THE OCCURRENCE OF THE SPIRAL
AFTEREFFECT IN CHILDREN

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The illusion, or aftereffect, following the rotation of the Archimedes Spiral has long been known to occur and has been used in a variety of psychological research areas. It has been of interest to experimentalists, for occurrence and duration of the aftereffect can be modified by several variables (e.g. velocity of the spinning stimulus, color, degree, etc.). The Spiral Aftereffect Test (SAET) has attracted the interest of clinicians for use as a technique for assessing memory impairments and brain damage among mental patients (Freeman & Josey, 1949; Standlee, 1953; Price & Deabler, 1955); however, a review of the literature has shown the SAET to be a somewhat unreliable measure of organic impairment.

Studies suggest that the afterimage is attenuated or altogether absent in individuals who suffer from some memory defect or brain injury. The evidence is obscured, however, by the fact that different groups, chosen by differing criteria, have been investigated more thoroughly than others, and various mechanical techniques and testing instructions have been utilized. In Freeman and Josey's study (1949), the SAET was used with normals and psychotics in an attempt to determine its effectiveness as a diagnostic tool for mental disorders. This study marked the beginning of examining the aftereffect for applied purposes rather than simply "for its own sake." Freeman and

Josey (1949) reported that there was a correlation between memory impairment and failure to perceive the afterimage. However, their population parameters were not clear, because the pathological group examined included not only schizophrenics and manic depressives but epileptics, arteriosclerotics, and other groups as well. The mean age of this group was 42.7, with a range of 19-76 years; whereas, the mean age of the control group was not reported but was assumed to have been a younger sample since it was drawn from high school and college populations. Freeman and Josey's scoring methodology has been criticized as well (Holland, 1956).

Standlee (1953) employed a more objective index of memory impairment (the Wechsler Memory Scale) rather than the "clinical assessment" criteria used by Freeman and Josey. The authors tested psychotics and normals and found that most subjects experienced the illusion and it was unimpaired by electroshock therapy.

Applied research dealt primarily with the SAET among the neurologically impaired. Price and Deabler (1955) have suggested high validity for the SAET in differentiating subjects with cortical damage from normals and/or patients diagnosed as having functional disorders. They reported that normals had 92.5% total perception of the afterimage, nonorganics had 95%, and organics had only 2% total perception. Total perception refers to the subject giving a correct response on every trial.

Following Price and Deabler's publication, clinicians began to

speculate upon the possibilities of the SAET as being "a valid, reliable, and two minute test of brain damage" (Holland, 1965). The number of studies in this area immediately increased.

In 1956 Gallese cross-validated Price and Deabler's study using normals, schizophrenics, lobotomized schizophrenics, and "brain damaged" patients. There were two unexpected findings resulting from his experiment. First, the lobotomized group was indistinguishable from the normals and schizophrenics in their abilities to perceive the afterimage. Second, those organics with diffuse brain injuries such as syphilis or encephalitis were less likely to report the perception than were those with alcohol or convulsive etiology. These results clearly indicate that the term "brain damaged" is too general and, for studies of this nature, needs to be defined more specifically.

Page, Rikita, Kaplan and Smith (1957) compared 20 organic patients with some type of cortical brain injury with 20 psychiatric patients who had no indication of organic pathology (12 diagnosed schizophrenics, 2 neurotics, 2 paranoids, 3 depressives, and 1 alcoholic). Here they used the duration of the effect as the test score as well as the incidence of the perception. The incidence of the aftereffect could differentiate the organic and nonorganic control groups, but the duration score failed to do so at an acceptable level of probability. The Page, et al (1957) study contained the same problem noted with Freeman and

Josey's (1949) work, namely multiple diagnostic groups were included in both the "functional" control group and the "organic" experimental group.

Spivack and Levine (1957) found support for earlier studies relative to differences of aftereffect perception with emotionally disturbed adolescents versus those with known brain damage. This study did, however, demonstrate significantly longer durations of the effect among organics who reported perceiving it; yet no relationship was found between the spiral scores and degree of memory loss. This is in conflict with earlier findings reported by Freeman and Josey (1949) and Page, et al (1957), and raises serious questions regarding the validity of the SAET as a diagnostic tool for brain damage. For example, Berger, Everson, Rutledge and Koskoff (1958) reported that there were significant correlation co-efficients ($p < .05$) between spiral scores and spinal fluid but not between the test scores and EEG or skull x-ray. They recommended further study.

In 1960 Blau and Schaffer carried this type of investigation further. From a group of 420 subjects 5 to 16 years old they chose 46 children who failed to report the perception of the aftereffect following eight 30-second trials and assigned them to the "abnormal" group. Twenty children matched for age, and who did perceive the illusion on all trials, were designated as "normals." All subjects were administered a Bender-Gestalt, a children's intelligence scale and the SAET. The results were then examined as a function of each subject's

EEG (2 hour) recording. They concluded that the SAET was a stronger predictor of EEG records than were all the other tests in the battery. Eighty-six and ninety percents of the "abnormal" and "normal" groups respectively were correctly identified by the SAET.

This study may indicate that the SAET could be a useful diagnostic tool for children with cortical damage that would be indicated by abnormal EEGs. A major problem that would have to be solved before such a test could be utilized is one of communication. The failure of an individual to report perception of the spiral visual aftereffect may not be caused by some neurological damage or immaturity. It may be due, in some cases, to an inability or even a fear to verbalize the perception.

Several studies dealing with adults have suggested that the impairment of perception of the brain damaged is actually a case of failure to report the image that is perceived. Mayer and Coons (1960) hypothesized that because hospitalized subjects are especially anxious to do well in testing situations they are extremely suggestible to the experimenter's instructions. In examining this hypothesis, they manipulated the test instructions given to groups of brain damaged or schizophrenic patients, either reassuring the "normality" of the aftereffect or causing anxiety by emphasizing that "ill" people perceived it. These two instructional cases were compared to the neutral instructions that asked that the subjects simply report what was happening. Results indicated that the schizophrenics were more likely than the brain damaged to report perception under the neutral and anxiety producing instructions, but there were no significant differences between the groups when reassuring instructions were given.

Anxiety seems to be a determining factor for reporting perception in children as well. Bryan and Loder's 1962 study found that fifth graders reported fewer spiral aftereffects following an anxiety provoking situation. Among young children the inability to verbally communicate what is perceived should be greater than that obtained with older subjects, and several studies have attempted to determine at what age the spiral aftereffect could be perceived. Harding, Glassman and Helz (1957) examined developmental and maturational parameters of the SAET and reported that children who were either below 55 months CA or 60 months MA responded to the SAET with less than 75% accuracy. The data were interpreted as being indicative of neurological immaturity, and the possible correlation between children and brain injured adults was noted. It was suggested that children under 55 months have not developed the appropriate cerebral maturity necessary for the perception of the aftereffect. It is also possible that the children lack the language skills that are required to explain what they see. This study, therefore, opened the area for a "faulty communication hypothesis" (Holland, 1965).

In 1958 Gollin and Bradford accused Harding and other spiral aftereffect researchers of failing to properly communicate with the subjects. Gollin and Bradford questioned young children's ability to understand

and describe the concepts of bigger and smaller. In an attempt to extend the work of Harding, Glassman and Helz (1957) into the area of determining the verbal designators operating for children, Gollin and Bradford examined 23 children who ranged in CA from 38 to 63 months and from 42 to 88 months MA. Since the aftereffect is not confined to the spiral per se, other objects and methods may be employed for an elicitation of a verbal report. Gollin and Bradford utilized inflated balloons inked with facsimile spirals. Before being accepted as a subject for the test proper, each child was required to verbally express whether an inflating or deflating balloon was getting larger or smaller. Then each child observed a rotating spiral disc for 30 seconds. At the end of the 30-second period the gaze was switched to the inked balloon. The child was then asked if the balloon was getting smaller or larger. In this study virtually all the children (17 of the 23) who could correctly respond to the actual conditions were also able to correctly report the spiral aftereffect. They also reported a lower CA and MA able to describe the image than was found by Harding, Glassman and Helz (1957) (45 months CA, 48 months MA).

Gollin and Bradford's study gives some indication of techniques necessary to insure true communication. The questions that still remain, however, are at what age a child understands the terms "bigger" and "smaller" and at what age he can properly communicate those terms. More recently, cognitive and psycholinguistic investigations have dealt with the development of the semantic frameworks of quantitative and comparative concepts (Donaldson & Wales, 1970, Lumsden & Poteat, 1968; Mataratsos, 1973; Tashiro, 1971). The studies cited here have suggested that children around 3 years of age more accurately understand "big" than do older children. They have a general notion of the term "big" at age 3, but as they grow older they come to interpret it only as an increase in the vertical dimension. One study describes this phenomenon particularly well with its title, "When is a High Thing the Big One?" (Mataratsos, 1973). It is important to note here that Mataratsos did not use the comparative term "bigger" in his study because "pilot work in previous investigations indicated that preschool children do not understand the term (Mataratsos, 1973)." This suggests that children under about age 6 cannot be expected to comprehend or use with accuracy the concepts and terms "bigger" or "smaller."

Mataratsos' speculation about the use of the comparative "bigger" with young children renders those studies that used 3 and 4 year olds questionable (Harding et al, 1957; Gollin & Bradford, 1958). Although in both studies it was crucial that the child verbally respond with a "bigger" or "smaller" discrimination, Harding, Glassman and Helz (1957) indicated that children as young as about 4 years 6 months could respond accurately to the SAET (75%), and Gollin and Bradford (1958) reported that a 3 year-7 month old child could describe the spiral aftereffect.

The purpose of this experiment was twofold. One, to determine what, if any, relationship exists between the child's capacity to discriminate bigger from smaller and his ability to accurately describe the

spiral aftereffect. Second, to assess how the ability to respond correctly to a test for bigger and smaller and the SAET changes as a function of age.

Method

Subjects

Sixty subjects (20 per group) were selected from the populations of local nursery schools, day care centers, and public schools in the Burlington, North Carolina, area. None had significant medical abnormalities or known visual defects or acuity problems. Each child was selected on the criterion that his IQ as indicated on the Peabody Picture Vocabulary Test fell in the normal limits of intelligence (90-109). The mean IQ scores for the 3, 5 and 7 year old groups were 98.85, 98.05, and 96.7, which were not found to vary significantly.

Apparatus

A black and white Archimedes arithmetic spiral (8 turns, thick) with a 9-inch diameter served as the stimulus disc. As a mounting for the spiral, an electric turntable was modified to operate forward and backward at 78 r.p.m. and was equipped to provide instant stopping. The spiral apparatus was mounted on a board and stand. The background mounting board of the spiral stimulus disc was painted flat black so as to provide contrast. Built into the frame was a second movable white screen for the purpose of concealing the stimulus disc. Movement of this concealing screen was provided by a cord attached to both ends of the screen and manipulated by an operator seated behind the stand. This operator also served to start, stop, and reverse the rotation of the stimulus disc. All other sections of the stand were painted flat black. See Figure 1.

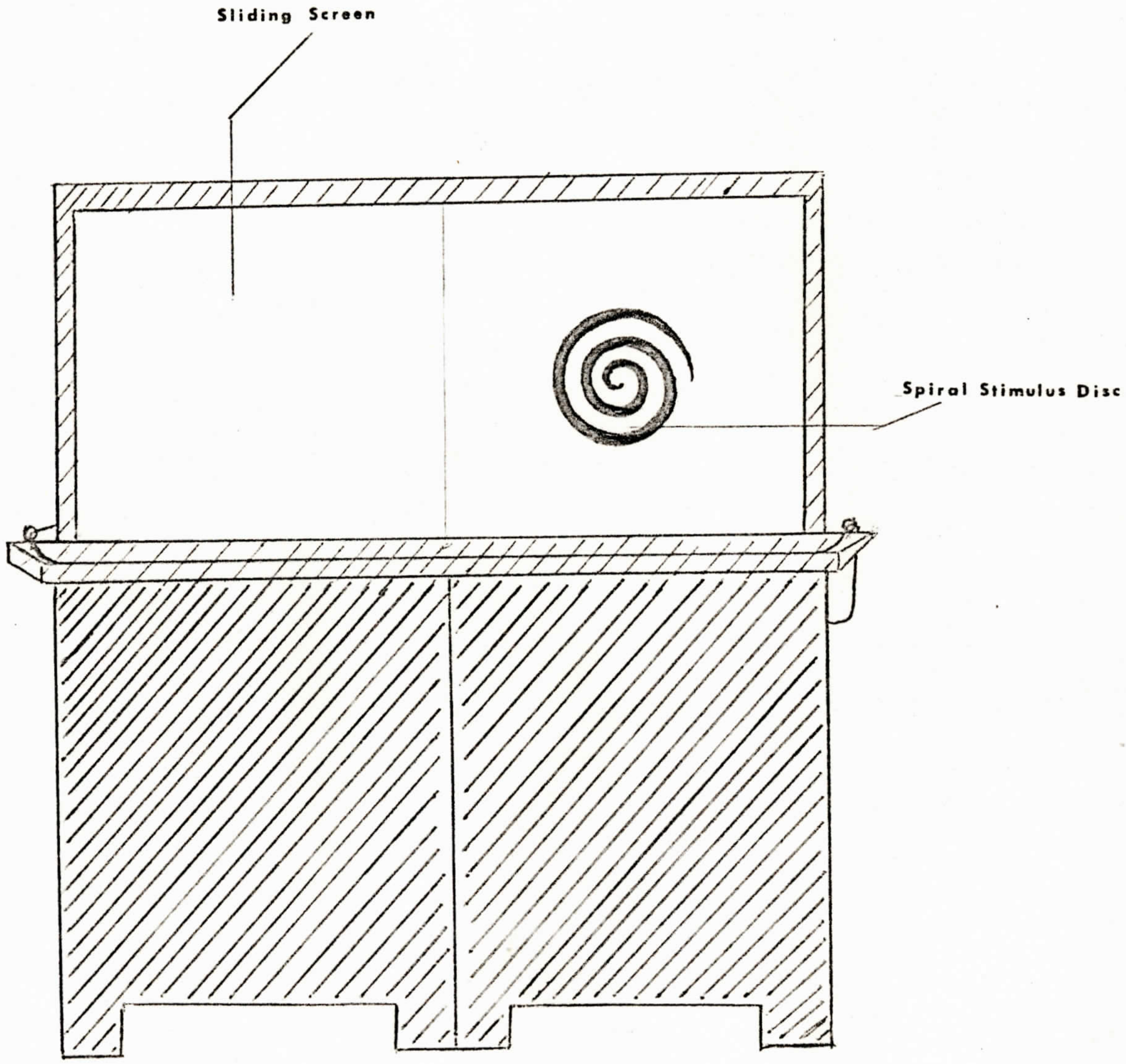

Figure 1

Subjects view of SAET apparatus

A photographic slide was prepared to replicate the spiral and served to black out all but the spiral itself. This slide was then projected onto the concealing screen in the same dimension and location as the stimulus spiral disc which was concealed behind the screen by a Kodak Ektagraphic slide projector. The projector was equipped with a zoom lens attachment which permitted expansion and reduction of the stationary disc projection in the same line of sight as the stimulus spiral disc. This was the apparatus used in connection with the Bigger-Smaller Test portion of the experiment.

Another slide was prepared with a round opening which would block out the surrounding area but allow the projected light to focus exactly on the size and location of the stimulus spiral disc. This was the apparatus used during the SAET portion of the experiment.

The combination movable concealing screen and fixed stimulus mounting screen made it possible, without distracting changes of the equipment, to change from the Bigger-Smaller Test to the SAET by simply changing slides in the projector.

The child was seated perpendicular to the line of sight at a distance of 10 feet from the screen. The projector was located at a distance of 5 feet from the screen and slightly to the left of the line of sight in order that the child's view of the screen would not be obstructed.

Procedure

Upon entering the testing room, the child was seated 10 feet from the screen (with the stimuli concealed), and several minutes were spent by the examiner in establishing rapport with the child. The Bigger-Smaller Test then began as the child viewed the projected spiral on the screen. The examiner then pointed to the spiral picture and said, "See this design? It's called a spiral. See how it goes round and round? Can you say spiral? I want you to watch this spiral and tell me if the spiral is getting bigger or if the spiral is getting smaller, or if the spiral is staying just the same size." (All verbal instructions in this experimental situation, as well as the SAET portion, are the same as those used by Gollin and Bradford (1958).) The directions, "Remember, each time, tell me if the spiral is getting bigger, or if it is getting smaller, or if it is staying just the same size," were repeated. Each child was given four trials in the order of bigger-smaller-smaller-bigger (ABBA) or smaller-bigger-bigger-smaller (BAAB). For example, starting at the normal 9-inch diameter projection, the picture was zoomed to 14 inches, reduced to 10 inches, further reduced to 6 inches, and returned to the original 9-inch projection (ABBA). After each size change, the instructions, "Tell me about the spiral now," were given. Any response which indicated an understanding of the correct change was accepted as a correct response (littler, giant, tiny, or showing change in size by gesturing, hand motions, etc.). Each response was recorded as correct or incorrect.

The concealing screen was moved to reveal the mounted stimulus disc which was framed in the light of the projector. The SAET began as the child was given the following instructions: "Now I want you to look at

this spiral. See this point right here (pointing at the center)? Look right at this point until I tell you to stop. Don't take your eyes off the point." The spiral was set into motion and within 15 seconds of the beginning of the rotation period each child was asked, "What does this spiral seem to be doing now?" (This was the only statement which was not verbalized in the Gollin and Bradford (1958) situation.) Continual encouragement was given to keep the child looking at the center. At the end of each 30-second fixation period the rotation was stopped. The instruction, "Tell me about the spiral now," was given.

Results

In order to test the hypothesis that the ability to verbalize changes in size is related to the ability to describe the spiral aftereffect (the "faulty communication hypothesis"), the Pearson Product Moment Correlation between these two measures was calculated (r=+.433, p<.01).

A one way analysis of variance was conducted in comparing the performance of the three age groups on the Bigger-Smaller Test. As shown in Table 1, significant differences were found between the three groups in their ability to describe size changes in a stimulus (F=48.84, df=2/59, p < .01). A Duncan's Multiple Range Test indicated that the three year olds' response rate was significantly different from both the five and seven year olds' but that the difference in responding between five and seven year olds was not significant (See Table 2.).

Insert Tables 1 and 2 about here

A second analysis of variance was run to compare the performance of the three age groups on the SAET, and the results were consistent with the analysis of the Bigger-Smaller Test data. Although the group main effect was significant (F-7.597, df=2/59, $p<.01$), a test of simple effects revealed the difference between the three year olds and the five and/or seven year olds to be significant, but the SAET performance of the five and seven year olds did not differ significantly (See Tables 3 and 4).

Insert Tables 3 and 4
about here

The regression of the SAET scores across four trials for the three age groups employed revealed asymptotic performance for the older groups but not for the three year old subjects, and no interaction of trials x group x trials was noted.

In order to compare the results of the present study with those of Gollin and Bradford (1957), the percentage of subjects who met the criterion of three out of four correct responses on each test was calculated. On the Bigger-Smaller Test only 25% of the three year old subjects reached criterion, while 100% of both the five and seven year old subjects attained the prescribed level of performance. Five percent of the three year olds met a criterion of 75% correct on the SAET, whereas 45% and 35% of the five and seven year olds, respectively, were able to achieve it (See Figure 2).

Insert Figure 2
about here

Figure 2 describes the difference in response rates of the groups. The number of children in each group that gave at least one correct response on the SAET, as compared with the number achieving passing criterion (3 or 4

responses), is illustrated. The drop in seven year olds achieving criterion is obvious here (See Table 5 and Figure 3).

Insert Table 5 and Figure 3
about here

Discussion

Before any test can be used meaningfully, it should be standardized on some "normal" group. Unfortunately, little research dealing with the SAET has attempted to collect data specifically from "normal" subjects. The early clinical SAET studies focused attention on the "abnormal" group--the organics and psychotics--and compared that group's responses with a "normal" control group (Berger, et al, 1958; Blau & Schaffer, 1960; Freeman & Josey, 1949; Gallese, 1956; Mayer & Coons, 1960; Page, et al, 1957; Price & Deabler, 1953; Spivack & Levine, 1957; Standlee, 1953). With the exception of the Blau and Schaffer (1960) study which determined normality on the basis of EEG profile, no other researchers selected their control group specifically on the basis of an objective criterion. Normal groups were usually selected from uninstitutionalized populations, and it was assumed, primarily upon this basis, that no organic or nonorganic problem existed. Later communication studies of SAET, which intended to investigate normal responses in children, tended to use children with above average intelligence (Gollin & Bradford, 1957; Harding, et al, 1957). If it could be determined how well normal children of different ages can accurately communicate the concepts of bigger and smaller, it might indicate how reliable the SAET could be with those populations. In an attempt to assure that this study was made using a normal group, all children who participated in this experiment achieved verbal IQs on a standardized test which fell in the average range and none had significant medical abnormalities or known visual defects or acuity problems.

Young children were at first likened to brain injured adults because of their inability to report the spiral aftereffect, and Harding, Glassman and Helz (1957) interpreted this as neurological immaturity. Gollin and Bradford (1957) rejected this explanation, opting instead for a faulty communication hypothesis based on the assumption that young children do not have the verbal concept skills required to accurately describe the after-image phenomenon. The correlation of +.43 between the Bigger-Smaller Test and the SAET reported here was significant and supports Gollin and Bradford's hypothesis that the child's proficiency at describing size changes in stimuli might have some bearing on the ability to describe the illusory change in the SAET. The evidence from both the Bigger-Smaller Test and the SAET indicated that less than 50% of three year olds with average intelligence are able to distinguish and describe "bigger-smaller" or accurately describe the spiral aftereffect. These results are predictable, since a significant correlation exists between the Bigger-Smaller Test and the SAET, and one would not expect a child who is lacking the necessary verbal and concept formation skills under tangible conditions to be able to describe an illusion which requires the same skills. It is particularly noteworthy that the one three year old who met the Gollin and Bradford (1957) criterion of three correct responses on the SAET did not pass the criterion on the Bigger-Smaller Test.

Mataratsos (1973) suggested that children under age six cannot be expected to comprehend or use accurately the concept of bigger and smaller,

but the present study indicated that by age five these skills had been developed. An ability to distinguish and verbalize bigger-smaller does not guarantee, however, that a child will verbalize the spiral after-effect. While 100% of the five and seven year olds achieved the success criterion on the Bigger-Smaller Test, less than 50% of each group met the criterion for the SAET. In the Gollin and Bradford study, 17 of the 23 children in the CA range 3.16 through 5.25 years (MA range 3.5 through 7.3 years) met the criterion for the SAET. The study also reported that five of six children who failed the SAET were unable to respond correctly to the pretest situation (Bigger-Smaller). This was not the case in the present study, since all the five and seven year olds who failed the subsequent SAET had passed the pretest bigger-smaller criterion.

It appears, therefore, that some other variable rather than simply poor bigger-smaller verbal skills accounts for the failure to respond to the SAET. Mayer and Coons (1960) first suggested that failure to respond to the afterimage could be a reaction to the subject's anxiety and suspicion in the testing situation rather than a failure of perception. They, of course, examined hospitalized patients and manipulated the test instructions, either emphasizing that "ill" people saw the aftereffect or reassuring the normality of the afterimage. Bryan and Loder (1962) reported that fifth grade children's response rates could be influenced in the same manner. The drop in response rates from five to seven year olds in the present study might be explained by the seven year olds' increased suspicion or anxiety in an unfamiliar test situation.

Although more seven year olds responded correctly to at least one trial on the SAET, they did not report three out of four to achieve criterion (18 seven year olds as opposed to 15 five year olds). Seven year olds, as a rule, were more reluctant than either the three or five year olds to enter the testing situation, and some rather distinctive behavior differences were noted during the SAET. For example, when asked what the spiral was doing after rotation ended, many seven year olds paused for a moment and then simply said it had stopped. Some would blink their eyes several times or shake their heads before responding. Five year olds, on the other hand, appeared less suspicious of the testing situation, investigating the apparatus as they entered the room, and were less inhibited in their responses. For example, some laughed and clapped their hands when they indicated seeing the spiral aftereffect.

"Faulty communication" may explain the three year olds' failure to report the spiral aftereffect, but an inability to understand and verbalize bigger-smaller concepts cannot alone account for those failures by five and seven year olds. More than half of the five and seven year olds in this study who could communicate "bigger-smaller" accurately failed to consistently report the spiral aftereffect. Even a suspicion/anxiety explanation may, only in part, explain the children's low response rates. Perhaps some neurological maturation does need to occur before the after-image can be perceived. That was the hypothesis presented by Harding, Glassman and Helz (1956) as they speculated that children were neuro-logically similar to brain injured adults.

The term brain injured or brain damaged has long been a point of

controversy in SAET research. "Brain damaged" experimental groups have included subjects diagnosed as having such problems as memory impairment (Freeman & Josey, 1949), diffuse brain damage (Gallese, 1956), abnormal spinal fluids (Berger & Everson, 1958), and abnormal EEGs (Blau & Schaffer, 1960). It is equally unfortunate that the results of these studies are inconsistent with each other. Probably the most reassuring research results in defense of the SAET as a diagnostic tool come from the Blau and Schaffer study which found a positive correlation between abormal EEGs and failure to report the spiral aftereffect.

Minimal brain dysfunction, or MBD, is the current term generally used to describe children who display abnormal behaviors and/or do not seem to achieve the academic levels which would be expected of them. There is usually no distinct indication of brain damage such as could be measured by an abnormal skull x-ray or abnormal EEG. It is unlikely, therefore, that the validity of the SAET as a measure of MBD could be checked by an objective means such as an EEG recording. The results of the present study also question the practicality of the SAET as a diagnostic instrument for MBD children. With the low response rate to the afterimage by "normal" seven year olds, one should not expect to use the SAET with younger chil-dren who display subnormal abilities or abnormal behaviors.

In conclusion, it is indicated here that the SAET would not be a valid or reliable test instrument for children seven years and under. More research in the area may determine at what age and under what conditions the SAET can be utilized with confidence.

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Table 1

Analysis of Variance:

Bigger-Smaller Test

Source	SS	df	MS	F
Total	5.412	59		
Between Age Groups	3.149	2	1.709	48.84
Within Age Groups	1.994	57	.035	

*$p<.01$.

Table 2

Duncan's Multiple Range Test:

Bigger-Smaller Test

	R_3=.124
7 Year Olds - 3 Year Olds..............................	.512 *
	R_2=.118
7 Year Olds - 5 Year Olds..............................	.012
	R_2=.118
5 Year Olds - 3 Year Olds..............................	.500 *

Table 3

Analysis of Variance:

SAET

Source	SS	df	MS	F
Total	7.761	59		
Between Age Groups	1.633	2	.817	7.597
Within Age Groups	6.128	57	.107	

*$p < .01$.

Table 4

Duncan's Multiple Range Test

SAET

	R_3=.2181	
7 Year Olds - 3 Year Olds	.350	*
	R_2=.207	
7 Year Olds - 5 Year Olds	.000	
	R_2=.207	
5 Year Olds - 3 Year Olds	.350	*

Figure Caption

Figure 1. Mean response rate on Bigger-Smaller Test and SAET by age groups.

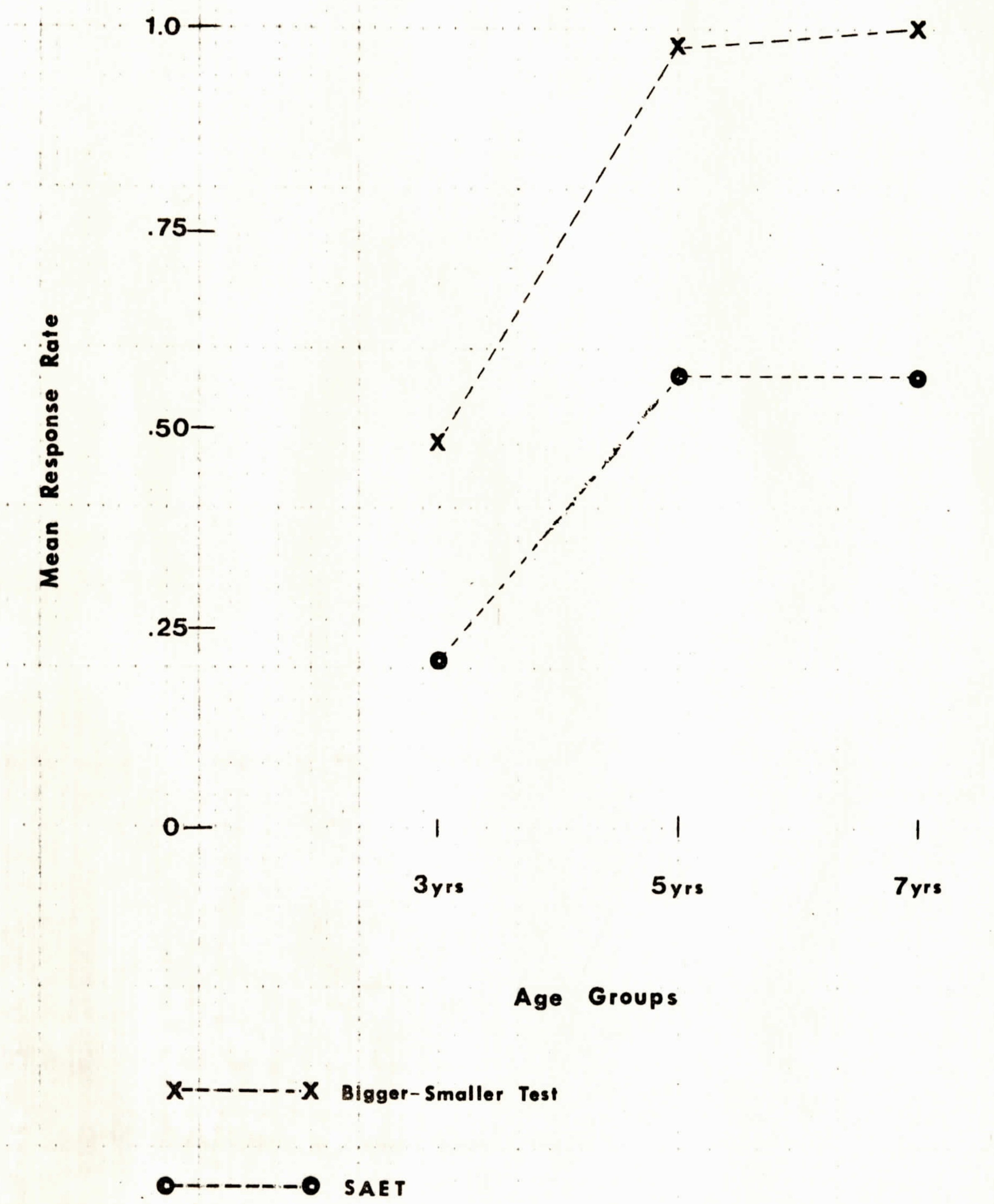


Table 5

Group Means and Standard Deviations

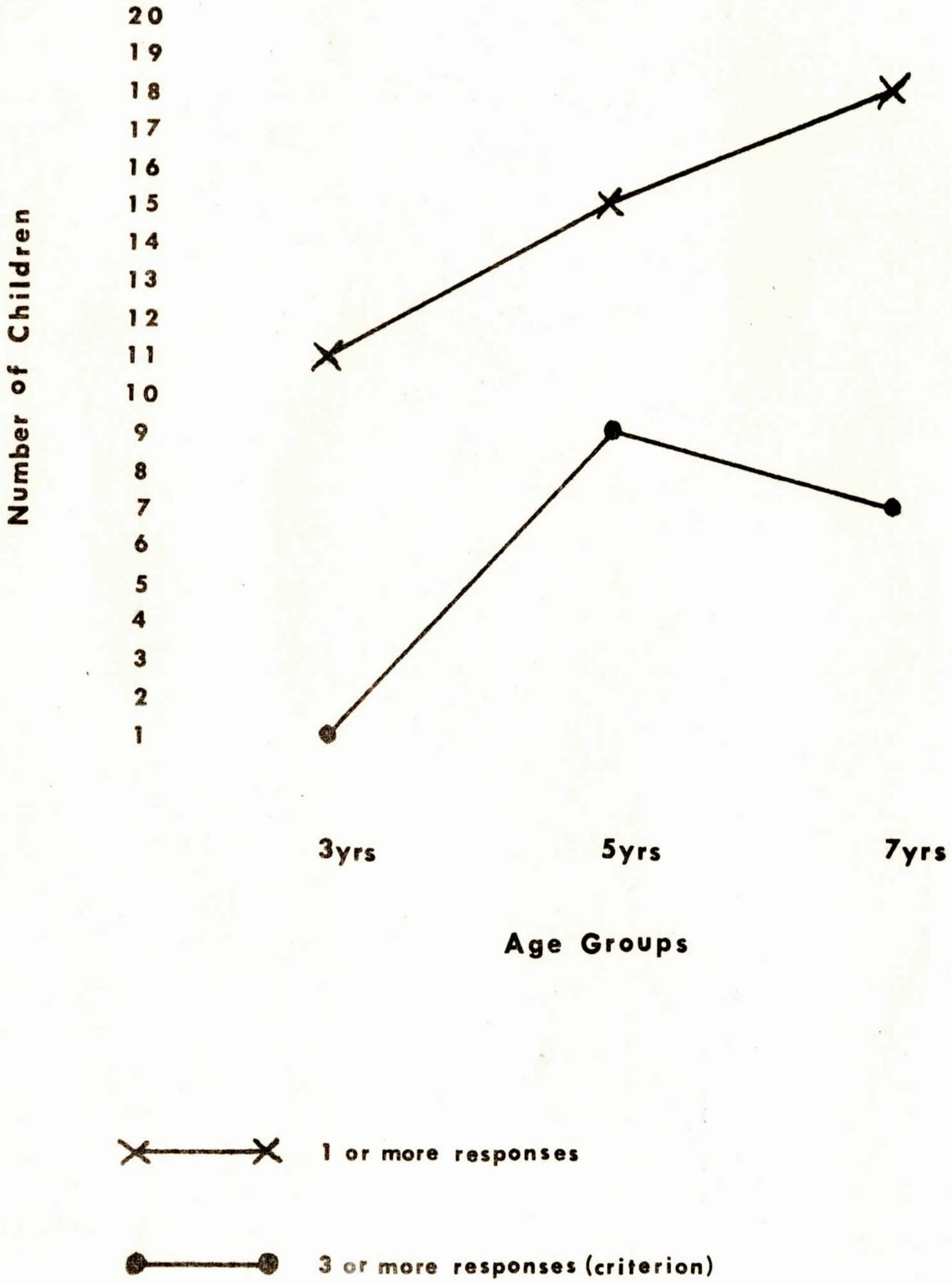
for Both Tests

TEST

		Bigger-Smaller		SAET	
		$\bar{X}$	SD	$\bar{X}$	SD
	3	.487	.31	.21	.22
AGE	5	.987	.003	.56	.16
	7	1.00	.00	.56	.01
		.825	.289	.443	.156

Figure Caption

Figure 2. Number of children in each group making at least one correct response on the SAET, and number of children in each group achieving criterion.



Number of Children
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
3yrs
5yrs
7yrs
Age Groups
1 or more responses
3 or more responses (criterion)