OPERANT MEASUREMENT OF SUBJECTIVE VISUAL ACUITY IN NON-VERBAL CHILDREN¹

JOEL MACHT

UNIVERSITY OF DENVER

The present experiment sought to develop a reliable procedure for measuring visual acuity in non-verbal retarded children. Five non-verbal retarded children and two literate adults were examined. The two adults were included in the experiment so that verbal communication with them could validate certain assumptions regarding the experimental procedures. By utilizing a lever press as the criterion response signifying a visual discrimination and employing the Snellen "E" discriminanda, a reliable subjective measure was obtained, not unlike those measures taken from verbal adults. Contrary to several antecedent procedures, a relatively precise measurement of subjective acuity was shown to be obtainable from non-verbal retarded children. Additionally, the procedure was successful in evaluating the effectiveness of prosthetic lenses previously prescribed for two of the children.

There exists a population of children who do not manifest appropriate behaviors required for an accurate subjective visual acuity examination. Whether they are very young or mentally retarded, these children lack a response repertoire that allows them to come under the necessary stimulus control needed for an acuity measurement. They may not speak or read. Frequently, such children are active and not confined easily to an examination chair for any length of time. They fail to follow verbal commands given by the examiner and do not focus on a stimulus object when it becomes necessary. They are often described as either "insufficiently intelligent", "insufficiently mature", or "unmotivated" to the degree required for ocular examinations.

Parents of such children are frequently requested to bring children back in six months when "he becomes more mature" and, on occasion, are given letter cards and instructed to train the child in recognition of the letters so that on returning to the physician the child can be tested. Present indications are that with

severely retarded children, the mere passing of time is small help. Untrained mothers are generally incapable of coping with the difficult discrimination training required in teaching a child to recognize visual symbols. The result is that many children are never given adequate visual examinations, and impairments may be undetected and, hence, uncorrected.

Visual Acuity

The ability of the visual apparatus to "distinguish" small spatial separations or intervals between portions of the visual field is known as visual acuity (English and English, 1958). It is determined by the smallest form that stimulates a retinal image, and is measured by the smallest object that can be clearly discriminated at a certain distance (Duke-Elder, 1965). In humans, distance acuity is measured with a letter chart (Havener, 1963), e.g., Snellen chart, which is placed 20 ft from the reader. Recording of acuity is by a ratio. The numerator represents the distance from the chart to the reader and the denominator indicates the distance at which the subject reads the line (Duke-Elder, 1965).

Two different measures of acuity. An "objective" measure of acuity is obtained when an examiner employs a retinoscope and an ophthalmoscope to observe the internal parts of the eye. The objective measure enables an

¹This research was in partial fulfillment of the Ph.D. degree under the chairmanship of Dr. Keith Van Wagenen. The author wishes to acknowledge with great appreciation the advice and support of his chairman. Reprints may be obtained from the author, Department of Educational Psychology, University of Denver, Denver, Colorado.

examiner to determine the physiological condition of the eye. Additionally, the physician estimates the refractory power of the optic apparatus through the objective examination. Relatively minimal behavior is required of a subject to complete an objective measurement of visual acuity. Having a patient sit in a chair with eyes remaining motionless generally is sufficient.

A "subjective" measure of acuity is obtained by placing a chart in front of a subject and requiring him to report what he sees. The subjective examination generally is employed for purposes of refining the objective measurement as well as estimating near and distance visual acuity. To obtain a subjective measure of acuity, a subject must have a complex behavior repertoire before necessary information can be conveyed to the examiner. He must "attend" to verbal commands and emit appropriate responses to differing stimulus objects.

Studies investigating sensory thresholds in infrahuman organisms are abundant (Blough, 1957, 1958; Blough and Schrier, 1963; Adler and Dalland, 1959; Elliot, Frazier, and Riach, 1962; Heise, 1953; Yarczower, Wolbarsht, Galoway, Fligsten, and Malcolm, 1966). Procedures developed by these researchers have afforded precise measurement of various acuity thresholds in infrahuman subjects. However, review of the research failed to evidence comparable methods for obtaining reliable estimates of subjective visual acuity in non-verbal children. Explanations offered for the difficulty in securing precise estimates of acuity with young and retarded children are varied.

Duke-Elder (1965) stated that ordinary tests of subjective acuity are totally dependent upon the patient's cooperation and may be inadequate for young children, malingerers, and illiterates. Allen (1957) added that there are always some children up to 5 yr of age who are "unable or unwilling" to cooperate for acuity measurements.

Adler (1962) indicated that because subjective methods of refraction depend upon the patient distinguishing between letters on the Snellen chart, the procedure is applicable only to patients old enough to respond appropriately to an examiner's verbal statements. Hence, Adler concluded that the subjective measurement of visual acuity was of little value in children less than 7 to 8 yr of age, or for "ignorant" adults.

Adler (1950) also held the opinion that when an individual was required to respond to a Snellen chart, various complex behaviors were necessary: "the power of attention, willingness and ability to read, motivation and cooperation." He further stated that there can be little doubt that failure to measure accurately most children's acuity is due to "their lack of cooperation and their low level of intellectual functioning."

Meyerson and Michael (1960), in reviewing research on auditory thresholds, encountered measurement reliability problems similar to those involved in measuring vision. They reported that almost all studies of auditory acuity of mentally retarded children demonstrate them to have considerably higher incidence of hearing loss than are found in the normal population. They concluded that these findings may not be justified, for their experimental data did not support the purportedly higher incidence of physiological impairment.

One explanation accounting for the apparent higher incidence of impairment may actually be a function of the procedures employed for the estimation of the sensory threshold. In view of the difficulties expressed by many examiners when attempting acuity measurements in "uncooperative" or "unmotivated" children, Meyerson and Michael (1960) asserted that a method is required whereby the examiner can be reasonably assured that his findings refer to limits in the child's ability to make appropriate discriminations and not to behavior deficits. They reasoned that any procedure so devised must not confound failure in revealing a discrimination with failure in sensation.

Several procedures are available for obtaining visual acuity estimates from children. Reviews of these methods are provided by Blackhurst and Radke (1968) and Wolfe and MacPherson (1960). The procedures include having a child chase after varying size balls, picking up the smallest one thrown by the examiner (Ivory Ball Test), or having a subject verbally indicate the direction of "fingers" on various size "E" letters (Illiterate E Test), or pointing his finger (Sjögren, 1939) in the direction of the "E" letter (Duke-Elder, 1965). In each case, the child is required to follow the directions given by the examiner. Failure to interpret the instructions may result in unreliable estimates of acuity. Other procedures

require the subject to identify pictures (Gundersen, 1955; Allen, 1957). The examiner must interpret when the child "recognizes" the stimulus object being presented. Recognition can be verbal *e.g.*, "Cow!", or recognition can be non-verbal, where the examiner must judge the facial expressions and hand movements of the child. In either case, acuity estimates rely heavily on the subject's behavior repertoire as well as the examiner's behavior of "grading" recognition. The optokinetic nystagmus effect test (Gorman, Cogan, and Gellis, 1957) does not require any overt behavior on the part of the subject with the exception of "attending" to the testing stimulus. By observing the eye movements, the examiner estimates the visual acuity of the subject. Newell (1970) indicated that the optokinetic nystagmus examination is the most popular procedure, although according to Gorman and his associates, the procedure yields acuity ratios equivalent to only 20/670 for young children. While the procedure yields a reliable estimate of acuity, it requires an examiner to "grade" rhythm of eye movement in relation to the passing of visual stimuli. Other tests employed are the Keystone Telebinocular test (Kelly, 1957) and the Massachusetts Vision test (Leverett, 1957). For the Keystone test, the subject is required to maintain a fixed head position against a forehead rest and possess sufficient verbal skills to indicate differences in positions and sizes of various stimuli. The Massachusetts test requires minimal verbal behavior, but the subject must maintain a stable head position by placing his chin on a chin rest and his forehead against a forehead rest. Additionally, the subject must peer through small "eye frames".

Additional problems are found with many of the above procedures. The criterion responses *e.g.*, "recognition" are at times ambiguous and difficult to observe. There is no experimental control to assure that the subject is responding to the stimuli presented rather than "cues" from the examiner. Finally, the alternative to testing the child who fails to "cooperate" with the examiner's instructions is the suggestion that the child be brought back when he is more "mature".

Current Investigation

The present study undertook the development of a procedure for measuring the subjective distance acuity of very young or re-

tarded children. For practical utility a method must incorporate specific requisites into its procedure. First, the operations must lead to accurate measurement of the criterion response. When the child responds to the stimuli presented to him, his response must be unambiguous, observable, and consistent. Second, the stimulus object presented must have a precise, measurable, quality in order to facilitate interpretation and communication. Third, there must be a means of maintaining responding until an examination can be completed. If the subject fails to respond to the stimuli, there must be an accurate explanation of why the response was not emitted. Finally, an assurance is required that the subject is responding to the stimulus object presented and not to some extraneous cue.

METHOD

Subjects

The experimental sample consisted of five children and two adults. The subjects are listed in the order they were examined. Diagnostic classifications were obtained from their medical files and no attempt was made by the experimenter to validate them. Characteristics and entering behavior of the subjects, thought important by the experimenter, were as follows:

Subject 1 was a 7-yr-old Down's syndrome female whose congenital bilateral cataracts were removed surgically when she was 3 yr of age. The child was nonambulatory, not toilet trained, did not feed herself, was non-verbal, and spent most of her waking day lying on the floor peering at sources of light. An ophthalmological examination had been attempted but, according to the physician, with little success. Corrective lenses of +10 diopter refraction were prescribed for the child. The +10 diopter lens is "standard" for aphakic children, although for most "retarded" children, a subjective examination of the lenses is not performed.

Subjects 2 and 3 were adults from the Department of Public Welfare who volunteered for the experiment. Both wore corrective lenses following surgery for removal of bilateral senile cataracts. Both subjects emitted "normal" speech and motor behavior. The subjects were employed to investigate the validity of the procedures employed with the remaining subjects.

Subject 4 was a 6-yr-old cerebral palsied female. She was ambulatory, toilet trained, but did not speak. She had a slight strabismus of the right eye, did not wear glasses, and had never had an ocular examination.

Subject 5 was a 5-yr-old female diagnosed retarded with "cerebral dysfunction". The subject spoke occasionally, but verbalizations generally needed elicitation. The child was thought by her mother to have normal vision, but she had never been professionally examined. She did not wear glasses.

Subject 6 was a 5-yr-old Spanish American Down's syndrome male. He was ambulatory and toilet trained, but did not speak. He followed verbal commands but would whimper for long periods of time if spoken to in a loud voice. He did not wear glasses and had never had an ocular examination.

Subject 7 was a 6-yr-old retarded female with severe bilateral strabismus and nystagmus. She did not speak but screamed a great part of the day. She had ocular examinations when she was 3 and 5 yr of age. The child's mother reported that the examinations were very difficult because of the child's "hyperactivity". Glasses were prescribed after both examinations but no subjective measure was taken to evaluate the prescription lenses. Records of the first pair were not available. The second pair had +5.25 diopter refraction lens, a strong correction. The child wore them infrequently, but when she did, she looked over the frame rather than through the lenses.

Apparatus

The major portion of the apparatus, depicted in Fig. 1, was specially constructed. This consisted mainly of a wheel that displayed the visual stimuli, and a table on which the response mechanism was mounted. The surface of the response table was 16 in. (30.5 cm) long and 8 in. (15.25 cm) wide. On the table top was a padded lever that closed a micro-switch when depressed. The table was set at different distances up to 20 ft from the stimulus wheel for measurement of visual acuity.

The stimulus wheel was constructed of tempered hard board and could be rotated in either direction. It was 22 in. (55.75 cm) in diameter with two 5.5 by 8.5 in. (14 by 21.5 cm) squares cut from the wheel 180° apart. Cards on which the Snellen "E" was presented were attached in these relieved areas.

When the two stimulus cards were perpendicular to the floor, the bottom card was transilluminated by two 100-w bulbs. Presentation and illumination of the cards was manually controlled. The subject's responses were recorded on a digital counter and on a Gerbrands cumulative recorder.

The visual symbols used were letter "Es" that duplicated various Snellen letter sizes (Duke-Elder, 1965). The forward facing "E" was called the S^D "E", in the presence of which the subject was to respond and receive reinforcement. The same letter, but reversed, was known as the S^A "E" in the presence of which the subject was not to respond.

The procedure had four arbitrarily defined phases. However, the phases were flexible and on occasion overlapped. In the initial phase, the subject was taught to press the lever. In the second phase, he was conditioned to press the lever in response to light but not to press it in the absence of light. In the third phase, the experimenter "faded in" the stimulus letters to establish a discrimination between a forward facing "E" (S^D) and a reversed "E" (S^A). Lever pressing was then under control of the letter presented. In the final phase, the subject's distance visual acuity was measured by decreasing the size of the E-discriminanda and moving the subject away from the stimulus letters. Following this measurement, the reliability of the subject's visual acuity threshold was determined by employing intrasubject replications (Sidman, 1960). This was accomplished by moving the subject back and forth across his measured threshold to determine if the derived acuity ratio was reliable. The dependent measures were the number of correct and incorrect responses under the independent variable conditions of stimulus card size and distance from the stimulus wheel.

Phase 1. The experimenter worked behind a cardboard blind over which he could observe the subject by rising slightly from his chair. This arrangement prevented subjects from watching the experimenter's facial expressions and hand movements, which conceivably were capable of providing cues to the learner.

Noises from the counters and switch boxes employed to count responses and pulse the cumulative recorder, were the same for both S^D and S^A conditions.

A trial was defined as either one response to

Fig. 1. Proportional diagram of stimulus wheel and response table.

a discriminandum or a specified lapse of time. The S^D condition was terminated when one response on the lever had been counted or when no response occurred within 3 sec. Termination of the S^A condition occurred after one response or after 10 sec of no responding. If the subject responded several times in an S^D period, he was credited with only one correct response and given one reinforcer. The reinforcer was some consumable *e.g.*, M&M, pretzels, cereal. The responses of Subjects 4, 5, and 6 were reinforced with M&Ms and pretzels, while hot breakfast cereal was employed with Subjects 1 and 7. The latter two subjects did not chew their food and their diet consisted of pureed substances. If the subject responded several times during an S^A period, only the initial response was punished and he was credited with one error response. Punishment was a slap on the responding hand paired with a loud verbal "no".

The subject was placed in a chair 29 in. (73.5 cm) from the stimulus wheel. The subject was in a comfortable position so that he could press the lever pad located on the response table, while facing the stimulus wheel that held the visual discriminanda, *i.e.*, black letter "E" mounted on white paper backing. Before beginning the discrimination trials, the experimenter placed two stimulus cards into bipolar slots on the front of the stimulus wheel. One was a large forward-facing letter "E". This was the discriminative stimulus (S^D) criterion card. Reinforcement was contingent upon the subject pressing the lever in the presence of this card. The S^D card was placed in the bottom slot of the wheel. A second "E" card, with the same dimensions as the first was placed in the top slot of the wheel. When the wheel was turned, the "E" as the top came to the bottom and appeared as a reversed "E". This reversed "E" was called the S^A criterion card, in the presence of which the child was not to respond on the lever. During Phase 1, the experimenter placed a piece of black drawing paper over the S^A "E" card to prevent the subject from viewing the letter. As the subject scanned the stimulus wheel, he saw only the S^D "E" card on the bottom, and the black paper on the top. The wheel was not turned in Phase 1.

The experimenter sat beside the subject. He held a switch in his hand that controlled bulbs positioned in a box located behind the

bottom card. All lights in the experimental room, excluding the bulbs behind the stimulus card, were turned off. The effect of illumination from behind the card was to project a clear image of the S^D "E" card to the subject. All lever-press responses emitted under these conditions were reinforced.

Phase 2. The second phase began when the experimenter observed a pause in the subject's stable lever-pressing behavior. When the pause occurred, lights behind the S^D "E" card were turned off. Lights off during this phase was called the S^A period. If the subject pressed the lever during the S^A condition, the experimenter said loudly, "no" and paired the verbalization with a slight slap on the subject's responding hand. After a few seconds of total darkness and no lever responding, the bulbs were illuminated and lever-pressing behavior was reinforced. The initial S^A periods were brief, *i.e.*, 2 to 3 sec. The latter S^A periods were gradually increased to a maximum of 10 sec. This procedure continued until the subject emitted a consistent rate of responding during S^D , *i.e.*, bulbs on, while not responding during the dark S^A period.

When appropriate S^D , S^A behavior was emitted, the subject's behavior was brought under control of the black card, rather than turning off the bulbs. This was accomplished by rotating the stimulus wheel so that the black card covered the bulbs, thus preventing light from coming through. The S^A condition was now defined as the black card covering the bulbs. Criterion behavior in Phase 2 was defined as pressing the lever in the presence of the forward "E" with the lights on, while not emitting lever pressing in the presence of the black card.

Phase 3. Behind the black card was a reversed letter "E" with exact dimensions of the S^D "E". The purpose of this phase was to remove successively the black card, bringing the subject's S^A lever behavior under control of the reversed "E".

The experimenter proceeded as follows: he turned the wheel positioning the S^D "E" on the bottom and reinforced lever pressing. He next inverted the wheel, bringing the S^A black card to the bottom and waited briefly. Again, the S^D procedure was executed. After several reinforced lever presses, the experimenter rotated the wheel, bringing the black card to the bottom. The experimenter removed the black

card and replaced it with a smaller black card that covered less of the reversed "E". This black card had 0.25 in. (0.6 cm) of black paper removed from the top and bottom, the width remaining the same. Eleven black cards were used successively, each of which was progressively 0.5 in. (1.25 cm) smaller than the former in its vertical dimension. The dimensions of the eleventh card were 8.5 in. (21.6 cm) wide and 0.25 in. (0.63 cm) high. The center of the black paper corresponded to the center of the white paper backing. If a subject failed to respond appropriately to the entirely exposed S^A "E" after the eleventh fading strip was removed, the strip was replaced at the center of the "E" and gradually moved "down" the paper. The eleventh strip was gradually faded out by placing it lower on each new S^A trial. When the subject responded to the forward S^D "E", while not responding to the reversed S^A "E", lever-pressing behavior was under control of the directionality of the "Es". The presentation of the forward and reversed "E" cards was randomized. Approximately equal frequencies of S^D and S^A periods were maintained. Variation of the number of periods was a function of the randomized sequence.

The stimulus cards employed to train a subject to discriminate the forward and reversed "Es" were 1.125 in. (0.3 cm) larger than the 20/200 "E" cards. This was done to increase the likelihood that all the subjects would make the initial discrimination.

Phase 4. The measurement of subjective distance acuity occurred in this phase. When the subject's lever-pressing behavior was under control of the "Es", he was moved from the stimulus wheel until bar pressing failed to occur according to the required criteria. In addition to the "E" criterion cards employed in phases 1, 2, and 3, six pairs of cards were constructed according to the criteria suggested by Duke-Elder (1965), that were identical topographical representations of Snellen's "Es", i.e., 20/200, 20/100, 20/70, 20/50, 20/30, 20/20.

A first step in measuring distance acuity was to present the criterion cards to the subject at a distance of 29 in. (73.5 cm) from the stimulus wheel. If appropriate responding was observed, the subject was moved to a distance of 47 in. from the wheel, then to 71, 95, 119, 143, 167, 191, 215, and finally 240 in. (119, 180, 241, 302, 363, 424, 485, 546, and 609.5 cm).

There was no significance for the chosen approximate 24-in. distance increments other than convenience.

Increasing the distance between subject and discriminanda was continued as long as appropriate responding was manifest. Final decision regarding appropriate responding was based on frequencies of S^D, S^A lever responding in relation to the number of S^D, S^A letter presentations.

If a subject responded correctly to the criterion cards at 240 in., he was returned to the 29-in. distance and a new pair of cards, 20/200, was placed on the stimulus wheel. The subject was again moved from the 20/200 cards by the same increments as with the criterion S^D, S^A "E" cards. If the subject successfully responded at 240 in. to the 20/200 cards, he was again returned to the 29-in. distance mark, and the 20/100 cards were introduced. This procedure continued until the subject either terminated all lever-pressing behavior or until there was a marked increase in S^A responding and a significant reduction of S^D responding.

The reliability of the threshold. When a subject ceased responding appropriately to the discriminanda, he was moved to a distance immediately before the point at which the correct S^D, S^A behavior was no longer observed. If the subject emitted appropriate lever pressing at the closer distance, he was returned to the distance where the appropriate discrimination behavior "broke down". If, once again the subject failed to discriminate the stimulus letters, he was placed at the closer distance where the correct responding behavior was observed. If the subject again responded according to the defined contingencies, the examination was terminated for that subject and a distance visual acuity ratio was formulated. A minimum of two successive and consistent threshold crossings were required before experimentation was terminated for a subject. If a subject failed to generalize from the criterion cards to the 20/200 cards, additional fading cards were constructed to approximate successively the size of the latter card.

When a subject ceased responding at a certain distance, and the experimenter could not reestablish appropriate discrimination behavior at a distance where the subject had been observed to respond appropriately, experimentation was postponed until either

Table 1

Time in hours required to complete the four phases of the study and the obtained subjective distance visual acuity ratios.

Subjects	Time in Hours					Visual Acuity Ratios	
	Phase				Total	Uncorrected	Lens Corrected
	I	II	III	IV			
S-1	5.5	19.5	42.0	39.0	106.0	20/400	20/180
S-4	.6	1.0	3.2	2.0	6.8	20/20	
S-5	1.8	2.2	4.0	2.2	10.2	20/23	
S-6	1.2	3.8	5.2	2.8	13.0	20/22	
S-7	2.2	1.8	3.2	3.2	10.4	20/32	20/32

Fig. 2. Response frequency to F-5 and F-6 cards at 29 in. in sequence for S-1 with glasses.

Fig. 3. Subject 1's intra-subject threshold crossing for the F-5 card with glasses.

later in the same day or the following day. This condition occurred several times in conjunction with an alteration of the feeding schedule of a subject initiated by one of the institution's attendants.

RESULTS

The data obtained demonstrate that a subjective measure of distance visual acuity is procurable from non-verbal retarded children. Table 1 presents the amount of time in hours required to complete the four phases of the experimental study.

The observed disparity in time required to complete the examination between S 1 and the remaining subjects was mainly a function of the experimenter's inability to identify a suitable reinforcing stimulus that maintained the subject's lever-pressing behavior.

Subjective measurement of distance visual acuity—phase 4. It will be recalled that when satisfactory discrimination to the forward and

reversed "E" had been achieved by a subject, the distance visual acuity was measured.

Subject 1. Subject 1 failed to make the required generalization from the 20/200 to the 20/100-E cards. To determine if the subject's visual acuity threshold was between the two cards, three new fading cards, *e.g.*, F-4, -5, -6 were constructed, each being successively reduced to approximate the 20/100-E card. The subject successfully discriminated the F-4 and F-5 "E" cards, but failed to generalize from the F-5 to the F-6 cards. Each side of the F-5 cards was 2.5 in. long. The size differential between the F-5 and F-6 cards was 0.25 in. on the top and 0.25 in. on the bottom. Figure 2 presents the response data for the F-5 and F-6 cards when the subject wore her glasses at 29 in. from the discriminanda. Subject 1 made the appropriate discrimination for the F-5 card, but failed to do so for the F-6 card. After observing that S 1's lever pressing behavior "broke down" on the F-6 fading card, final acuity measurement was obtained employing the F-5 card. Since S 1 had been

Fig. 4. Subject 1's intra-subject threshold crossing for the F-5 card without glasses.

prescribed "corrective" lenses, two measurements were taken. Figure 3 presents the response data for the F-5 card with glasses on and Fig. 4 presents the response data for the same card when S 1 did not wear her glasses. The subject with glasses, discriminated the F-5 card at 95 in. from the discriminanda but failed to do so when placed at 119 in. from the stimulus cards. When the glasses were removed, S 1 appropriately discriminated the F-5 card at 47 in. but not at 71 in.

Table 2 summarizes the acuity measurements employing the criterion cards, 20/200, and F-5 "E" cards. The subject's measured distance acuity was 20/180 with glasses, and 20/400 without glasses. The data can be understood by viewing the distance the subject was placed from the discriminanda and seeing the degree of success in emitting the appropriate response. If the subject had successfully discriminated the 20/100 card at 240 in. then the minimal distance acuity would have been 20/100. However, S 1 failed to discriminate beyond the F-5 "E" card (0.75 in. larger than the 20/100 "E") and discriminated the F-5

Table 2

Maximum distances at which Subject 1 discriminated the criterion, 20/200, and F-5 cards with and without eyeglasses.

Cards	Distance from Discriminanda	
	With Glasses	Without Glasses
Criterion	240 in.	191 in.
20/200	240 in.	71 in.
F-5	95 in.	47 in.
Distance Acuity Ratio	20/180	20/400

card at only 95 in. with the glasses. Thus, the distance acuity threshold was between 20/200 and 20/100. Since the discrimination "broke down" short of halfway between 0 and 240 in. from the discriminanda for the F-5 card (half the size difference between the 20/200-20/100 cards) the acuity ratio was slightly higher than 20/150, i.e., 20/180, while wearing glasses.

Subjects 2 and 3. The adult subjects were used to validate certain assumptions regarding the procedures. They were examined exactly

Fig. 5. Subject 5's intra-subject threshold crossing for the 20/20 card.

as the other subjects except that the experimenter asked them questions regarding potential "cues" in the experimental environment. According to the ophthalmological examination of the two subjects, S 2 had 20/20 corrected vision and S 3 had 20/30 corrected vision. The results of the experimental procedure yielded acuity results for S 2, 20/20, and S 3, 20/22. Uncorrected acuity ratios were not obtained from the physician; however, according to the present procedure, S 2 had 20/300 uncorrected acuity, while S 3's uncorrected vision was 20/275.

Subject 4. Subjective distance acuity measurements obtained from this subject revealed a minimal visual acuity ratio of 20/20. This subject's lever responding continued to be under the control of the "E" directionality of the 20/20 cards at 240 in. Two experimental hours distributed over six sessions were required to complete measurement of the subjective distance visual acuity (phase 4) for S 4.

Subject 5. This subject's distance visual acuity ratio was 20/23. Figure 5 graphically displays S 5's intra-subject threshold crossing for the 20/20 "E" cards. Evidence is offered that S 5's visual acuity threshold was between 143 and 167 in. Subject 5 required 2.2 hr of experimental treatment over six experimental sessions to complete measurement of the subjective distance visual acuity.

Subject 6. Subject 6's subjective distance visual acuity was approximately 20/22. The response data obtained from the 20/20 "E" cards show that S 6's lever responding was controlled by the directionality of the "Es" until he was placed 215 in. from the discriminanda. Figure 6 shows S 6's intra-subject threshold crossing for the 20/20 "E" cards and demonstrated that the subject's threshold was between 191 and 215 in. The proportion of S^D responses decreased when the subject was moved from the 191-in. to the 215-in. distance. Nine experimental sessions, in total 2.8 hr,

Fig. 6. Subject 6's intra-subject threshold crossing for the 20/20 card.

2.8 hr, were spent completing Phase 4 for S 6.

Subject 7. Several different acuity measurements were taken with S 7. This subject had been prescribed lenses without the benefit of a subjective examination. A detailed account of the procedures and results are described in a further paper (Macht, 1970). Subject 7's lever responding became undifferentiated at 215 in. from the discriminanda. Figure 7 graphically shows S 7's intra-subject threshold crossing for the 20/30 "E" cards. Figure 7 offers evidence that S 7's threshold was between 191 and 215 in. Based on these data, S 7's uncorrected subjective distance acuity was 20/32. The corrected acuity ratio reported in Table 1 referred to the observed performance with new lenses prescribed by an ophthalmologist after S 7 had been tested by the present procedure.

DISCUSSION

It is apparent from the present research that there are critical features that must be incorporated into procedures designed to obtain information from children. First, a child's

behavior repertoire must be sufficiently inclusive to afford emission of an objectively observable response. If a child fails to emit a response, an examiner must be cautious about inferring an absence of ability due to the absence of appropriate behavior. Without the observable response, an examiner is relegated to inferential behavior and, at Meyerson and Michael (1960) pointed out, the inferred conclusions may not be substantiated by later empirical investigations. Second, the employed stimulus conditions that eventually control responding should be adequately scheduled. By employing successive approximations to criterion behavior, the experimenter has a powerful tool that not only maximizes information feedback but increases the probability that a child's behavior will be reinforceable.

In general, the present findings make suspect Adler's statement (1962) that a subjective method of refraction is of little value in children younger than 7 to 8 yr of age. The five children employed in the experimental sample were 7 yr of age and younger. Additionally, it is now possible to take a somewhat modified view of Adler's earlier statement (1950) that

Fig. 7. Subject 7's intra-subject threshold crossing for the 20/30 card without glasses.

"failure to accurately measure most children is due to their lack of cooperation and their low level of intellectual functioning." The more recent interpretation gives attention to procedural inadequacies, rather than to the presence or absence of some quality attributed to the child.

By viewing the experimenter, *i.e.*, educator or therapist, as the object of probable deficiency, rather than explaining away unpredicted or unaccountable outcomes due to subject inadequacy, one builds "self-correction" into his methods.

REFERENCES

- Adler, F. H. *Physiology of the eye*. St. Louis: C. V. Mosby, 1950.
- Adler, F. H. *Textbook of ophthalmology*. Philadelphia and London: W. B. Saunders, 1962.
- Adler, H. E. and Dalland, J. I. Spectral thresholds in the starling. *Journal of Comparative and Physiological Psychology*, 1959, 52, 438-445.
- Allen, H. F. Testing visual acuity in preschool children. *Pediatrics*, 1957, 19, 1093-1100.
- Blackhurst, R. T. and Radke, E. Vision screening procedures used with mentally retarded children—a second report. *Sight Saving Review*, 1968, 38, 84-88.
- Blough, D. S. Spectral sensitivity in the pigeon. *Journal of the Optical Society of America*, 1957, 47, 827-833.
- Blough, D. S. A method for obtaining psychophysical thresholds from the pigeon. *Journal of the Experimental Analysis of Behavior*, 1958, 1, 31-43.
- Blough, D. S. and Schrier, A. M. Scotopic spectral sensitivity in the rhesus monkey. *Science*, 1963, 139, 493-494.
- Duke-Elder, S. *The practice of refraction*. St. Louis: C. V. Mosby, 1965.
- Elliot, D. N., Frazier, L., and Riach, W. A tracking procedure for determining the cat's frequency discrimination. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 323-328.
- English, H. B. and English, A. C. *A comprehensive*

- dictionary of psychological and psychoanalytical terms*. New York: David McKay Company, 1958.
- Gorman, J. J., Cogan, D. C., and Gellis, S. S. An apparatus for grading visual activity of infants on the basis of optokinetic nystagmus. *Pediatrics*, 1957, 19, 1088-1092.
- Gundersen, T. Amblyopia ex anopsia: a preventable form of blindness. *Pediatric Clinics of North America*, 1955, 2, 625.
- Havener, W. H. *Synopsis of ophthalmology*. St. Louis: C. V. Mosby, 1963, 13-15.
- Heise, G. A. Auditory thresholds in the pigeon. *American Journal of Psychology*, 1953, 66, 1-19.
- Kelly, C. R. *Visual screening and child development: the North Carolina study*. Raleigh: North Carolina State College, 1957.
- Leverett, H. M. Vision test performance of school children. *American Journal of Ophthalmology*, 1957, 44, 508-519.
- Macht, J. E. Examination and re-evaluation of prosthetic lenses employing an operant procedure for measuring subjective visual acuity in a retarded child. *Journal of Experimental Child Psychology*, 1970, 10, 139-145.
- Meyerson, L. and Michael, J. L. The measurement of sensory thresholds in exceptional children: An experimental approach to some problems of differential diagnosis and education with special reference to hearing. *Monographs in Somatopsychology*, 1960, 4.
- Newell, F. W. *Personal communication*, 1970.
- Sidman, M. *Tactics of scientific research. Evaluating experimental data in psychology*. New York: Basic Books, 1960.
- Sjögren, H. New series of test cards for determining visual acuity in children. *Acta Ophthalmologica*, 1939, 17, 67.
- Wolfe, W. G. and Macpherson, J. R. Comparative investigation of methods of testing auditory and visual acuity of trainable mentally retarded children. U.S. Office of Education, *Cooperative Research Bureau*, SAE 6447, 1960.
- Yarczower, M., Wolbarsht, M. L., Galloway, W. D., Fligsten, K. E., and Malcolm, R. Visual acuity in a stump-tail macaque. *Science*. 1966, 152, 1392.

Received 16 December 1969.