as a potential procedure for the testing of hearing in the young child. Their results did not report threshold but were refined by Cody and Bickford (1965), McCandless (1967), Price and Goldstein (1966), Rapin and Graziani (1967) and Suzuki and Taguchi (1968). The majority of these studies, however, only reported identification audiometric results and, as Rapin and Graziani (1967) stated, this method does not indicate whether the child can "hear", whether he is consciously aware of the stimulus and can utilize it as a useful signal to modify his behavior. It may, however, be a useful estimate of the sensitivity of the cochlea and auditory nerve in children. McCandless reported threshold testing by EEG procedures on 128 patients, fifty-six of whom were under three years of age. Unsatisfactory testing was reported for a substantial percent below three years of age. And though test-retest procedures were followed, thresholds for children under the age of 2 varied as much as 30 dB. Recent research (Lentz and McCandless, 1971) using average electroencephalic audiometry in infants reports, for normal infants, threshold estimates considerably above ISO zero (40 dB). Furhter testability of subjects was inversely related to age.

The specific purpose of this research was to assay the effectiveness of operant audiometry on two year olds. The operant methodology employed will basically follow the procedures developed by Spradlin, Lloyd and Fulton for testing the hearing of previously untestable retardates.

Assessment of these operant audiometry procedures was made according to several criteria: (1) Adequate stimulus control for each subject was defined as a 90 percent response to pure tone stimulus presentations with a response probability of less than 10 percent ot the time interval between presentations. (2) The testability of subjects was defined as the percentage of subjects performing the required psychophysical task following stimulus control training; and (3) the reliability of obtained threshold estimates, determined by test-retest procedures.

CHAPTER II
METHOD

The procedures followed in this research may be described in reference to selection of subjects, apparatus, specific procedures and methods used for recording results.

Subjects

The subjects for the research were ten children, ages ranging from 18 months to 30 months, with a mean of 26.3 months. Seven of the ten subjects were obtained through a church affiliated Sunday nursery, the other subjects were obtained through advertisement. Three of the 10 subjects were male and seven were female.

Apparatus

The pure tone stimuli (250, 1000, 4000Hz) were generated and controlled by a Maico (Model MA-8A) audiometer using TDX-39 earphones. At the onset of this study the audiometer was calibrated with a Bruel and Kjaer Calibration unit. All tests were administered in an acoustically-treated auditory test suit (Industrial Acoustics Company, Model 1203). Included in the sound treated room were a table with the response reinforcement delivery box, phone jacks for the earphone cords and two chairs. The response-reinforcement delivery box contained a Davis Universal Feeder (Model 310) wired so that it could be activated by the programming equipment in the control room. The Universal Feeder allowed 36 reinforcements to be delivered into a plexiglas reinforcement tray without reloading. The tray was illuminated for approximately 1 second when reinforcement was delivered. To the right of the reinforcement tray was the manipulandum, a perforated metal plate activated by

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

the subject's touch. During training and testing conditions the manipulandum was continously illuminated through the perforated surface of the plate.

Stimulus intensity and frequency were controlled at the audiometer by the Experimenter. The stimulus duration, reinforcement delivery and stimulus-response records were controlled and recorded by a relay rack consisting of timers, relays, and counters. The program controlled by the relay rack is shown in a Mechner diagram form in Figure 1. At the onset of S^D conditions a pure tone is presented to the subject's ear phones. A response (R), within the determined time interval (T_2), recycling to S^{Δ} occurs without reinforcement. The pure tone sound is terminated with recycling to the S^{Δ} condition. Lapse of a variable time period (VT) leads to a subsequent presentation of S^D. If a response occurs during S^{Δ} , the S^D condition is delayed for a fixed time interval (T_1) and recycles to the S^{Δ} condition. To allow for rise-time of the pure tone intensity, the response mechanism is disabled for 300 milliseconds at the onset of the S^D condition.

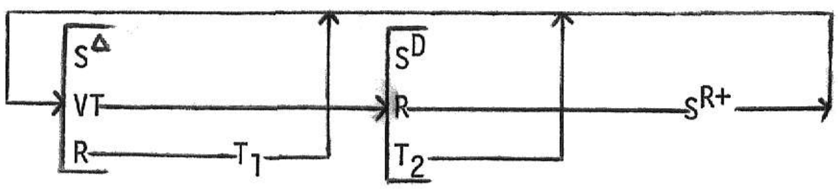

FIGURE 1. Mechner diagram of training and testing program; S^D = tone, S = no tone, and R is touching manipulandum.

Procedure

The procedure consisted of four phases: 1) Determining an effective reinforcer; 2) stimulus control training, encompassing conditioning of responding to onset of a 1000 Hz, 70 dB tone (re: ISO) presented through the earphones; 3) stimulus intensity generalization training at each test frequency; and 4) obtaining threshold estimates for .25K, 1K, 4K Hz by descending method of limits.

Effective reinforcers were determined through sample and exposure procedures reported by Ayllon and Azrin (1968). The subject was shown a selection of candies, cereals and small toys displayed on a table and was asked to select the items 'he wanted' (all edible reinforcers were sampled). If the child failed to manipulate the displayed items, the Experimenter manipulated the toys and demonstrated eating the edible items. The subject was then escorted by an Experimenter into the test room and observed while the selected items were loaded into the feeder.

The subject was then seated in front of the response-reinforcement delivery box, and earphones were then placed on his head. The light then came on under the manipulandum and a 1K Hz continuous tone was presented as the discriminative stimulus (S^D). Initially the tone was presented at 70 dB, re: ISO. At the onset of the S^D presentation, Experimenter II attracted the subject's attention and demonstrated the response by touching the manipulandum. Continuous response contingent reinforcement was delivered to the reinforcement tray. Several children responded appropriately after the first demonstration. However, if the child did not respond appropriately, the Experimenter demonstrated the desired response a second time. No more than two demonstrations were provided per session.

Once the response was established, the S^D period was shortened to 20 second tone, alternated with a variable interval (VI) 1 second S^{Δ} condition, controlled by the above mentioned programming equipment. As subjects demonstrated stimulus control i.e., responding to S^D, the tone interval was gradually reduced to two seconds and the S^Δ condition increased to a VI 10 second period. This approach termed "errorless discrimination learning" as Michael (1963) suggests, yields less responses to S^Δ periods and decreases discrimination training time. The VI period lead to presentation of tones after varying periods of silence (S^Δ) ranging from 5 to 25 seconds with a mean of 10 seconds. If the subject responded during the S^Δ period his response delayed the onset of the light and the tone for 5 seconds. Once the subject was responding to the VI 10 second period, he was not considered under stimulus control until he responded to more than 90 percent of stimulus presentations with less than a 10 percent probability of response during intervals between stimulus presentations (S^Δ). Computations were made after each session. The percent of S^D's responded to was determined by dividing the number of reinforcements delivered by the number of S^D's presented. Probability of response during the S^Δ period was computed by determining the number of 2 second periods possible in the S^Δ condition and dividing that number into the number of responses which occurred during the S^Δ condition.

While proceeding with the stimulus control training described above, if the subjects did not accept the earphones, the Experimenter held them within three inches of the child's ears and gradually moved them closer until the child was wearing the earphones.

Reinforcement exposure and selection procedures preceeded each stimulus control training session and each threshold test. Testing was limited to each subject's right ear. Threshold estimates were taken at .25K, 1K, and 4K Hz. At the onset of threshold estimate testing, a pure tone stimulus of 70 dB at 1000 Hz, was presented, the same as the training stimulus, and was then lowered in 10 dB steps to 30 dB. This step functioned as an intensity generalization procedure and also as a criterion for continuing the testing procedure. A subject had to respond to 5 of the 5 S^D's and make no response during the intervals between stimulus presentations for threshold testing to proceed. If the subject did not meet these criteria, a training rather than testing session was instituted. The percent probability of responding to the S^Δ condition was determined after each threshold estimate. If the probability was above 10 percent, the threshold estimate was excluded and another threshold estimate was obtained for that frequency.

Threshold estimates were taken by the Jerger-Carhart modification of the descending method of limits. The tone was presented at 30 dB and lowered in 10 dB steps until the subject failed to respond. Then the tone was increased 10 dB and decreased in 5 dB steps until the subject did not respond to a stimulus presentation, in which case the tone was again increased 10 dB and lowered in 5 dB steps. Three out of six responses or 50 percent was considered a threshold estimate. After a threshold estimate was obtained for 1000Hz, 250Hz and 4000 Hz were tested following the same procedure, including stimulus intensity generalization procedures with stimulus control checks.

Re-testing followed the same procedures as discussed for testing. Subjects were re-tested at each test frequency; the stimulus control checks were made for each frequency. Testing and re-testing were not done in the same session.

The procedures used in the present research differed from those employed by Fulton and Spradlin (1968) with retardates. At the onset of stimulus control training with retardates, the response priming procedures of response exposure and response sampling were used (Ayllon and Azrin, 1968).

These techniques for response development of simple segmented behavior are more efficient than response-shaping and prompting-shaping procedures when the subject has some language. To eliminate variance from presence or absence of language and other response contingency history, the present research utilized contingency shaping with a minimum of prompting. Hence, the subjects began on a continuous reinforcement schedule with one or two prompts at the onset of the first sessions. When a high response rate was observed on this schedule the program was shifted to a VI schedule of long S^D periods and short S^{Δ} periods, then gradually to shorter S^{Δ} priods and longer S^D periods. The latter schedule, with heavy reliance placed on response priming procedures, was employed by Fulton and Spradlin at the onset of stimulus control training to bring the behavior under control of the schedule.

Reinforcement selection, exposure, and sampling procedures of the present study differed from the procedure used with retardates. Fulton and Spradlin exposed the subject to a variety of edible items at the onset of training. The items the subject took from the experimenter and chewed were utilized as reinforcers. The present study repeated the reinforcement exposure and sampling procedure throughout training and threshold testing sessions. In addition to edible items this study also utilized small toys which would fit into the Davis Feeder.

Stimulus control training with the retardates included both frequency and intensity generalization training prior to threshold testing. The present research omitted frequency generalization training, but intensity generalization training immediately preceded threshold tests at each frequency.

In both studies stimulus control checks of S^D and S^{Δ} response rates were plotted throughout training. Immediately prior to each threshold test, S^D and S^Δ stimulus control checks were made. The present study also tracked S^Δ stimulus control throughout threshold testing.

CHAPTER III
RESULTS

The purpose of this research was to assay the effectiveness of operant audiometry on two year olds. The results of this research are presented in reference to stimulus control training, threshold estimates and reliability measures.

Stimulus Control

Stimulus control was defined in terms of adequate control of the intensity of the pure tone stimulus (pure tone stimuli presented to the subject through earphones held in a headband) and in terms of discriminative control of the response to a pure tone stimulus (S^D), defined as responding to 90 percent of pure tone presentations with a less than 10 percent probability of response during variable time intervals between tone presentation (S^Δ).

Eight of the ten subjects accepted wearing earphones at the onset of the first training session. One subject accepted wearing earphones within the first session and one subject was wearing earphones by the onset of session two.

Results of stimulus control for training are shown in Table 1.

Table 1 about here

The 10 subjects met the 90 percent criterion for responding to the pure tone stimulus (S^D). The range was 92 percent to 100 percent with a mean of 98.4 percent. In the S^Δ condition, ten of the subjects' response probability was below 10 percent. The range was 0 percent to 8 percent with a mean of 2 percent. The number of training sessions required to

TABLE 1. Observed stimulus control to 1000 Hz at 70 dB stimulus in the session prior to testing (S^D = discriminative stimulus, S^{Δ} = no tone intervals).

Subjects	Stimulus Control S^D	S^{Δ}	No. of Sessions	Training Time (min.)
S-1	100%	0%	6	180
S-2	92%	1%	5	120
S-3	100%	3%	7	180
S-4	100%	0%	9	180
S-5	100%	8%	4	45
S-6	100%	0%	4	90
S-7	100%	0%	3	90
S-8	100%	4%	2	40
S-9	92%	4%	5	120
S-10	100%	0%	2	40

achieve stimulus control ranged from 2 to 9 sessions with a mean of 4.7 sessions. The total time for these sessions ranged from 40 minutes to 180 minutes with a mean of 108 minutes. Ten subjects met the criteria for stimulus control. A variable was the number of sessions or training time required to achieve the desired level of stimulus control.

None of the ten subjects met the criterion of 5 out of 5 responses to the S^D while descending in 10 dB steps from 70 to 30 dB (ISO). The tenth subject failed to meet this criterion by air conduction, but did so by subsequent bone conduction testing. This subject (S-10) will be treated in detail later in this chapter.

Testability and Reliability

Data on the testability factor, defined as the percentage of subjects who yielded sufficient data to permit threshold estimates by the Jerger-Carhart modification of the descending method of limits, indicated 100 percent of the subjects were testable. Table 2 shows the test-retest data by frequency, subject, and age. Also represented in Table 2 is the

---

Table 2 about here

---

obtained mean probability of response in S^{Δ} periods during test-retest measurements. The percent of subjects which met the reliability criterion of ± 5 dB was 100 percent for each of the three frequencies tested. Of the 30 retests, 25 of the threshold estimates were the same as the test threshold estimates. Two retest threshold estimates shifted 5 dB higher and three shifted 5 dB lower than test threshold estimates. With respect to the absolute values of the test threshold estimates: (1) At 250 Hz, 6 subjects tested at 0 dB, 1 subject 10 dB, 1 subject 15 dB, 1 subject 20 dB,

TABLE 2. Age, test and retest threshold estimates results for 250,1000, and 4000 Hz. The mean percent of probability of response to no tone periods during test and retest sessions.

S	Age		250 Hz	1000 Hz	4000 Hz	Stimulus Control Mean %
S-1	25 mo.	Test	0 dB	0 dB	0 dB	2
		Retest	0 dB	0 dB	0 dB	6
S-2	24 mo.	Test	0 dB	0 dB	0 dB	3
		Retest	0 dB	0 dB	0 dB	0
S-3	24 mo.	Test	0 dB	0 dB	0 dB	3
		Retest	0 dB	0 dB	0 dB	0
S-4	28 mo.	Test	0 dB	0 dB	0 dB	2
		Retest	0 dB	5 dB	0 dB	3
S-5	30 mo.	Test	0 dB	0 dB	0 dB	0
		Retest	5 dB	0 dB	0 dB	0
S-6	29 mo.	Test	15 dB	0 dB	0 dB	1
		Retest	15 dB	0 dB	0 dB	1
S-7	30 mo.	Test	0 dB	0 dB	0 dB	4
		Retest	0 dB	0 dB	0 dB	7
S-8	18 mo.	Test	20 dB	0 dB	0 dB	3
		Retest	15 dB	0 dB	0 dB	1
S-9	30 mo.	Test	10 dB	0 dB	0 dB	4
		Retest	10 dB	0 dB	0 dB	0
S-10	23 mo.	Test	35 dB	35 dB	40 dB	0
		Retest	30 dB	35 dB	35 dB	0

and 1 subject 35 dB; (2) at 1000 Hz, 9 subjects tested at 0 dB and 1 subject 35 dB, and (3) at 4000 Hz, 9 subjects tested at 0 dB and 1 subject 40 dB.

As shown in Table 2, during the testing session the observed mean probability of response during S^{Δ} periods ranged from 0 to 4 percent. On retest the S^{Δ} stimulus control percentages ranged from 0 to 7 percent. Comparison of S^{Δ} stimulus control during test and retest sessions indicated the probability of response during periods of no tone decreased in four subjects, remained the same in three subjects and increased in three subjects. In all cases the criterion of less than 10 percent probability of response to S^{Δ} was achieved. A cursory inspection of Table 2 fails to reveal a relationship between age, obtained threshold estimates or S^{Δ} stimulus control. Subject 3 tested 0 dB on test and retest, but one testing session was discarded because the criterion of less than 10 percent probability of response to S^{Δ} was not met. With the exception of subject 10, all subjects' threshold estimates were within normal limits (20 dB, ISO or less) for the frequencies tested.

Subject 10's threshold estimate as indicated in Figure 2 did

Figure 2 about here

---

not fall within normal range (20 dB, ISO). Initial threshold estimates indicated his threshold estimate at 1000 Hz and 250 Hz was 35 dB and at 4000 Hz he tested 40 dB. On retest the subject tested 35 dB at 1000 and 4000 Hz and he tested 30 dB at 250 Hz. Employing the same procedures as those for air conduction testing, a bone conduction test of the right ear was accomplished while presenting 50 dB of noise

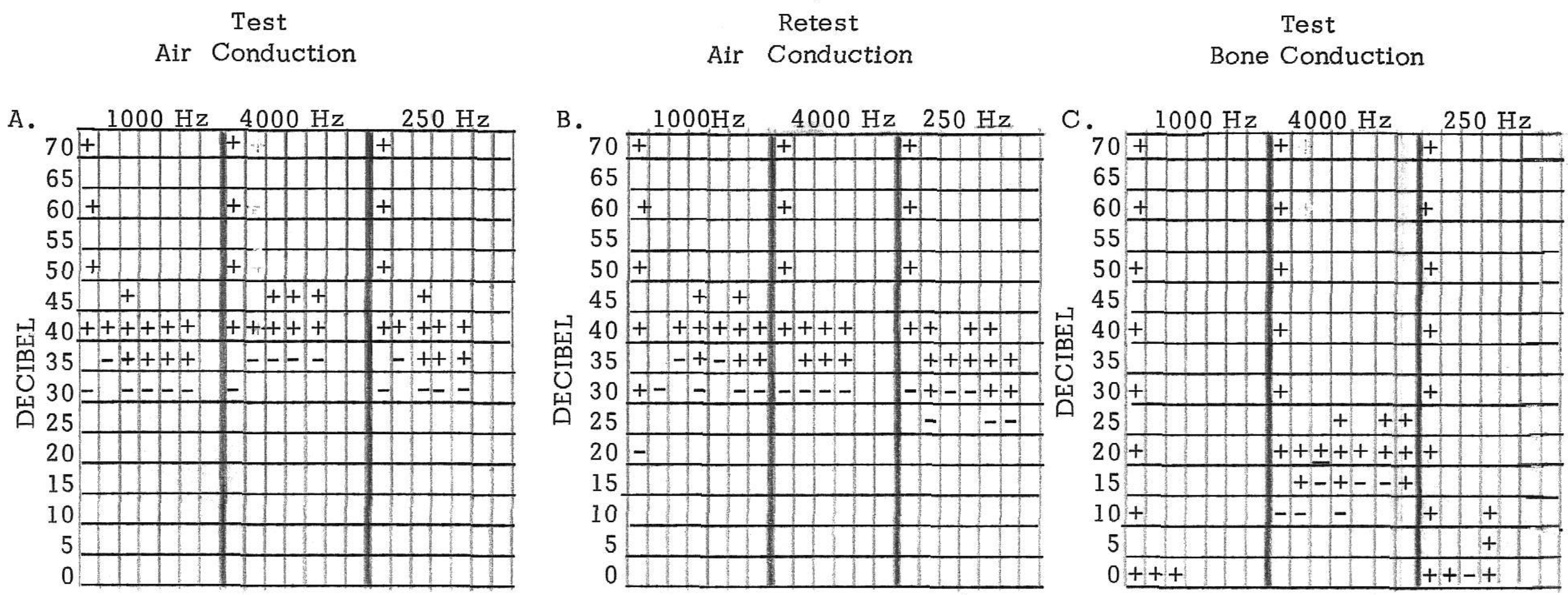

FIGURE 2. Subject 10's A) Test, air conduction threshold estimate, B) Retest, air conduction threshold estimate, C) Test, bone conduction threshold estimate. (+ = response to tone, - = no response to tone)

to the left ear. The results indicated 0 dB bone conduction threshold estimate at 1000 and 250 Hz and 15 dB at 4000 Hz. Subject ten's mother reported that prior to testing he had been ill with a 105^{o} temperature for three days. The subject was subsequently placed under medical treatment.

CHAPTER IV
DISCUSSION

The findings of this research on operant audiometry with two year olds are comparable to the findings of operant audiometry with low-level retardates. The results indicate that 100 percent of the two year olds tested achieved stimulus control in terms of wearing earphones, responding to pure tone stimulus presentations and inhibition of responses to the time intervals between stimulus presentations. Stimulus control with low level retardates was establishes with 84 percent of the subjects tested. The observed difference in the percentage of subjects in which stimulus control was achieved may relate to differences in the population studies, slight differences in the training procedures, or methods for the selection and priming of reinforcers. Lloyd, Spradlin and Reid (1968) attributed failure in bringing 16 percent of the retardates under stimulus control in inability to identify appropriate reinforcers. It is also possible that data for subsequent subjects (eleven and twelve of the current study) may not meet the stated criteria for stimulus control. Of the two year old subjects in which stimulus control was achieved in the present research, 100 percent yielded threshold data. Lloyd (1968) reported threshold data on 93 percent of 42 retarded subjects. The results of both studies imply generalization between stimulus control training conditions and threshold testing conditions. The generalization is sufficient to regard either the stimulus control training conditions reported by Lloyd, Spradlin and Reid (1968) or those of the current study as effective antecedent conditions to threshold testing.

In the present study, operant audiometry procedures yielded ±5 dB test-retest reliability for the ten subjects at the three frequencies tested.

Fulton and Spradlin (1968) report test-retest reliability for six consecutive threshold determinations on six subjects. Their results indicated none varied over 10 dB and 5 out of 6 subjects were within ± 5 dB for five of the six sessions. The data of the present study confirms the conclusion that operant audiometry provides reliable thresholds with subjects under stimulus control. Fulton and Spradlin (1968) advocate stimulus control checks prior to each threshold determination. The procedure of the present study utilized stimulus control checks of S^D and S^Δ prior to each threshold test and a check on S^Δ control during the testing for threshold estimates.

Nine of the ten subjects' threshold estimates were within the limits of normal young adult ears (20 dB, ISO or less). The tenth subject was demonstrated to have an air-bone gap with bone conduction threshold estimates within normal limits. It is uncertain how this data validates the present procedure. It is of interest, however, to point out that thresholds for two year olds probably does not exceed ISO values for the normal young adult ears at the frequencies tested.

The findings on operant audiometry contained herein are not consistent with the findings reported for other methods of testing the hearing of two year olds. Variations of the peep show method have been reported for two year olds by Statten and Wishart, (1960) and Haug and Guilford (1960). Neither of these studies reported more than 50 percent success (respectively, 34 and 47 percent) in obtaining threshold data on subjects at the two year age level. Play audiometry, involving conditioning a response such as placing a block in a basket, or placing a ring on a peg in the presence of the test stimuli, presumably for social praise or other unspecified reinforcer, is another method utilized for testing the hearing of two year olds. Barr's research (1955) is typical of the play audiometry findings with two to three year olds. He reported reliable thresholds for 40 percent of the subjects under 3 years of age and for 20 percent of the subjects under 2½ years of age. Barr defined reliability in terms of any two of a number of threshold determinations within ± 5 dB of each other. The peepshow and play audiometry methods assume that the appearance of the puppet or the play task is reinforcing the subject in question and, further, that once a response contingency relationship is observed that the reinforcer will not satiate. Recent work by Ayllon and Azrin (1968) clearly demonstrates that effective reinforcers must be empirically established for each subject. Once a reinforcer has been demonstrated as effective there is no assurance that satiation of that reinforcer will not occurr. The present research took these factors into account. Each subject selected the reinforcer appropriate to him. Satiation was prevented by repeating the selection procedure throughout the period of time the child was participating in the study.

Electrophysical methods presently employed to assay the hearing acuity of two year olds, electroencephalic (EEG) and evoked response audiometry (ERA), are not comparable with operant audiometry. Unlike operant audiometry, these methods do not indicate whether the subject is attending to the stimulus nor if the S^D can be utilized in a response contingency paradigm to modify behavior. They are, rather, assumed measures of cochlea and auditory nerve responses to stimuli at the cortex. Both operant audiometry and electrophysical audiometry, however, share a common problem when collectively comparing these methods to conventional audiometry. Conventional audiometry employes a <u>yes</u> - <u>no</u> response (the verbal instruction, "Raise your finger when you hear the tone and lower your finger when you don't hear the tone"). The operant audiometry procedures utilize a lapse of time with no response to the stimulus to indicate a no response. In EEG and ERA procedures, a time lapse with no response to the stimuli is also utilized as a no response. The relationship of these no response indicators to a definitive, overt no response is not clear. The question of how either operant, EEG or ERA audiometry relate to an independently defined measure of threshold is an interesting research problem. In operant audiometry the problem of developing a two response procedure, one to indicate yes, "I hear the tone", and the other to indicate no, "I don't hear the tone", is technical in nature. (Blough, 1966).

The generality of the findings in the present research is also limited by the number of subjects tested (n=10). Future research should test the generality of operant audiometry on high risk subjects and attempt to extend the procedure to younger age levels. Consideration and study should be given to response latency measures as latency has been systematically related to determination of threshold in both psycho-physical and conditioning literature.

Operant audiometric methods hold promise for reliably determining the absolute threshold estimates of young children, previously considered untestable by other available audiometric tests. The fact that the tests on the children in this study yielded reliable threshold estimates is encouraging. This technique has not been sufficiently researched, however, and it is the feeling of this author that application as a general clinical tool not be advocated at this time.

CHAPTER V
SUMMARY

This research assayed the effectiveness of operant audiometry on two year olds. The specific, free operant methodology utilized was a modification of the procedure developed by Spradlin, Lloyd and Fulton for testing the hearing of low level retardates.

Data of the effectiveness of operant audiometry procedure was collected by several measures: (1) Percent of subjects brought under stimulus control. Stimulus control was defined in terms of adequate control of the intensity of the pure tone stimulus (pure tone stimuli presented to subject through earphones held in a heabdand) and in terms of discriminative control of the response to a pure tone stimulus (defined as responding to 90 percent of pure tone presentations with a less than 10 percent probability of response during variable time intervals between tone presentations); (2) testability factor, defined as the percent of subjects who produced sufficient data to permit threshold estimates by the Jerger-Carhart modification of the descending method of limits; and (3) the percent of subjects which met reliability criterion defined by test-retest procedures of threshold estimates of ± 5 dB.

The mean age of the 10 subjects was 26 months, ranging from 18-30 months. Subjects were excluded from the study whose mothers' reported a history of ear disease in the child or related familial factors. The stimulus duration, variable time intervals between stimulus presentation, response detection, reinforcement delivery and stimulus-response records were controlled and recorded by automatic programming equipment. Stimulus intensity and frequency were controlled at the audiometer by the Experimenter. Procedural sequence for each subject was as follows:

1. Stimulus control training, encompassing conditioning of responding to onset of a 1000 Hz, 70 dB tone (re: ISO) presented through earphones.
2. Intensity generalization for 1000 Hz tone.
3. Obtaining threshold estimate for 1000 Hz by descending method of limits.
4. Steps 2 and 3 for 4000 Hz tone.
5. Steps 2 and 3 for 250 Hz tone.
6. Re-test of steps 2 through 5.

Reinforcement exposure and selection procedures preceeded each stimulus control training session and each threshold test. Testing was limited to each subject's right ear.

The data on stimulus control training indicate that 10 of 10 subjects were successfully trained to wear earphones and respond to more than 90 percent of stimulus presentation with less than a 10 percent probability of response during intervals between stimulus presentations. A mean number of 4.7 sessions, with a range of 2 to 9 sessions, were required to achieve the stated level of discriminative responding. Training sessions varied in length from 15 to 30 minutes. Threshold estimates were obtained in 10 of 10 subjects. Reliability of these 30 threshold estimates (250 Hz, 1000 Hz, 4000 Hz X 10 Ss) on a test-retest basis was ± 5 dB. Nine of the ten subjects' threshold estimates were within the limits of normal hearing (20 dB, ISO or less). The air conduction threshold estimates for the tenth subject were 35 dB at 250 Hz, 35 dB at 1000 Hz, and 40 dB at 4000 Hz. Bone conduction threshold estimates for this subject were 0 dB at 250 Hz, 0 dB at 1000 Hz and 15 dB at 4000 Hz.

Findings of this research with two year olds, with respect to achievement of stimulus control, testability, and reliability compare favorably with the findings of Fulton, Lloyd, and Spradlin on low level retardates. The generality of these findings for normal and high risk infants needs to be researched.

BIBLIOGRAPHY

Ayllon, T., and Azrin, N., The Token Economy: A Motivational System for Therapy and Rehabilitation. Appleton-Century-Crofts, New York, 1968.

Barr, B., Pure Tone Audiometry for Pre-school Children. Acta Oto-Laryngol. Supplement 121, 1955.

Blough, D. S., The Study of Animal Sensory Process by Operant Methods. Honig, W. K., (ed.), Operant Behavior: Areas of Research, Appleton, Century, Crofts, New York, 1966, 345-379.

Bordley, J., Hardy, W., and Richter, C., Audiometry with the Use of Galvanic Skin-resistence Response. Bulletin. John Hopkins Hospital 82, 1948. 569.

Bordley, J., and Hardy, A study in Objective Audiometry with the use of a Psychogalvanometric Response, Annal of Otology, Rhinology, and Laryngology 58: 1949, 751-760.

Carhart, R., and Jerger, J., Preferred Method for Clinical Determination of Pure-tone Thresholds, JSHD, 24, 1959, 330-345.

Cody, D., and Bickford, R., Cortical Audiometry: an objective method of evaluating auditory acuity in man. Mayo Clinic Proceedings, 40, 1965, 273-287.

Dix, M.R., and Hallpike, C.S., The Peepshow. A new technique for pure tone audiometry in young children. British Medical Journal, 2, 1947, 719-723.

Eagles, E., and Wishik, S., Trans American Acadamy. Ophthalmol. Otolaryngol. 65, 1961, 261.

Fulton, R.T. and Spradlin, J.E., Operant aduiology with severly retarded children. Parsons Demonstration Project Report No. 90, Parsons (Kansas) State Hospital and Training Center, 1968. (Paper presented at the Ninth International Conference of Audiology, London, September 1968).

Frisina, D.R., Measurement of Hearing in Children. Jerger, J., (ed.) Modern Developments in Audiology. Academic Press, New York and London, 1963, 126-166.

Fulton, R.T., and Lloyd, L.L., Audiometry for the Retarded with Implications For the Difficult-To-Test. The Williams and Wilkins Co., Baltimore, 1969.

Goldstein, R., Electrophysiologic Audiometry. Jerger, J. (ed.) Modern Developments in Audiology. Academic Press, New York and London, 1963, 167-192.

Guilford, F., and Haug, O., Diagnosis of Deafness in Young Children, Trans American Acadamy of Ophthalmology and Otolaryngology. 64, 1960, 269.

Lentz, W.E., and McCandless, G.A., Averaged Electroencephalic Audiometry in Infants. JSHD, 36, 1967, 19-28.

Lloyd, L., Operant Conditioning Audiometry with Mentally Retarded Children, Waldon, E.F. (ed.), Differential Diagnosis of Speech and Hearing Problems of Mental Retardates. The Catholic University of America Press, Washington D.C., 1968, 103-121.

Lloyd, L.L., Spradlin, J.E., and Reid, M.J., Operant conditioning audiometry with low-level retardates: a progress report. Parsons (Kansas) State Hospital and Training Center, 1966.

Lloyd, L.L., Spradlin, J.E., and Reid, M.J., An operant audiometric procedure for difficult-to-test patients. JSHD, 1968, 33, 236-245.

Marcus, R., Gibbs, E., and Gibbs, F., Electroencephalography in the diagnosis of hearing loss in the very young child. Diseases of the Nervous System. 10, 1949, 170-173.

McCandles, Geary A., Clinical application of evoked response audiometry, JSHR, Vol. 10, 1967, 468-478.

Michael, J., Laboratory Studies in Operant Behavior. McGraw-Hill Book Company, Inc., New York, 1963.

Myerson, L., and Michael J., The measurement of Sensory Thresholds in Exceptional Children: An Experimental Approach to Some Problems of Differential Diagnosis and Education with Special Reference to Hearing, U.S. Office of Education, Cooperative Research Project, No. 418, University of Houston, Houston, Texas (1961).

Myklebust, H., Auditory Disorders in Children. Grune and Statten, New York, 1954.

O'Neill, J.J., and Oyer and, H.J., and Hillis, J.W., Audiometric Procedures Used with Children, JSHD, 25, 1961, 61-66.

O'Neill, M.E., Services for Hard of Hearing Children, J. Irish Medical Association, 62 (385), 1969, 263-264.

Price, L., and Goldstein, R., Averaged cooked responses for measuring auditory sensitivity in children. JSHD, 31, 1966, 248-256.

Rapin, I., and Graziani, L., Auditory-evoked responses in normal, brain-damaged, and deaf infants. Neurology, 17, 1967, 881-894.

Spradlin, J.E., and Lloyd, L.L., Operant conditioning audiometry (OCA) with low level retardates: a preliminary report. Lloyd, L.L., and Frisina, D.R., (eds). The Audiologic Assessment of the Mentally Retarded: Proceedings of a National Conference. Parsons, Kansas: Speech and Hearing Department (PSH & TC), 1965.

Spradlin, J.E., Locke, B.J., and Fulton, R.T., Conditioning and Audiological Assessment. Fulton, R.T., and Lloyd L.L., (eds) Audiometry for the Retarded with Implications for the Difficult-to test. The Williams and Wilkens Co., Baltimore, 1969, 125-163.

Statten, P., and Wishart, D., Pure-tone Audiometry in Young Children; Psychogalvanic-skin-resistance and peep show., Annal Otology, Rhinology, and Laryngology 65, 1956, 511-534.

Syzuki, T., and Taguchi K. Cerebral evoked response to auditory stimuli in young children during sleep. Annals of Otology, Rhinology, and Laryngology, 77, 1968, 103-110.

OPERANT AUDIOMETRY WITH TWO YEAR OLDS

by

MARSHA MARLENE NOWELS

B.A., Western Washington State College, 1969

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARTS

Department of Speech

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1971

This research assayed the effectiveness of operant audiometry on two year olds. The specific free operant methodology utilized was a modification of the procedure developed by Spradlin, Lloyd and Fulton for testing the hearing of low level retardates.

Data of the effectiveness of operant audiometry procedure was collected by several measures: (1) Percent of subjects brought under stimulus control. Stimulus control was defined in terms of adequate control of the intensity of the pure tone stimulus (pure tone stimuli presented to subject through earphones held in a headband) and in terms of discriminative control of the response to a pure tone stimulus (defined as responding to 90 percent of pure tone presentations with a less than 10 percent probability of response during variable time intervals between tone presentations); (2) Testability factor, defined as the percent of subjects who produced sufficient data to permit threshold estimates by the Jerger-Carhart modification of the descending method of limits; and (3) The percent of subjects which met reliability criterion defined by test-retest procedures of threshold estimates of ± 5dB.

The mean age of the 10 subjects was 26 months, ranging from 18-30 months. Subjects were excluded from the study whose mothers' reported a history of ear disease in the child or related familial factors. The stimulus duration, variable time intervals between stimulus presentation, response detection, reinforcement delivery and stimulus-response records were controlled and recorded by automatic programming equipment. Stimulus intensity and frequency were controlled at the audiometer by the experimenter. Procedural sequence for each subject was as follows:

1. Stimulus control training, encompassing conditioning of responding to onset of a 1000 Hz, 70dB tone (re: ISO) presented through earphones.
2. Intensity generalization for 1000 Hz tone.
3. Obtaining threshold estimate for 1000 Hz by descending method of limits.
4. Steps 2 and 3 for 4000 Hz tone.
5. Steps 2 and 3 for 250 Hz tone.
6. Re-test of steps 2 through 5.

Reinforcement exposure and selection procedures preceeded each stimulus control training session and each threshold test. Testing was limited to each subject's right ear.

The data on stimulus control training indicate that 10 of 10 subjects were successfully trained to wear earphones and respond to more than 90 percent of stimulus presentation with less than a 10 percent probability of response during intervals between stimulus presentations. A mean number of 4.7 sessions, with a range of 2 to 9 sessions, were required to achieve the stated level of discriminative responding. Training sessions varied in length from 15 to 30 minutes. Threshold estimates were obtained on 10 of 10 subjects. Reliability of these 30 threshold estimates (250 Hz, 1000 Hz, 4000 Hz X 10 Ss) on a test-retest basis was ± 5dB. Nine of the ten subject's threshold estimates were within the limits of normal hearing (20dB, ISO or less). The air conduction threshold estimates for the tenth subject were 35dB at 250 Hz, 35dB at 1000 Hz, and 40dB at 4000 Hz. Bone conduction threshold estimates for this subject were 0dB at 250 Hz, 0dB at 1000 Hz and 15dB at 4000 Hz.

Findings of this research with two year olds with respect to achievement of stimulus control, testability, and reliability compare favorably with the findings of Fulton, Lloyd, and Spradlin on low level retardates. The generality of these findings to normal and high risk infants needs to be researched.