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A SIMULTANEOUS DISCRIMINATION PROCEDURE FOR THE MEASUREMENT OF VISION IN NONVERBAL CHILDREN[1]

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Few nonverbal developmentally disabled children ever receive adequate vision assessment because of their limited language skills. The present study details a simultaneous discrimination procedure for measuring subjective visual acuity in such children. A stimulus fading procedure was used to train a discrimination between Snellen Es differing in orientation, and a psychophysical tracking method was used to determine acuity thresholds. The procedure was tested with 11 nonverbal autistic and schizophrenic children and validated with four nonpsychotic children. Eight of the psychotic children were successfully examined in one to three sessions. Two of these children were identified as having significant acuity losses. The validity assessment showed that the experimental procedure resulted in thresholds equal to or slightly lower than those obtained with the Illiterate E chart.

DESCRIPTORS: visual acuity, vision testing, tracking, fading, stimulus control, discrimination training, methodology, nonverbal children

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The large majority of severely retarded and psychotic children never receive adequate vision screening. When such children are suspected of having a loss in visual acuity (the ability to discriminate small spatial separations), they are generally referred for evaluation by "objective" methods. In an objective evaluation, each eye is examined with a retinoscope and a gross estimate of acuity is made, based on the apparent refractive properties of the eye. More accurate measurements of acuity can be obtained only in a "subjective" evaluation, in which the child looks at a standard set of stimuli and indicates their discriminability by naming them (*e.g.*, the letters on the Snellen chart or the pictures on the Kindergarten chart) or by indicating their orientations (*e.g.*, the Snellen Es on the Illiterate E chart). However, commonly used subjective acuity tests for children (reviewed by Hirsch, 1963; Macht, 1971) require the comprehension of verbal instructions and the reliable reporting of perceptions. These are skills that severely developmentally disabled children do not have as a result of their minimal or nonexistent proficiency in language. In addition, it is often difficult to motivate such children to participate in test procedures long enough to obtain conclusive results.

One successful approach to the measurement of visual acuity in nonverbal children is based on operant conditioning. Noting that researchers in animal psychophysics (see Stebbins, 1970) have been measuring vision in nonverbal organisms for some years, Macht (1970, 1971) devised a successive discrimination procedure for use with nonverbal retarded and brain-damaged children. The children were taught to discriminate left- and right-facing Snellen Es through the reinforcement of bar-press responses when one orientation was presented and the extinction of responses when the other orientation was shown. By systematically varying the sizes of the stimuli and the distance between the child and the stimuli, Macht was able to obtain accurate,

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reliable thresholds from four previously untestable children in 6.8 to 106 hr of training and testing.

The present study describes a different operant procedure for measuring subjective visual acuity thresholds in nonverbal children, suggested by Blough's (1971) method for measuring distance acuity in pigeons. First, a simultaneous (choice) discrimination paradigm was used in training and testing because basic research with normal and retarded children indicates that simultaneous discriminations are learned more rapidly than successive discriminations when the stimuli are similar (Horowitz, 1965; Jeffrey, 1961; Lipsett, 1961; Loess and Duncan, 1952). Second, a graduated stimulus change, or fading, procedure was used to teach a discrimination between Snellen Es differing in vertical-horizontal orientation, since fading procedures have successfully taught other orientation discriminations to retarded and psychotic children (Macht, 1971; Schreibman, 1975; Touchette, 1971). Third, a limit of 4 hr was imposed on the total time devoted to training and testing, since the ultimate goal of this research program is to develop a vision test for low-functioning children that will approach maximum efficiency. Fourth, equipment was kept to a minimum in an effort to make the procedure usable in virtually any setting. Only the stimulus cards were specially made; the additional equipment (tables, chairs, and a blackboard) is readily available in institutions and schools. Finally, only children with primary diagnoses of autism or childhood schizophrenia were studied. Such children are often suspected at some time in their lives to suffer from sensory deficits, yet there are apparently no previous reports describing the successful measurement of their subjective visual acuity.

METHOD

Subjects

Nine autistic and schizophrenic children were selected on the basis of their availability for testing from the nonverbal residents of the Children's Treatment Center of Camarillo State Hospital. Two additional autistic children were referred from the Santa Barbara County Autism Project. The children's chronological ages ranged from 5 yr seven months to 16 yr; their mental ages, as recorded in their records, ranged from untestable to 5 yr nine months. Seven of the children were mute or made only unintelligible vocalizations; four (Dana, Debbie, Ruth, Melissa) used a few one- or two-word requests. All of the children responded appropriately to very simple instructions (*e.g.,* "sit down", "hands quiet") but none reliably responded to more complex commands. All but Harry were toilet trained. None played appropriately with toys or engaged in age-appropriate social interactions with peers or adults. All but Dana and Mickey exhibited considerable repetitive, stereotyped, self-stimulatory behavior in unstructured situations. One boy, Denny, engaged in severe headbanging episodes three to six times a week on his home unit, where they were being treated with some success with contingent timeout. Mac had been found by EEG audiometry to have a severe binaural hearing loss. There were no reports of either objective or subjective visual acuity examinations in any of the children's records. All the hospitalized children were given brief peripheral ocular examinations during their yearly medical evaluations, but no ocular pathologies were noted in the records and none of the children wore glasses. The children serving as experimental subjects are listed and characterized in Table 1.

To determine the validity of the experimental procedure, four additional children from the Center were tested with both the experimental stimuli and an American Optical Company Illiterate E Chart. These children were diagnosed with one of the behavior disorders of childhood (*e.g.,* unsocialized aggressive reaction, overanxious reaction), and their chronological ages ranged from 10 yr eight months to 15 yr. All had IQs in the dull normal to normal range and were normal language users. None had been prescribed glasses and all had passed vision

Table 1
Subject Characteristics

Name[a]	*Sex*	*CA*	*MA*[b]	*Diagnosis*
Ben	M	10-6	5-9	Autism
Dana	F	5-7	3-5	Autism
Debbie	F	13-1	4-5	Schizophrenia
Mickey	M	11-3	4-2	Autism
Denny	M	16-0	2-10	Schizophrenia
Ruth	F	11-2	2-3	Schizophrenia
Mac	M	10-10	4-3	Autism
Melissa	F	8-9	2-5	Schizophrenia
Harry	M	14-5	U[c]	Autism
Jack	M	10-0	U	Schizophrenia
Brandon	M	9-1	1-9	Schizophrenia

[a]Fictitious
[b]Peabody Picture Vocabulary Test
[c]Untestable, *i.e.,* unable to achieve a basal MA of 1-9.

screenings at a level of 20/20 during annual medical examinations.

Equipment

Two sets of stimulus cards were constructed with white poster board and ink. One set (the training cards) was used for training a discrimination between a Snellen E whose prongs pointed down (S+) and one whose prongs pointed left (S—) from the child's viewpoint. The other set (the test cards) was used for measuring the acuity threshold. All cards were 16 cm square and were covered with transparent Contact Paper. Figure 1 illustrates selected pairs of training and test cards.

Two S+ cards were used in training the E discrimination. The first had three 159.6- by 31.9-mm vertical black stripes and served as S+ in all training steps except the last. The other S+ card bore a downward-pointing Snellen E with 159.6- by 31.9-mm segments. It was used in the last training step and also served as the first S+ test card. Eighteen S— cards were used in training. They included (a) one blank card; (b) 16 cards with three 159.6- by 31.9-mm stripes, which decreased in brightness across cards from very light gray to fully black; and (c) one card bearing a leftward-pointing black Snellen E with 159.6- by 31.9-mm segments, which also served as the first S— test card.

There were 16 pairs of test cards, each pair bearing black Snellen Es of the same size but different in orientation. On the 16 S+ cards, the Es pointed down; on the 16 S— cards, the Es pointed to the left. The widths of the segments and spaces of each E in a given pair were equal and subtended 1 min of visual angle in the "normal" eye at a distance in feet specified in the denominator of the Snellen acuity ratio corresponding to the test letter. The following formula, derived from one given by Riggs (1971), was used to calculate these widths: segment width (in mm) = distance from stimulus to subject as specified in the Snellen ratio denominator (in mm) × 0.0002908 (the tangent of 1 min of visual angle). For example, the widths of the segments and spaces in the 20/30 E were found by multiplying 9144 mm (= 30 ft) by 0.0002908, which equals 2.7 mm after rounding off. The overall size of a Snellen test letter is found by constructing an imaginary square whose sides are five times the width of each segment. Thus, the size of the 20/30 E was

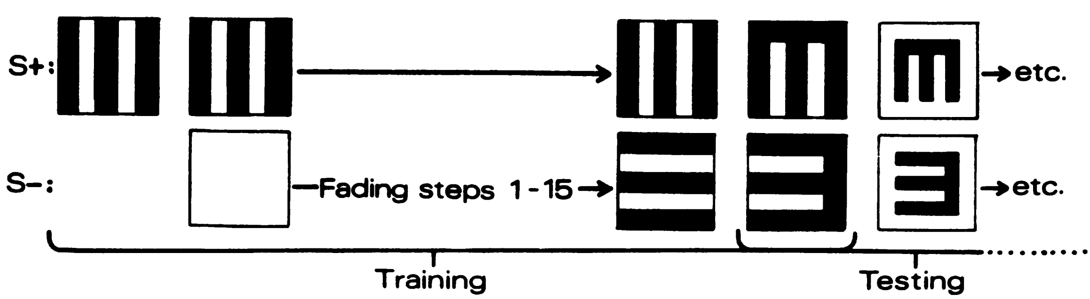

Fig. 1. Representative stimulus cards showing the sequence of steps (from left to right) used in training and testing.

13.5 mm^2 (= 2.7 × 5), and the sizes of the Es on each pair of test cards may be similarly calculated with reference to one of the right-hand ordinates in Figure 2. The numerator in the Snellen ratio specifies the stimulus-to-subject distance in the test situation. This distance was always 6.1 m in the present study, as is standard in clinical acuity evaluations. Acuity ratios will be referred to in English rather than metric notation throughout this report, since that convention is still current and familiar.

The room used for training and testing was 7.3 by 3.4 m in size. Against the wall at one end stood a large easel-type blackboard, 1.2 m wide and 1.9 m high. Its chalk tray, used to display the stimulus cards, was 0.93 m from the floor. Four tables, each 1.5 by 0.74 m, were arranged in the form of a T: three tables placed end to end joined one table placed crosswise at the stimulus display end of the room, 0.83 m from the front of the blackboard. Thus, the tables formed a barrier down the middle of the room, creating a passageway on either side for the child to approach the blackboard. An adult experimenter sat at the middle of the table at the top of the T to conduct the procedure and record data. The child sat at the opposite end of the tables (the bottom of the T), 6.1 m from the blackboard. The room was illuminated by fluorescent lamps mounted in the ceiling. The illumination of the stimulus cards was 107.6 lx (as measured with a Sekonic L-28c incident light meter), a level within the range recommended for vision screening (National Society for the Prevention of Blindness, 1971).

Procedure

Trials were conducted identically in the training and test phases as follows. The adult placed a pair of stimulus cards on the chalk tray of the blackboard, one at each end, then looked at the seated child and said, "(name), look at the cards." When satisfied that the child had looked at both of the cards, the adult commanded: "Come touch the correct card", or simply, "Come get it." The child stood up and began walking down one of the passageways toward a card. If the side chosen was correct, the adult praised the child as he or she approached and delivered an edible reinforcer (an M&M, a sip of soda, or a bite of ice cream) when he or she arrived and touched the card. If the wrong side was chosen, the adult said: "No—wrong one; go sit down", as soon as the child had clearly entered the wrong passageway. While the child returned to the seat, the adult removed the cards. The cards for the next trial were not displayed until the child was seated again at the full test distance. The left-right position of the correct card was determined by a Fellows (1968) order.

Training phase. Initially, the experimenter placed only the first, vertically striped S+ card on the chalk tray on each trial until the child readily came to the correct side on two successive unprompted trials. (During the first two or three trials with some children, an assistant manually prompted the child to stand up and start walking toward the correct card when the experimenter commanded an approach.) The S+ card was then paired with the blank S− card until the child chose the S+ card on two successive trials, once on each side. At this point, the program for fading in the horizontal stripes on the S− cards began. The S− card with the lightest horizontal stripes was presented with the S+ card; if the child made the correct choice, the S− card with the next-darkest horizontal stripes was presented with the S+ card, and so on. As long as correct choices were made, S− cards with successively darker stripes continued to be presented at the rate of one brightness step after each correct response. When the child made an incorrect choice, the fading program stopped and remained at the brightness step at which the error occurred until the child made five correct choices in a row. Superimposed on this "program stop" procedure was a correction procedure: after each error, the left-right arrangement of the cards was repeated on the following trial and succeeding trials until a correct response was made, whereupon the Fellows order resumed. The purpose of the correction procedure was to eliminate the possibility that the child would adopt a strategy of always going to one side and thus obtain at least 50% of the reinforcements without learning the discrimination. If the child could not make five correct choices in a row within 15 trials, he or she was returned to the beginning of the training program. Three such restarts were allowed before the training procedure was considered inadequate for a given child and training efforts ended. After the child made five correct responses in a row within 15 trials, the regular fading program resumed at the rate of one step per correct response. When the child reached the next-to-last fading step (16: fully black S— stripes), five successive correct responses were again required to ensure that the terminal vertical-horizontal discrimination was well learned.

The last manipulation in the training phase was the conversion of the vertical and horizontal stripes to a downward-pointing Snellen E and a leftward-pointing Snellen E, respectively. This was done in Step 17 by substituting the 20/360 S+ test card for the first S+ training card and the 20/360 S— test card for the last S— training card. Once again the child was required to make five successive correct choices in 15 trials before continuing into the test phase.

Test phase. Testing began immediately after the child met criterion on Step 17 of training. Starting with the 20/360 cards, pairs of test cards with progressively smaller Es were presented until an error was made. When an error occurred, the child was given seven additional trials at that size to make five consecutive correct choices (a "criterion run"). If he or she did so, the next smaller pair of Es was presented, and the child was again required to make five consecutive correct choices. If the child failed to make a criterion run, the experimenter presented the next larger Es and again required a criterion run before continuing. Thus, the commission of the first error in the test phase changed the rate at which the size of the Es could be changed. After the first error, all movements—either forward to smaller Es or backward to larger Es—required that the child pass or fail the criterion of five successive correct choices in eight trials. It was not necessary that all eight trials be completed; as soon as the five consecutive correct trials were completed, or as soon as it became impossible to satisfy the criterion by making an error on the fourth or any later trial, the change to the next smaller or larger size was made. The test phase continued until the child's trial-by-trial record showed a regular oscillation between sizes only one step apart, achieved by alternating three criterion runs at a given size with failures to meet criterion at the next smaller size. The acuity ratio corresponding to the size at which the three successful criterion runs occurred was considered to be the child's subjective binocular distance acuity.

Each session lasted a variable number of trials (26 to 96) and a correspondingly variable length of time (30 to 90 min). The basis for terminating a session was the experimenter's judgement that the child's motivation was waning, as indicated by increasing delays in approaching the stimulus display and slowness in consuming reinforcers. Sessions were conducted one to seven days apart, late in the afternoon just before the child's dinner. No reliability checks were made, since the choice of one passageway or the other was unmistakeable.

Validity assessment. Each of the four nonpsychotic children was tested with the experimental procedure in the same manner as the other children, with two major exceptions. The E discrimination was established by instruction, using the 20/360 cards, and the indicator response was an exaggerated pointing movement of the arm and hand. Following threshold determination with the experimental procedure, the children were tested with the Illiterate E chart. For two children, testing with the chart was conducted by the experimenter, who instructed each child to point in the directions of the Es in each line of figures, until one or more errors occurred. The line on which the first error occurred and the lines immediately above and below it were each presented at least two more times. The acuity ratio corresponding to the line at which no errors occurred over three presentations was considered the child's threshold for validity purposes. The two remaining children were referred for a binocular acuity assessment by the Center's pediatrician, who was not informed of the experimental reason for the referral. She routinely used the Illiterate E chart in conducting vision screenings.

RESULTS

Every child learned to approach the S+ card when it was presented alone and when it was paired with the blank S— card within seven trials at the start of training. Of the 11 children observed, eight were successfully trained and tested, four within a single session. Three children failed to learn the vertical-horizontal stripe discrimination during four training attempts and consequently were not tested.

Figures 2 and 3 show each tested child's progress through the fading program and the vision test. Figure 2 shows that Ben, Dana, Debbie, and Mickey learned the vertical-horizontal E discrimination and were successfully tested in one session. Ben's progress through the training phase was errorless, and Dana, Debbie, and Mickey made only one to three errors in learning the orientation discrimination. During the vision test phase, these children correctly discriminated progressively smaller Es until they made errors at a size that was one or two sizes smaller than their eventual thresholds. Each child failed to advance beyond the point of his or her first error because an additional error was made on the fourth trial (Ben, Debbie, Mickey) or on the sixth trial (Dana). When Debbie was backed up to the next larger E size, she immediately began a series of three criterion runs separated by failures to satisfy the criterion at the next smaller size. The acuity ratio corresponding to the size at which she made the criterion runs was 20/15. Ben, Dana, and Mickey each backed up two sizes before beginning the criterion runs that would establish their acuity ratios. Ben and Mickey, like Debbie, had excellent vision, *i.e.,* 20/15. Dana's acuity ratio was 20/50, which is significantly worse than the mean acuity of children her age (20/30), according to Weymouth (1963).

The bottom panel of Figure 2 shows the results for Denny, who was trained and tested in two sessions. Denny learned the E discrimination with three errors, and during initial testing progressed down to the E size that would later be established as his threshold. At this point, however, a temporary breakdown in stimulus control occurred; Denny was unable to make a criterion run until he was returned all the way back to the largest Es. When the test phase was repeated the following day, Denny produced a threshold curve indicating a serious vision impairment; his acuity ratio was 20/70. (Mean acuity of children 12 yr and older is 20/20 [Weymouth, 1963]).

Figure 3 shows that Ruth, like Ben, learned the E discrimination errorlessly. During the test phase, she worked down to an E size near her threshold before making an error. She immediately satisfied the criterion for continuing to the next smaller size, where she again made one error followed by five correct choices. At the 20/15 size, she failed to make a criterion run, and testing was terminated because she appeared satiated. In the following session (Test 2), she made consecutive correct choices until she overshot her threshold, then backed up and produced the curve that established her visual acuity as 20/18.

Mac and Melissa (Figure 3) were more difficult to train and to test than the other successful children. Mac progressed easily through the fading program until he reached Step 15, the darkest gray S— stripes; he had considerable difficulty making a criterion run at this step and at Step 16, the fully black S— stripes. In his first vision test, Mac moved down to the E size of his eventual threshold (20/30) before making an error, and subsequently moved back and forth around this size but failed to satisfy requirements for establishing an acuity threshold. During the next session, Mac's test performance was once

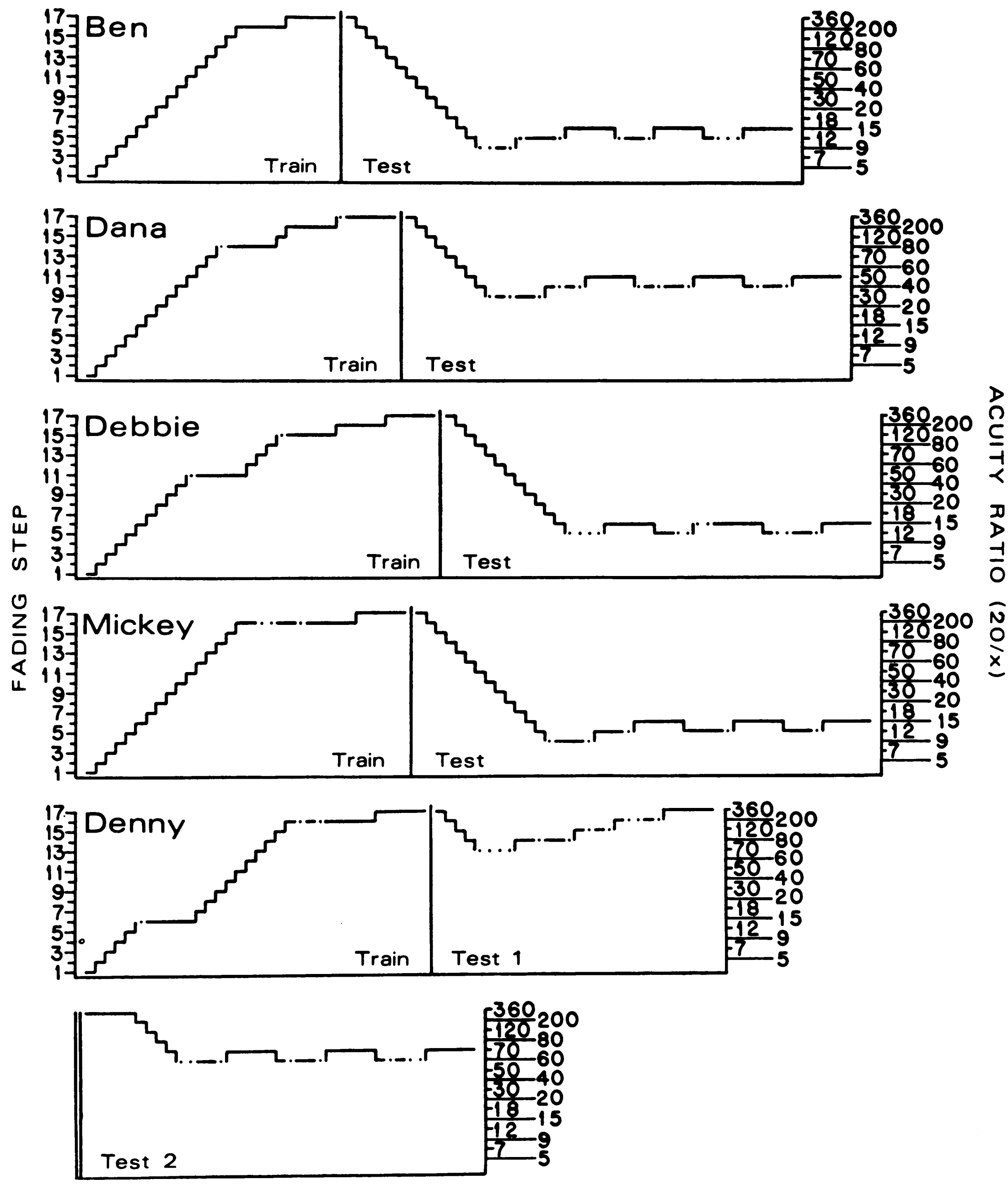

Fig. 2. Performance during training and test phases of Ben, Dana, Debbie, Mickey, and Denny. (The left ordinate indicates fading steps; the right ordinate indicates the sizes of the test Es in terms of the denominators of their acuity ratios. The horizontal segments of each curve represent correct choices and dots represent incorrect choices. A single vertical line separates phases conducted within a session; double vertical lines separate sessions.)

again erratic at the beginning but stabilized during the second half of the session and resulted in the curve establishing his acuity at 20/30.

The entire first session with Melissa was devoted to training (Figure 3). Numerous errors resulted in program stops at six steps, ending at

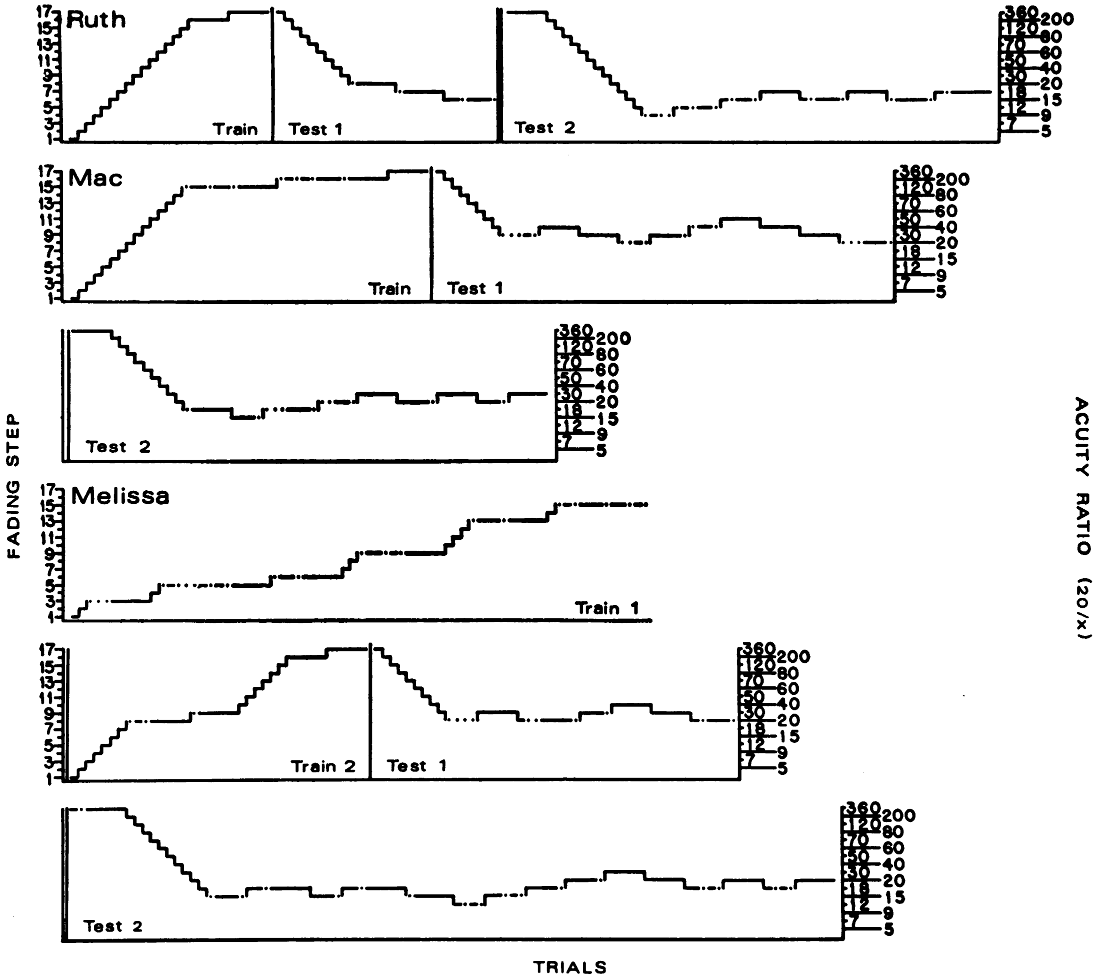

Fig. 3. Performance during training and test phases of Ruth, Mac, and Melissa.

Step 15. In the second session, Melissa was started at the beginning of the training procedure once more. This time she succeeded in mastering the orientation discrimination after making mistakes at only two steps. Vision testing began during the same session, but because she failed to satisfy the threshold-determination requirement she was tested again during a third session. This time, she eventually made a series of choices that resulted in a satisfactory threshold curve, with a corresponding acuity ratio of 20/20.

Figure 4 shows that we failed to teach the orientation discrimination to Harry, Jack, and Brandon using the fading program in four attempts with each boy. Harry and Jack both advanced to the penultimate step (16), but neither was able to make five correct choices in a row in the allotted 15 trials. Brandon progressed to Step 15 in each of his three final attempts, but was never able to move beyond that step to the terminal discrimination.

Validity Measures

Each of the four nonpsychotic children tested with the Illiterate E chart achieved an acuity ratio of 20/15 in the experimental procedure. Two of these children were tested with the chart by the experimenter and achieved ratios of 20/15 and 20/20. The two who were examined by the pediatrician were reported to have ratios of 20/20 and 20/30.

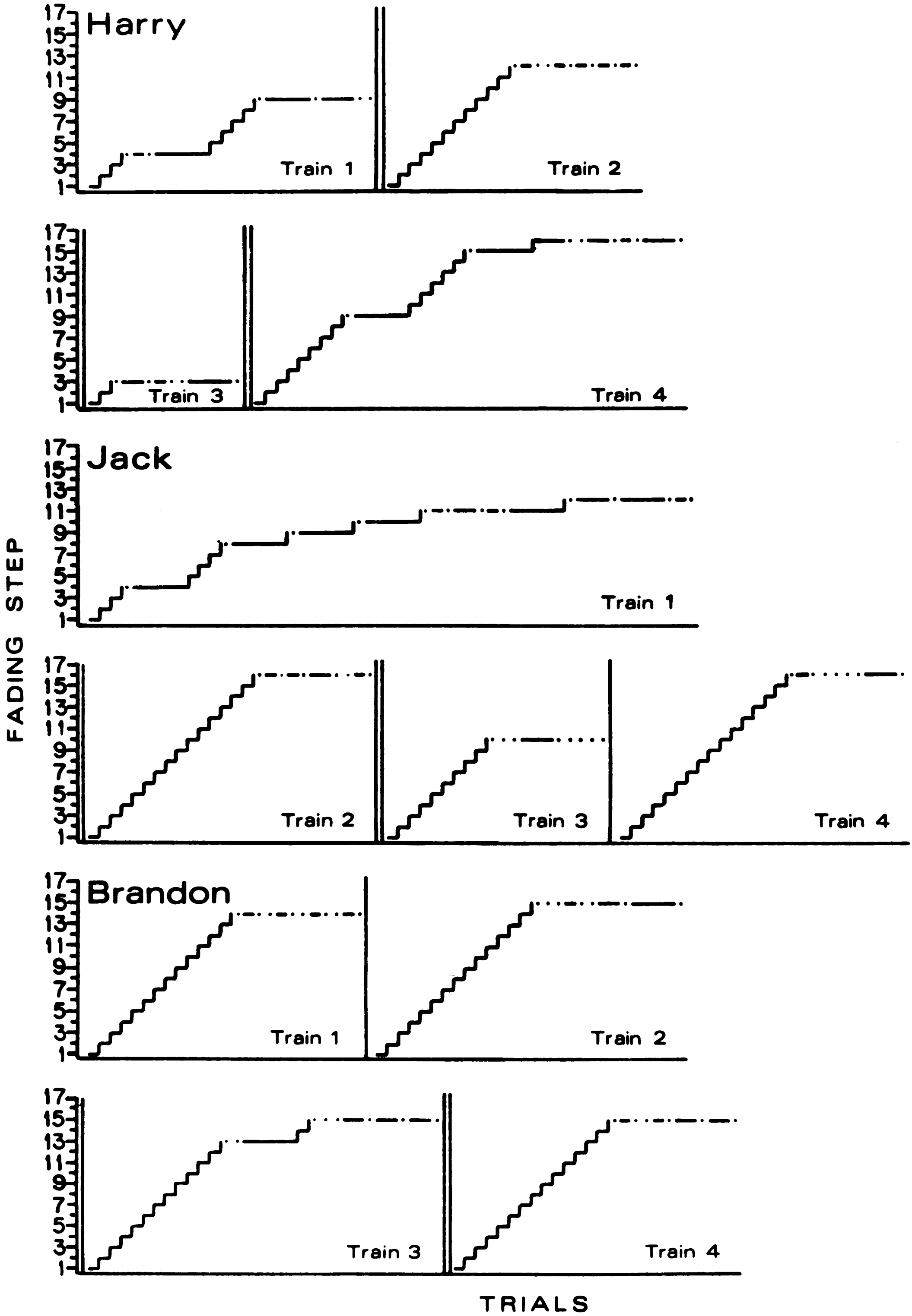

Fig. 4. Performance during training phases of Harry, Jack, and Brandon.

DISCUSSION

Subjective visual acuity thresholds can be obtained from many nonverbal, severely psychotic children relatively rapidly and inexpensively. Each of the autistic and schizophrenic children who were successfully examined required a total of 1 to 3 hr to be trained and tested. The present experimental procedure made possible the measurement of significant acuity impairments in two children whose subnormal vision was previously unsuspected. These two children were referred for opthalmic evaluations. Denny, the self-destructive boy, was found to have a lesion 1 by 3 mm in size in the central posterior lens capsule of each eye. Corrective lenses of −3.00 diopters were prescribed and worn successfully in situations where he could be closely supervised. The opthalmologist who examined Dana, the 5-yr-old girl, found no structural abnormalities, but suggested that she be given preferential seating in school and be examined regularly so that glasses can be prescribed if her vision fails to improve as she matures.

The three children who failed to learn the vertical-horizontal discrimination were apparently victims of our fading procedure, which required a shift in stimulus control from stimulus intensity to stimulus orientation. By the fourth training attempt, each child's stimulus control breakdown occurred very late in the fading progression, either at the step constituting the final stripe discrimination (Harry, Jack) or at the step just before it (Brandon). The locations of these disruptions coincided with the elimination of the difference in intensity between the S+ and S− stripes, suggesting that the boys' choices were controlled by the intensity dimension to such an extent that they never came under the additional control of the orientation dimension. Several investigators (Ray and Sidman, 1970; Schusterman, 1967; Sutherland and Mackintosh, 1971; Touchette, 1971) have suggested that stimulus control of a response by two stimuli must exist simultaneously at some point during fading if control is to shift from one stimulus to another. Fields, Bruno, and Keller (1976) demonstrated such simultaneous control before successful shifts in stimulus control in pigeons. It may be significant that the three children whose choices failed to transfer from intensity to orientation were the lowest-functioning children in the study (see Table 1). Schover and Newsom (1976) found that the tendency of both psychotic and normal children to attend to one dimension of a stimulus overselectively, or to the exclusion of other relevant dimensions, increases as developmental level decreases. Other failures in transferring stimulus control with developmentally disabled children have been reported by Koegel and Rincover (1976), Schreibman (1975), Sidman and Stoddard (1966) and Touchette (1971). These failures highlight the continuing need for the development of more effective discrimination training procedures for this population.

The validity assessment showed that acuity ratios obtained with the present procedure are acceptably close to those obtained with the Illiterate E chart. In three of the four cases, the experimental procedure yielded slightly lower thresholds, and these discrepancies may have occurred for one or more of the following reasons. First, it is known that measurement with stimuli differing in only two orientations results in somewhat lower acuity thresholds than does measurement with letters in four orientations like those on the Illiterate E chart (Emsley, 1948). Second, the contrasts between the letters and backgrounds of the experimental stimuli (as measured with a Macbeth illuminometer) ranged from 94 to 97%, slightly yet discriminably greater than those of the stimuli on the Illiterate E chart (90 to 94%). Third, it is known that visual acuity can be improved through training (*e.g.*, Cornsweet and Crane, 1973; Province and Enoch, 1975), and Rosenberger (1970) noted that tracking procedures can function like fading programs to shape progressively finer discriminations. The present study does not allow a conclusion regarding the extent to which these factors may have been responsible for the lowered thresholds of three of the four nonpsychotic subjects in the experimental procedure. However, the tendency of the present procedure slightly to overestimate a child's acuity seems a negligible risk when the alternative may be no estimate at all.

The present study, along with Macht's (1971), represents the beginning of a technology for the measurement of subjective vision in nonverbal retarded and psychotic children. The present findings are particularly significant with regard to autistic children, a population whose "apparent sensory deficits" often raise the first suspicions of abnormality by parents (Lovaas and Newsom, 1976). Clearly, it is important to develop rapid, accurate procedures that will separate actual deficits from such "apparent" deficits (*i.e.,* those due to orienting and attentional abnormalities) so that appropriate diagnostic and treatment decisions can be made.

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