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EFFECTS OF TWO PARAMETERS OF VISUAL REINFORCEMENT ON THE FREE-OPERANT BEHAVIOR OF NORMAL AND AUTISTIC CHILDREN

by

JONAS WAIZER

A dissertation submitted to the Graduate Faculty
in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy,
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date

Florence L. Denmark
Executive Officer

6/20/74
date

Doreen Berman

6/16/74
date

Joseph Church
Joseph Church

The City University of New York

ABSTRACT

EFFECTS OF TWO PARAMETERS OF VISUAL REINFORCEMENT ON THE FREE-OPERANT BEHAVIOR OF NORMAL AND AUTISTIC CHILDREN

by

Jonas Waizer

Adviser: Professor William F. Oakes

Two independent studies relating parameters of visual reinforcement to free-operant behavior were conducted with six normal and six autistic boys, 3 yrs., 7 mos. - 7 yrs., 4 mos. of age. Subjects were seated within an enclosed chamber. A 10 second view through a window of each of three conditions of stimulus complexity (an electric train set with the train moving, stationary, or removed) was made contingent upon contact with a non-moving bar. The number of reinforcements obtained was similar for both groups and was a monotonic function of complexity. Normal subjects, however, emitted significantly more non-reinforced extraneous responses (while the window was open). In a second study, each of five light intensities (.01 - 100 ftL) was presented as a 3 second reinforcer. Analysis of response patterns of normal children indicated an inverted U-shaped relationship between intensity and rate. Autistic children were most responsive to the brightest intensity. The conflicting observations reported in the literature of autistic children as withdrawn from or hyperreactive to visual stimulation, and theories of etiology of autism, are discussed.

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INTRODUCTION

Research of the mid-50's and early 60's yielded a large literature suggesting that visual stimuli can act as reinforcers of behavior. These stimuli satisfied the operational definition of reinforcers for learning, i.e., response-contingent stimuli which produce relatively permanent behavioral changes (Kish, 1966). Two parameters of visual stimuli of interest in the present study, complexity and intensity, were found to influence sensory-reinforced behavior.

Studies of free-operant behavior in animals have provided evidence for a direct relationship between stimulus complexity and behavior, and for a curvilinear relationship between light intensity and response rate. Studies of these variables in humans have been conducted primarily with infants and new-borns, and have focused on subject preferences in two-choice tasks. This paradigm limits propositions of functional relationships between stimulus parameters and behavior to statements of relative preferences. Parametric studies of free-operant response rates, where access to visual stimulation is contingent upon the subject's behavior, allow for a more precise specification of the functional role of stimuli (Caron, 1967). Such techniques permit determination of the relative degree of control exerted by stimuli of different values. These procedures permit the general shape of the functional relationship between response rate and stimulus intensity or complexity to be determined.

Autistic children have been reported in the literature to exhibit abnormal responses to sensory stimulation (O'Gorman, 1967). It is the purpose of this investigation to explore the influence of complexity and intensity of visual stimuli on the free-operant response rates of normal and autistic children.

Stimulus complexity

Kish (1966) reviewed studies of visual complexity as a parameter of sensory-reinforcement and concluded that the greater the stimulus pattern complexity, the greater its reinforcing value. Similarly, Berlyne (1966) concluded, "more vigorous and prolonged exploration will generally be attracted by objects that offer more varied or irregular stimulation" (p. 27). Both investigators based their conclusions on the results of studies conducted with infants and employing two-choice, preference designs (Berlyne, 1958; Brennan, Ames & Moore, 1966; Spears, 1964; and Thomas, 1965), as well as on the results of animal studies.

A number of investigators have studied the free-operant response rates of infants less than one year of age for visual reinforcers (Caron, 1967; Levison & Levison, 1967; Lipsitt, Pederson, & De Lucia, 1966; Simmons, 1964; and Siqueland & De Lucia, 1969). In one study, using in this case children up to five years of age, contact with a proximity switch was reinforced simultaneously with colors and music (Rheingold, Stanley, & Doyle, 1964). In contrast with the above choice task studies, however, these investigators did not study the relationship of parameters of the visual reinforcers to behavior. Only in one of these studies (Caron, 1967) was it suggested that the infant's rate of response was influenced by stimulus complexity in the free-operant situation, but this parameter was not systematically varied.

Data from free-operant studies using monkeys as subjects suggest a direct relationship between stimulus complexity and sensory-reinforced response rates. Butler (1954) required monkeys to panel-press in order to obtain views of stimulus situations differing in complexity. He found that response rates were directly related to the complexity of the stimulus views. The present study employs a modification of Butler's free-operant design similar to that previously used with monkeys by Waizer, Baumbach, Berman, & Berman (1972). Systematic data on the functional relationship between visual stimulus complexity and response rates in humans will thus be obtained.

Intensity of illumination change

Hershenson (1964) used a differential-fixation method with a two-choice task to demonstrate that infants are selectively responsive to brightness. The duration of fixation was greater with brighter stimuli. Siqueland and De Lucia (1969), in order to study free-operant response to brightness in newborns, utilized the technique of conjugate reinforcement, in which the intensity of the stimulus is controlled by the rate of performance of the pre-selected operant. Their technique involved control of illumination of the visual stimulus as a function of the infant's rate of sucking. The authors found brightness to be an effective reinforcer of free-operant sucking behavior in three-week-old infants, and subjects increased their sucking rates to increase the intensity of illumination. Although behavioral control by stimulus brightness was demonstrated, the shape of the functional relationship between brightness and response rate was not elucidated. The technique commonly used in animals to determine such a functional relationship involves comparison of response rates at different light intensities. No such study using human subjects has related stimulus brightness to free-operant response rates.

Contingent illumination change has been found to be an effective reinforcer for kittens (Symmes, 1963) and for monkeys (Waizer, Berman, Berman, & Waizer, unpublished). Evidence from rodents (Henderson, 1957; Barnes, Kish & Wood, 1959; and Lockard, 1962) and chicks (Meyer & Auguston, 1969) indicates that free-operant response rates were related to brightness in a curvilinear fashion. Stimuli at low levels of illumination were found to be relatively weak reinforcers, while very high degrees of brightness were aversive. There is thus an optimal range of illumination for sensory reinforcement defined by the occurrence of maximal response rates at these intensities, with a reduction in the reinforcing potential for stimuli at intensities outside that range (Berlyne, 1960). The free-operant design employed in the present study permits determination of the nature of the functional relationship between intensity of light change and response rates in human subjects.

Visual reinforcers and autistic children

Contrasting theoretical explanations of the autistic child's abnormal behavior to sensory stimulation appear in the literature. An analysis of these theories in terms of the influence of external stimuli on the behavior of autistic children indicates conflicting points of view. There appear to be three suppositions concerning the autistic child's free-operant response for visual reinforcers, each with its proponents and with clinical and/or experimental support: Autistic children find external stimuli either (1) more aversive, (2) of fluctuating attraction and aversion, or (3) more attractive than do normal children. These suppositions will be considered more fully below.

Supposition I: Autistic children will exhibit decreased response rate to visual reinforcers, compared to normal children.

Moore and Shiek (1971) presented a highly original theory of autism based on the assumption that autistic children come from intelligent parents with a resulting acceleration of normal developmental processes. They suggested that autism resulted from premature, prenatal "imprinting" on low levels of in-utero stimulation, while normal children "imprint" postnatally on normal (higher) levels of stimulation. The authors suggest:

> the level of stimulus variation the organism experiences early in its development is an important determinant of the optimal cortical arousal for adaptive behavior. Because there is little stimulation prenatally, the (autistic) child's optimal cortical arousal is low. After birth, normal levels of en-

> vironmental stimulation constitute
> an unaccustomed overload with con-
> sequent cortical hyperarousal (p. 455).

Moore and Shiek (1971) found support for their contention in the work of Hutt and Hutt (1969), who reported that the EEG records of autistic children showed irregular low-level activity indicative of chronic cortical hyperarousal. Furthermore, exploration of new objects began only after repeated exposure and was accompanied by an EEG change characterized by a medium/high voltage of well established rhythmicity, indicative of a low level of arousal. Because of the chronic high cortical arousal, Moore and Shiek believe that normal levels of sensory stimulation are overwhelming and, therefore, aversive for the autistic child.

Many observers of the autistic child's response to environmental stimuli interpret such behavior as defensive or withdrawn. Supporters of such a view, including many clinicians and psychoanalysts, report that the primary response of the autistic child to external sources of stimulation is to withdraw from them. Fraknoi and Ruttenberg (1971) believe that insufficient maternal tactile stimulation relative to threshold in the infant results in the development of an autistic reaction to external stimuli. They believe that children subjected to such understimulation fail to respond positively later in life to external stimulation and withdraw from stimuli. Mahler (1963) and Bettelheim (1967) suggest that autism results from a history of an overbearing mother who anticipated the child's every need and removed from him the opportunity to explore, differentiate, and experiment. As a result, the child has "withdrawn interest" from exploration and fails to respond to environmental stimuli. Alternately, according to Bettelheim (1967), an indifferent mother, careless of the child's basic needs, will produce an autistic reaction to the "hostile" environment, so that the child withdraws from environmental stimuli. Spitz (1964) maintains that the autistic child suffers from an "emotional overload and psychotoxic response" to the damaging effects of excessive and noxious stimulation. The result is a defensive withdrawal from external stimuli by the autistic child.

Bergman and Escalona (1949) have suggested that autistic children suffer perceptual distortion and sensitivities resulting from an inadequate stimulus barrier. They imply that because normal levels of sensory stimulation appear as overwhelming to the autistic child, his reaction is to withdraw. Goldfarb (1964) concluded that autistic children avoid the use of the distance receptors of vision and hearing, preferring the proximal receptors of touch, taste, and smell.

The position common to all of these theorists is that autistic children find external stimulation noxious and overwhelming and withdraw from it. If such is the case, then it would suggest that within a free-operant conditioning situation, where delivery of visual reinforcers is contingent upon the subject's behavior, the response rates of autistic children for such sensory reinforcers should be lower than those of normal children.

Supposition II: Autistic children will exhibit greater variability in their response rates for visual stimuli than will normal children.

Ornitz and Ritvo (1968) found the autistic child's response to stimulation to be "paradoxical." They stated, "Heightened awareness, hyperirritability, and obliviousness to external stimulation may all occur in the same child. All modalities of sensation may be involved." The authors described what they considered to be the paradoxical nature of the autistic child's behavior:

> Heightened Awareness of Sensory Stimuli...
>
> Visual. - Prolonged regarding of writhing movements of the hands and fingers, brief but intense staring, and scrutiny of visual detail are noted.
> Vestibular. - The children are unusually aware of things that spin and can become

> preoccupied with car wheels, phonograph records, or washing machines - far beyond the interest expressed transiently by normal children. (They also tend to whirl themselves or spend hours spinning objects.)
>
> Heightened Sensitivity and Irritability...
>
> Visual. - Change in illumination will occasionally precipitate fearful reactions. Vestibular. - A marked aversion to being tossed in the air or to ride in elevators occurs. Intense interest and pleasure in spinning objects may alternate with fearful, disturbed, and excited reactions to them (p. 82).

Aberrations of the auditory, tactile, olfactory, and gustatory senses occur as well.

Ornitz and Ritvo postulate that the physiological basis for autism rests with faulty homeostatic regulation of perceptual input within the vestibular system. They suggest that inadequate and uneven amplification of environmental stimuli result in perceptual inconstancy and the inability to organize stimuli, whether external or internal. They believe that the autistic child fails to maintain perceptual constancy, resulting in a random underloading or overloading of the CNS. He therefore seems to alternate between receiving too much or too little sensory input. They further claim that these states seem to alternate without relation to the environment. According to this view it would appear that the same stimulus may overload the CNS at one moment (and therefore be aversive) then underload it the next (and be either neutral or attractive). The child would thus fluctuate in his response, sometimes avoiding and sometimes responding to the same stimuli.

Such fluctuations in response to sensory stimuli should influence the response rates of autistic children in the free-operant paradigm discussed earlier. If the contention of Ornitz and Ritvo is correct, it would follow that, compared to normals, the response rates of autistic children should show greater variability as a result of the alternating CNS "overloading and underloading" to constant sensory stimuli.

> Supposition III: Autistic children will exhibit greater response rates for visual reinforcers than will normals.

Ornitz and Ritvo (1968) observed that autistic children often exhibit heightened attraction towards sensory stimuli, although they believe this to alternate with fearfulness towards the same stimuli. Many theorists, including Fraknoi and Ruttenberg (1971), have suggested that the stereotyped motor activities of such children are actually attempts at self-stimulation. In fact, the high level of such "self-stimulating" behavior suggests an elevated need for sensory input in autistic children.

In an effort to investigate whether the behavior of autistic children could be interpreted as stimulus seeking, Ornitz and Brown (1970) examined the effect of restriction of visual input on their stereotyped activity. They felt that the children might compensate for the restricted visual input with increased stereotyped activity (self-stimulating behavior). They found an increase in such activities in one autistic child and a decrease in another. The results were thus inconclusive.

Early deprivation and autism

Freedman (1968) found autistic behavior in congenitally blind or deaf infants for whom parents failed to provide compensatory stimulation. He referred to the occurrence of autism in maternally- (and stimulation-) deprived institutionalized children. Other theorists support the contention that the etiology of autism is based on early deprivation of direct sensory input (Moore & Shiek, 1971). Still further theories of autism are based on assumptions of an organic dysfunction affecting reception of sensory input resulting from early oxygen deprivation (Rimland, 1964), or of a deprivation of maternal tactile stimulation and contact (Bettelheim, 1967; Fraknoi and Ruttenberg, 1971; Kanner, 1949).

Studies of reactivity to stimulation in animals following early deprivation

A survey of the literature reveals that few developmental studies of reactivity to sensory reinforcers in animals deprived of oxygen, sensory stimulation, or of biological mothers have been conducted. Before reviewing this literature, certain qualifications must be imposed. Organisms removed from the mother are incidentally exposed to limited conditions of visual, auditory, thermal, vestibular, tactual, kinesthetic, and olfactory stimulation and will be considered separately from animals deprived of specific modalities of sensory stimulation (e.g., light or sound). More important, the present review will consider only those studies concerned with sensory-reinforced behavior, rather than with measures of learning ability or performance under conditions of stress. Finally, employment of visual reinforcers has frequently been confounded with auditory, tactual, and kinesthetic stimuli, especially when the operant response requires working a movable manipulandum. Particular attention will be paid to the reinforcers used and to the responses studied.

Studies of sensory reinforcers in sensory deprived animals:

Levison and Levison (1971) reared seven infant rhesus monkeys from birth in restraining chairs, restricting their motor experience. Vision was also restricted for five of the subjects by enclosing their heads in translucent chambers. The animals were later tested for bar-pressing rates with projected slides of varying complexity. The authors suggested that the two visually-unrestricted monkeys were more responsive to visual stimuli of greater complexity than were the visually restricted monkeys, although this difference was not statistically significant.

The difficulties with this study are numerous. The data for the small groups of restricted and unrestricted subjects overlap at many points. The visually-deprived monkeys exhibited considerably greater gross motor retardation than the visually-unrestricted subjects, although all subjects were similarly motor-restricted (Levison, Levison & Norton, 1970). Finally, the monkeys were isolated from their mothers, as well as being motorically and visually-deprived. The data are, therefore, difficult to interpret and inconclusive.

Lockard (1963) compared the response rates for light reinforcement of albino rats reared under different luminance conditions. The main difference was found between rats reared in total darkness and those reared under alternating periods of light and dark, with the dark reared rats significantly less responsive to the progression of test luminances. This experiment, however, was confounded by the inclusion of a moving lever as the response manipulandum. As suggested earlier, the possibility that self-produced kinesthetic feedback could act as a reinforcer for lever-pressing must be ruled out before conclusions can be drawn concerning other sensory-reinforcers.

Wendt, Lindsley, Adey and Fox (1963) isolated two newborn monkeys from their mothers and reared them in total darkness (except for one hour daily of unpatterned light to prevent retinal degeneration). Two control monkeys, reared with their mothers, were kept in similar dark isolation only during the testing period. Both groups were compared on a paradigm involving light contingent bar pressing, with 1 second of unpatterned light as the reinforcer. The two deprived animals performed at means of 2300 and 3400 responses per hour; the controls 100 and 500 responses per hour. When the reinforcement contingency was terminated all subjects rapidly extinguished, thereby ruling out the lever as a source of reinforcement. The authors concluded that, "The (experimental) animals showed apparently insatiable responding, at rates that were extremely high as compared with rates for normally reared controls." (p. 336). The evidence supports the hypothesis that early rearing under deprived conditions of light results in increased performance for such stimulation later in life.

A confounding variable appears in the study above, in that only the visually deprived monkeys were removed from their mothers after birth. The authors acknowledge that, "Since the experimental design prevented assessment of factors such as isolation from other animals and reduced auditory stimulus, we cannot be certain that light deprivation was the essential factor in producing the high rates of self-maintained visual stimulation, although this seems highly likely." (p. 337). (It will later become clear that maternal deprivation has the opposite effect on sensory reinforced behavior.)

Berkowitz (1970) also used a design controlled for kinesthetic feedback. He reared groups of rats under different levels of auditory and visual stimulation. Throughout the procedure all rats were reared with their mothers and litter mates. He found that rats raised under low levels of stimulation engaged in greater stimulus-seeking behavior than those raised with higher levels, and that the most deprived group engaged in significantly more stimulus-seeking activity than did the least deprived group. He reported this monotonic relationship for both auditory and visual sensory modalities. This lends further support to the suggestion that if sensory deprivation is a primary cause of autism, such children should respond at higher rates for visual reinforcers than should normals.

In summary, Levison and Levison (1971) failed to find a significant difference between visually restricted and unrestricted monkeys, but their study suffered from a weak experimental design. Lockard (1963) found dark reared rats less responsive than controls when tested in a dark chamber for light-contingent-bar-press. While this evidence cannot be ruled out, he did not control for movement produced reinforcers during lever-pressing. In two studies, where comparison of operant levels and extinction rates permit us to disregard movement produced self-stimulation, Berkowitz (1970) and Wendt, et al. (1963) found that early sensory deprivation resulted in increased stimulus-seeking activity for that sensory modality. Should infantile autism be a product of early restriction of visual input, as Freedman (1968), Moore and Shiek (1971) and others have suggested, then autistic children should prove more responsive than normal children to visual reinforcers (Supposition III).

Studies of sensory reinforcers in oxygen deprived animals:

Rimland (1964) considered the possible connection between respiratory complications at birth and the later development of autism. A number of studies of the effect of neonatal asphyxiation have been conducted with rhesus monkeys. These animals were subjected to acute asphyxiation of limited duration during delivery by Caesarean section. In a series of behavioral tests and observations of home cage activity (Berman, Waizer & Dalton, 1971), neonatally asphyxiated, partial isolation-reared monkeys were found to be relatively non-responsive during infancy, and highly emotional at 1-2 years of age. During this period of pre-adolescence they exhibited rocking, sucking, huddling, jumping, cage-circling, and self-mutilating behavior. Similarly reared age-matched controls showed considerably less abnormal activity. Asphyxiated animals had difficulty habituating to the testing environment and were more difficult to train than non-asphyxiated controls. The authors were struck by the similarity of the behavior patterns observed in these animals to descriptions of behavior patterns in autistic children.

Responsivity to visual stimulation (a view through a window in an enclosed testing box) was then studied in four asphyxiated rhesus monkeys (Waizer, et al., 1972). They exhibited significantly higher rates of response for complex visual reinforcers than did controls. In addition, their response rates decreased for views of decreasing complexity and returned to high levels as complexity was reinstated. In a second study (Waizer, et al., unpublished), such animals also bar-pressed at significantly higher rates than did controls for 2-sec. flashes of light. Since visual structures and visual perception were not found to be affected by the asphyxiation procedure (Faro & Windle, 1969), it was suggested that changes in motivation or regulation of sensory input resulted from the early oxygen deprivation. Damage to brainstem areas involving the reticular system following neonatal asphyxiation (Faro & Windle, 1969) could have affected reactivity to stimulation of these monkeys in much the same way as was suggested by Rimland (1964). The oxygen deprivation model predicts that autistic children should exhibit greater stimulus-seeking activity for stimuli of greater complexity, compared to normal children (Supposition III).

Studies of sensory reinforcers in maternally deprived animals:

Studies of the effects of maternal deprivation on sensory-reinforced behavior seem to have been restricted to primates. As discussed earlier, maternal deprivation involves reduced visual, auditory, vestibular, olfactory, and kinesthetic stimulation, but does not involve the total restriction of any of these.

Harlow (1958) reared three groups of infant monkeys under different conditions of isolation: (1) with both wire and cloth surrogate mothers, (2) with a single cloth mother, and (3) without any mother surrogate. At 40 to 50 days of age the animals were tested in a Butler box (similar to the viewbox used in this study). A lever press opened a small window, affording the subject a view of another chamber containing the presentation stimuli. Examination of the data suggests that the monkeys reared without any surrogate mothers were most responsive to those stimuli of greater complexity, while all monkeys were equally unresponsive to a view of an empty chamber. Unfortunately, this study is inconclusive in that no comparison to maternally reared monkeys was made on this test. Comparisons were made only among groups reared under qualitatively different conditions of isolation. Unfortunately for our purposes, the investigators were interested in studying other issues and drew no specific conclusions regarding the effects of sensory-reinforcers. Furthermore, the authors did not provide statistical analyses or sufficient data to permit readers to draw their own conclusions.

In contrast to the preceding experiment, Green and Gordon (1964) conducted a controlled study in which five individually reared maternally-deprived monkeys were compared to four maternally-reared monkeys. Animals were tested over the first eight months of life in a two-choice Butler box, where presentation of competing stimulus views was used to study the animals' preferences under free-operant conditions. The maternally-reared monkeys were found to be many times more responsive than the isolation-reared monkeys to all stimulus views. This finding fails to confirm the suggestions made in the preceding study by Harlow (1958).

Maternal deprivation differs from visual or auditory deprivation in that the former involves more diffuse sensory restriction and includes vestibular and tactile sensory modalities. The two also differ with respect to their effects on visually reinforced behavior. While visual restriction results in increased reactivity to visual reinforcers, maternal deprivation seems to produce the opposite effect (disregarding Harlow's results as uninterpretable on this issue). Thus, if autism results from the more diffuse deprivation of maternal attention or from isolation (Bettelheim, 1967; Fraknoi & Ruttenberg, 1971; Kanner, 1949), then autistic children should be less responsive to visual reinforcers than their normal controls (Supposition I).

Studies of reactivity to sensory stimulation in autistic children:

Hewett (1965) found that food and candy failed to act as reinforcers in controlling the behavior of a 4-1/2 year old autistic boy because he was highly variable in his response towards food. In order to obtain a potent reinforcer for the child, Hewett constructed an enclosed room in which light, music, and rides on a revolving chair could serve as positive reinforcers, with darkness and isolation serving as negative reinforcers. He found these effective with this subject as well as with four other autistic boys. Hewett's immediate interest as a behavioral engineer was to find a reinforcer with which to condition imitation of social and verbal behavior, rather than to compare the effectiveness of sensory stimulation in this population with normal children.

Wolf, Risely & Mees (1964) attempted to modify the behavior of a 3-1/2 year old boy variously diagnosed as psychotic, autistic, or retarded. Isolation in a bare room was made contingent upon undesired behaviors while opening the door was contingent upon the absence of tantrums in the isolation room. The result was the successful suppression of tantrums, self-destructive behavior, and refusal to stay in bed or to wear glasses. The authors attributed the success of treatment to the punishment of undesired behavior through the removal of social reinforcers. An alternate interpretation is that the experimenters were punishing inappropriate behavior by isolation in a small, dimly lit and silent room - an aversive reinforcer. The opening of the door (light) upon active suppression of tantrums might have been a potent positive reinforcer for the child.

Fineman (1968) was able to increase rate of "verbalization" of a 4-1/2 year old autistic girl by using a color-organ, sensitive to pitch and volume of sounds. He found the visual-color feedback of the girl's vocalizations into a microphone to be reinforcing. Rate of verbalization more than doubled over the operant rate when feedback was provided, although clarity of speech deteriorated.

Several studies have compared the reactivity to stimulation of autistic children to other populations. Metz (1967) compared autistic to schizophrenic and normal groups of children for auditory preferences on lever-controlled volume of recorded sound and music. He found that autistic children maintained more intense levels of auditory stimulation than either schizophrenic or control children. Schizophrenics, on the other hand, were more variable in their preferences than either of the other groups. However, as Hingtgen & Bryson (1972) indicate in their review of that study, "since a light was always present in the position of highest volume, the autistics may have been responding to the light rather than the auditory intensities." This criticism, however, does not change the conclusion that the three groups showed different reactivity to external stimuli, whether auditory or visual.

Hermelin and O'Connor (1964) compared the preferences of psychotic children with autistic symptoms to those of retarded children for light, sound and tactile stimulation. Subjects were given candy for pointing to the direction of either of a pair of simultaneously presented signals, regardless of choice. Position of signals was randomized to control for position preferences. With simultaneous presentation of light and sound, both groups showed a preference for the light. When the intensities of the signals were varied, both groups preferred the sound when its intensity was high and that of light was low. Psychotic children exhibited a more evenly distributed response pattern, however, and were considered to have a stronger position dominance. In other choice tests light was found dominant over touch for both groups. The two groups differed when sound and touch were simultaneously presented, with psychotics choosing touch and retardates preferring sound. These investigators were not comparing the children's sensitivities within any one stimulus modality as measured by free-operant response rates, as is done in the present study. Rather, stimuli were presented in discrete two-choice trials. In Hermelin and O'Connor's study simultaneous presentation of stimuli may result in interaction, as the stimuli may compete for attention and interfere with each other. In the present study only one stimulus will be assessed at a time.

In summary, studies which deal with the use of sensory stimuli as reinforcers have demonstrated the effectiveness of such stimuli in modifying the behavior of autistic children (Hewett, 1965). Results have suggested that autistic children prefer higher levels of auditory stimulation than normals (Metz, 1967). This evidence suggested that when exposure to sensory stimuli is under the autistic child's control, he emits responses consistently (rather than withdrawing). Hermelin and O'Connor (1964) compared the responsivity to stimulation of autistic-like psychotics with another population - retardates. In that study no differences were found between the two groups in their preferences for auditory vs. visual stimulation.

It is hoped that the paradox of the autistic child's response to stimulation can be clarified by comparing his response patterns to those of normals within a free-operant paradigm. The present concern is with the nature of the functional relationship between stimulus brightness, stimulus complexity, and behavior in normal and autistic children. In particular, an attempt will be made to elucidate whether sensory stimuli can be used to reinforce the free-operant responding of autistic children. If they are found to influence the response rates of autistic children, it will be of interest to determine whether the shape of the functional relationship between stimulus parameters and behavior is the same for autistic children as for normal children. It is one purpose of this study to determine whether the resulting configuration for the autistic child shifts in the vertical (overall increase or decrease in response rate) or horizontal (shift along stimulus dimension to right or left) direction, or has greater variability, relative to that of the normal child. That the response rates of autistic children should be greater than those of normals is suggested by the high levels of their self-produced stimulation, and by their preferences for higher intensities of auditory stimulation (Supposition III).

Summary

Two parameters of visual stimulation, complexity and intensity, have been found to influence sensory reinforced behavior. Kish (1966) concluded that the greater the stimulus pattern complexity, the greater its sensory reinforcing value.

Studies of the reinforcing properties of stimulus complexity involving human newborn or infant populations have dealt only with discrete trial and two-alternate choice tasks. In general, neonates and newborns exhibit preferences for more complex patterns and shapes. No study has been conducted which systematically compared free-operant response rates for stimuli of varying complexity. Evidence from studies conducted with monkeys, however, suggests a direct relationship between stimulus complexity and reinforced response rate.

A curvilinear relationship between stimulus intensity and effectiveness of light reinforcement has been found in rodents and in chicks. While infants demonstrate a preference for brightness, no parametric study of this variable as a sensory reinforcer for operant behavior has been made with children.

A concern of this study is to compare the effects of these two parameters of visual reinforcement on the behavior of autistic as compared with normal children. A central feature of the autistic population is the abnormal responses of these children to sensory stimulation (O'Gorman, 1967). Confusion exists in the literature as to the nature of the reactivity to visual stimuli which distinguishes autistic from normal children. An analysis of various descriptions of the autistic child's response to sensory stimuli permits the categorization of theories regarding such sensitivity into three groups, each leading to a different supposition and a different expectation for the present study: (1) Autistic children withdraw from normal levels of stimulation because such external stimuli are aversive. If this supposition is correct, then their response rates for visual reinforcers should be less than for normals. (2) Autistic children suffer from fluctuations in arousal - with alternating attraction and aversion towards the same stimulus. If this is correct, autistic children should exhibit greater variability in response rates to visual reinforcers than normal children. (3) Autism involves intensified stimulus-seeking activity. If this is correct, then when exposure to sensory stimulation falls under the autistic child's control (as in the free-operant situation) the response rates for such reinforcement should be greater than those of normal children. A review of studies conducted with autistic children yields greatest support for the last supposition.

STATEMENT OF HYPOTHESES

The hypotheses being investigated in the present study are the following:

1. There will be a monotonically increasing relationship between the complexity of a stimulus and its effectiveness as a reinforcer in a free-operant situation.

2. The relationship between the intensity of a light and its effectiveness as a reinforcer in a free-operant situation will be in the form of an inverted U-shaped function.

3. The response rates of autistic children will be higher than those for normal children for each of three conditions of stimulus complexity under hypothesis 1.

4. The absolute rate of response under hypothesis 2 will be higher for autistic children than for normal children, within the optimal range of intensity.

METHOD

Subjects

The subjects were six autistic and six normal boys. The six autistic boys were selected from an outpatient population attending the Pediatric Psychopharmacology Research Unit of Downstate Medical Center in Brooklyn, N.Y. This unit is housed at Kings County Psychiatric Hospital, where the present study was conducted.

Each child was diagnosed as psychotic based on Creak's (1961) Nine Point Screening Summary for Schizophrenic Children, and further diagnosed as autistic by a child psychiatrist. The Rimland (E-1) Diagnostic Checklist for Behavior Disturbed Children (Rimland, 1964) was completed by the mother of each child in order to confirm the psychiatrist's diagnosis of autism. The Rimland scores for each child are presented in Table 1.

The itemized characteristics of these six children, also presented in Table 1, demonstrate their conformity to the essential features of autism as summarized (O'Gorman, 1967):

a) Inability to relate to people from the beginning of life.

TABLE 1

Itemized Descriptions of Autistic Children Obtained from Parents and the Child Psychiatrist

	SUBJECTS					
	JR	DM	JB	WJ	SZ	RF
AGE (months)	88	80	79	67	46	41
RIMLAND (E-1): AUTISM MINUS CHILD.-SCHIZ. SCORE	18	10	22	12	18	26
EARLIEST AGE AT WHICH ILLNESS SUSPECTED (months)	30	12	18	24	7	18
SYMPTOMS						
1. Birth Complications	X[1]	X[2]				
2. Unresponsive as infant to being lifted	X			X	X	X
3. Suspected deafness in infancy		X				X
4. Fleeting eye contact	X	X		X	X	X
5. Follows strangers indiscriminantly	X	X	X	X		
6. Fails to play with other children	X	X	X			X
7. Abnormal affect: tantrums, laughing	X	X	X		X	X
8. Gross motor hyperactivity	X	X	X	X		X
9. Motor stereotypies: hand-waving, rocking	X	X	X	X	X	X
10. Incomplete toilet training		X	X	X	X	X
11. Short attention span, poor concentration	X	X		X	X	X
12. IQ untestable (retardation)	X	X	X	X	X	X
13. No communicative speech (sounds only)	X	X	X	X	X	X
14. Echolalia	X	X				X
15. Injures self: hits head, pulls hair	X	X		X		X
16. Scrutinizes hands		X	X		X	X
17. Examines objects with mouth and hands	X	X	X	X	X	X
18. Spins self and/or objects repeatedly		X	X	X	X	X
19. Unusual food fads: textures, hot-cold	X		X	X		
20. Unusual interest in music	X	X	X	X		X
21. Selectively deaf to loud sounds	X	X				X
22. Fails to blink at lights	X	X	X		X	

[1] Staining and breech delivery - no further complications

[2] Premature delivery - no further complications

b) Serious intellectual retardation but with evidence of good cognitive potential (i.e., not primary mental retardation).

c) Failure to acquire speech.

d) Abnormal response to one or more types of sensory stimulus.

e) Gross and sustained (stereotyped) exhibition of mannerisms or movements, including hyperkinesis.

f) Pathological resistance to change.

Items 15-22 of Table 1 underscore the bizarre responses exhibited by these children to auditory, tactile, vestibular, and visual stimuli.

Parents of five of the children reported observing the first indications of abnormalities within the first two years of life, satisfying Kanner's (1949) criterion for distinguishing autism from other psychoses. The parents of the sixth child reported the first occurrence of such abnormalities at 2-1/2 years. However, these parents separated because of this child's illness and it is suspected that they denied the child's problem until it could no longer be ignored. The six autistic boys ranged in age from three years, five months to seven years, four months (mean = 5 years, 7 months) at the start of testing. Three boys were black, three were white.

The six normal children were volunteers whose parents had answered an advertisement placed in a local newspaper. Since no black families answered this advertisement, all the normal children were white. They ranged in age from three years, five months to seven years, four months (mean = 5 years, 8 months).

All parents were informed of the nature and purpose of the research, and of their right to withdraw at any time. They were invited to observe the training procedure after written informed consent was obtained. The children were repeatedly questioned and no evidence of coercion appeared. All parents were reimbursed for traveling expenses on a sliding scale of $1.40 to $3.00 per session. All children were offered novelties, toys, and candies at the end of each session. At no time was reimbursement of any nature contingent upon performance.

In addition to the six children in each group reported in this study, three autistic and one normal child dropped out during training. In each case parents found the daily traveling too difficult to maintain, especially with autistic children, and withdrew from the study.

Apparatus

The subject was seated in a closed sound-attenuated chamber, 2 ft. x 3 ft. x 6 ft., 5 in. He sat facing the narrow wall from which a manipulandum protruded. Positioned above the manipulandum was a Plexiglas window 17.5 in. x 12.5 in. The window was covered outside by an electrically operated opaque shutter, which opened and closed slowly for a total exposure time of 10 seconds. A table was positioned two feet outside the window. During the first experiment the table was covered by an electric train set, including an electric transformer, an oval track 4 ft. x 3 ft., cardboard houses and tunnel, telegraph poles, and an engine with four cars. The view of the room outside the chamber was restricted to the area surrounding the table.

During the second experiment, the opaque shutter was replaced by a translucent screen of 1/4 in. white light diffusion Plexiglas. A Polaroid projector, three feet in back of the screen, illuminated it. The projector was controlled by a Variac voltage transformer, with an ammeter wired in series with the bulb. This system permitted the control and correction of current delivered to the bulb so that intensities were kept at pre-calibrated constants. The luminance, measured at the maximum intensity at the inside surface of the screen, was set 100 foot-lamberts (ftL). Neutral density filters 1,2,3, and 4 were inserted to reduce the luminance at the screen to 10, 1.0, 0.1, and 0.01 ftL, respectively.

The luminance for each intensity was calibrated with a Macbeth Illuminometer. Slight voltage adjustments were required for the two lowest intensities. This system provided five pre-calibrated light intensities for testing. A low-wattage light (below .01 ftL at the screen) was centered in the ceiling to facilitate training, reduce the childrens' fears, and allow responses in the otherwise dark chamber.

Equipment was programmed by electromechanical relays and timers. Responses were recorded automatically on counters. Two metal bars 3 in. x 1 in. x 3/8 in., between which was sandwiched a strip of plastic insulation, formed a non-movable manipulandum. The bars were connected to a Scientific Prototype Drinkometer, which closed a relay when the electrical resistance between the two bars was reduced, i.e., when both bars were touched simultaneously. Contact with the manipulandum resulted in delivery of a reinforcer of predetermined duration. Responses during a period of reinforcement did not prolong its duration. Only discrete responses following the termination of one reinforcement resulted in another. The two dependent variables recorded during each 15-minute session were the total reinforcements obtained, and the total number of responses made, including the ones reinforced plus those occurring during periods when the window was open (extraneous responses).

Procedure

During the acquisition period two autistic children received antipsychotic medication as part of their medical treatment. These medications were replaced with placebo during training (with parental consent), before the experiment described below was conducted. The four other autistic children were either receiving placebo at the onset of training or had not received medication.

During training, contact with the manipulandum was reinforced with a 10-second view of the experimenter seated or standing near the window. The two autistic children receiving medication were trained to this "experimenter view" until they had each acquired stable rates. The medications were then withdrawn, and after approximately one week they were retrained on the same "experimenter view" condition. The other autistic and normal children were also trained on this condition. As each child completed training, he was advanced to the testing procedure described below. The criterion for asymptote was a range of 25% or less of the maximum number of reinforcements received on three successive training sessions.

Two types of visual reinforcers were studied. The first consisted of a 10-second exposure of a view through the window of the testing chamber, beginning immediately following a response. Three stimulus conditions, described in order of decreasing complexity, were presented: (A) A toy train continuously running along the oval track, plus miniature accessories; (B) the same scene but with the train motionless at the point closest to the window. (C) the bare oval track with the train and accessories removed.

There are six possible orders combining these three conditions. Each of the six autistic children and each of the six normal children were randomly assigned to one combination. Thus, each combination was used only once in each group, counterbalancing for order of presentation. Test sessions lasted 15 minutes and each condition was presented for two successive days to each child.

The second visual reinforcer was studied with the same subjects, after completion of the preceding experiment. The room within which the chamber and light projector were placed was totally darkened. A response was followed by 3 seconds of illumination of the screen-covered viewing window. Each subject was randomly assigned to one of five intensities of light for the first test session. On successive sessions he was tested on the remaining intensities, selected randomly, until each subject was tested on all five light intensities. Only one intensity was presented to each subject during any one 15-minute session. The order of stimulus conditions for each subject is presented in Table 2.

Each subject was instructed to sit in the chamber for 15 minutes. During this time he was permitted to play with the "game" (manipulandum) as he wished, but was not obligated to do so. He was shown how to operate the equipment, told to wait 15 minutes, and the door was closed. Parents repeated the instructions. During training the experimenter remained within view of the window. The non-verbal autistic children were given the same instructions, were repeatedly shown how to operate the window, and were shaped by successive approximations when necessary.

TABLE 2

Order of Presentation of Randomly Assigned Stimuli to Normal and Autistic Children in Two Studies of Visual Reinforcement

SUBJECT	VIEWS	INTENSITIES (FT.-LAMBERTS)				
NORMAL						
PN	A, C, B	1	10	100	.1	.01
ST	C, A, B	.1	.01	1	100	10
MN	B, A, C	1	.1	10	.01	100
JN	B, C, A	100	1	10	.01	.1
RA	A, B, C	100	10	.01	.1	1
JA	C, B, A	1	.01	100	10	.1
AUTISTIC						
JR	B, C, A	.01	.1	10	1	100
DM	A, B, C	.1	.01	1	100	10
JB	B, A, C	100	10	.01	1	.1
WJ	A, C, B	10	.01	.1	100	1
SZ	C, A, B	10	100	.01	.1	1
RF	C, B, A	100	.01	1	10	.1

RESULTS

Figure 1 shows the mean number of reinforcements obtained by normal and autistic children during the two studies. Included are the training data with a view of the experimenter (E) as the reinforcer. The mean number of reinforcements for the last three days of training (criterion of asymptote) have been used. Group differences for these means are not significant ($t = 0.382$, $df = 10$, $p<.80$). Figure 2 illustrates the mean total responses emitted by the two groups during the two studies. Although the training data indicate that normal children emit, as a group, 68% more responses for condition (E) than do autistic children, once again these group differences failed to reach significance ($t = 1.581$, $df = 10$, $p<.20$).

Stimulus Complexity

Table 3 includes the reinforcement data for both groups on three levels of stimulus complexity in decreasing order (A,B,C). A two factor analysis of variance with repeated measures on one factor (Edwards, 1968) yielded the following results (Table 4):

(a) Differences between groups are not significant

(b) The group x condition interaction is not significant

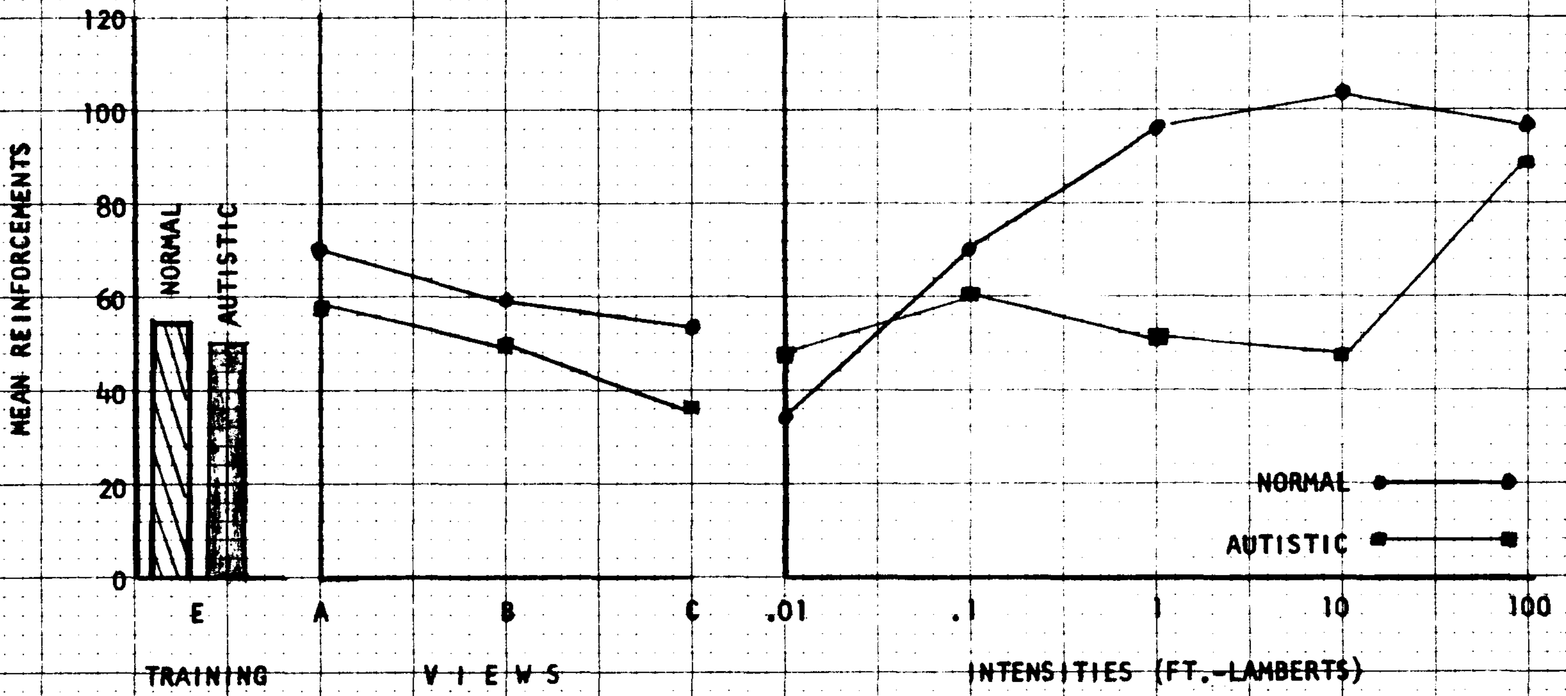

Figure I. Mean reinforcements obtained by groups of normal and autistic children during training and two studies of visual reinforcement.

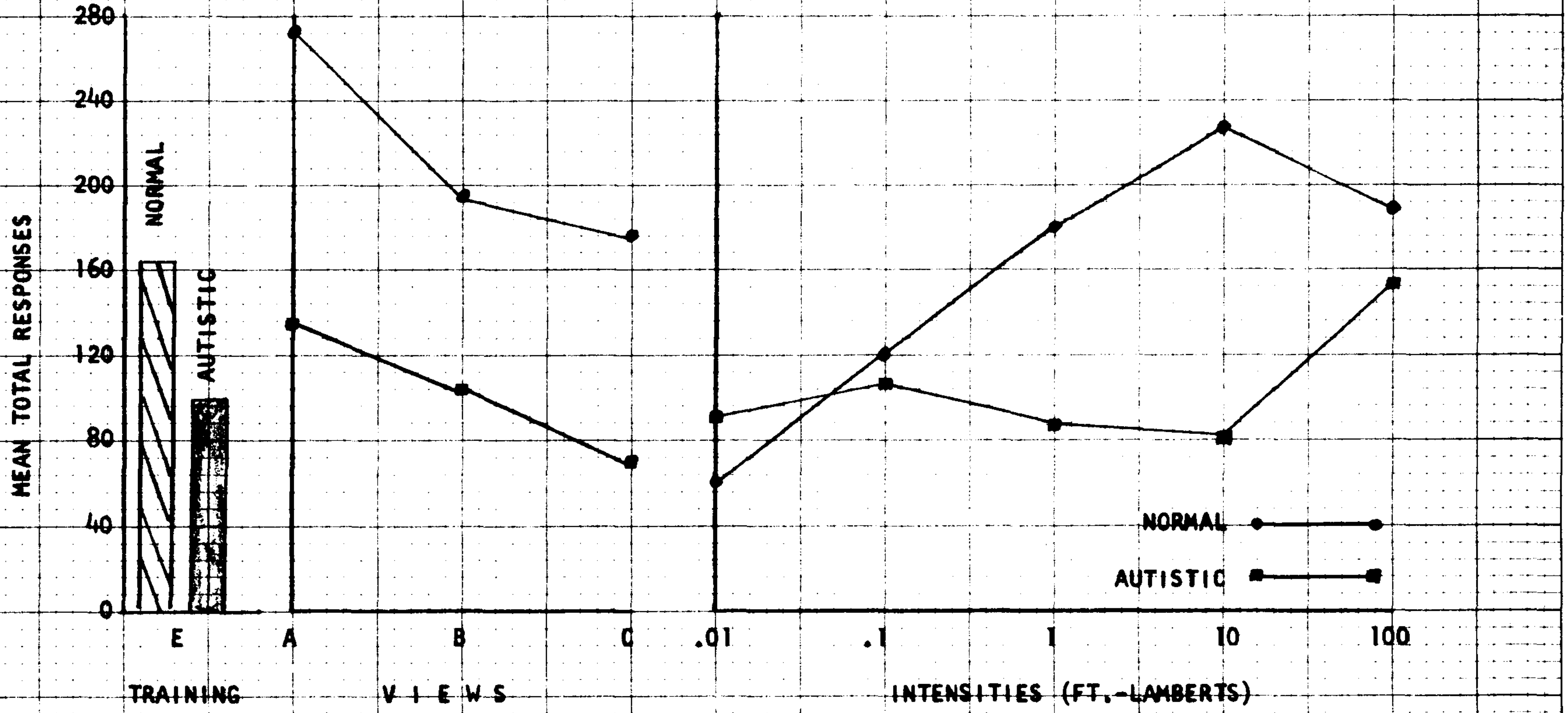

Figure 2. Mean total responses by groups of normal and autistic children during training, and two studies of visual reinforcement.

TABLE 3

Two Measures of Performance by Normal and Autistic Children on Training (E) and Three Levels of Stimulus Complexity in Decreasing Order (A,B,C)

GROUP	REINFORCEMENTS				TOTAL RESPONSES			
	E	A	B	C	E	A	B	C
NORMAL								
PN	30.3	74.5	62.0	65.0	38.6	202.0	131.0	120.5
ST	32.0	40.5	31.5	28.0	82.0	181.0	106.0	129.0
MN	64.0	86.0	62.0	74.0	285.3	556.5	287.0	402.5
JN	71.7	82.5	78.0	79.0	199.3	173.0	236.0	190.0
RA	65.7	66.5	63.0	29.0	213.6	291.5	229.5	77.5
JA	58.7	70.5	59.5	51.5	161.6	239.5	187.5	139.0
Mean	53.73	70.08	59.33	54.42	163.40	273.91	196.16	176.41
S.D.	17.98	16.21	15.17	22.15	90.41	145.14	62.45	116.49
AUTISTIC								
JR	76.0	68.0	60.5	36.0	187.0	168.5	89.0	81.5
DM	61.7	79.0	64.5	54.0	111.3	228.5	152.0	102.5
JB	43.0	67.5	48.5	32.5	77.0	106.5	77.0	47.5
WJ	19.0	21.0	31.5	8.5	49.6	48.5	113.5	24.5
SZ	70.7	74.5	69.5	69.0	89.0	142.0	115.5	118.5
RF	23.7	43.5	30.0	19.0	69.0	110.5	79.0	45.0
Mean	49.01	58.92	50.75	36.50	97.15	134.08	104.33	69.92
S.D.	24.23	22.26	16.98	20.29	48.57	61.32	26.16	36.72

TABLE 4

Analysis of Variance of Reinforcements Obtained by Normal and Autistic Children for Three Levels of Stimulus Complexity

Source of Variation	SS	df	MS	F	p
Between Groups	1,418.7	1	1,418.7	1.41	n.s.
Error	10,039.8	10	1,003.9		
Condition	2,175.5	2	1,087.7	17.17	$< .001$
Group X Condition	139.3	2	69.6	1.10	n.s.
Error	1,266.9	20	63.3		
Total	15,040.2	35			

(c) The condition effect is significant

The three stimulus conditions in this study were randomly assigned in counterbalanced order among subjects of each group. The order of presentation may therefore be ignored. We conclude that the number of reinforcements obtained by both groups is a direct function of the stimulus complexity of the view. Furthermore, there appears to be no difference between normal and autistic groups on this measure. Both groups obtained the greatest mean number of reinforcements for the stimulus of maximal complexity (A) and the smallest for the stimulus of minimal complexity (C).

A second measure was the total responses made by each subject (Table 3). The findings of an analysis of variance of the total response data of both groups on the three levels of complexity are as follows (Table 5):

(a) Differences between groups are significant

(b) The condition effect is significant

(c) The group x condition interaction is not significant

Figure 2 presents the total response data for both groups in the study of stimulus complexity. Comparison of this graph with Figure 1 illustrates that only the total response data are different for the two groups. The difference between measures of reinforcement and total responses will be discussed below.

TABLE 5

Analysis of Variance of Total Responses by Normal and Autistic Children for Three Levels of Stimulus Complexity

Source of Variation	SS	df	MS	F	p
Between Groups	114,356.6	1	114,356.6	6.55	$<.05$
Error	174,374.2	10	17,437.4		$<.01$
Condition	40,626.3	2	20,313.1	7.83	n.s.
Group X Condition	3,630.2	2	1,815.1	0.69	
Error	51,870.7	20	2,593.5		
Total	381,858.0	35			

Light Intensity

Table 6 presents the reinforcement data for the normal and autistic children on five light intensities, in increasing order. The results of a two factor analysis of variance of the data are summarized as follows (Table 7):

(a) Differences between groups are not significant

(b) The condition effect is significant

(c) The group x condition interaction is significant

Group means for normal and autistic children approach each other at three of the five light intensities (Figure 1). In fact, they cross each other at the lowest two intensities. The absence of an overall difference between groups is, therefore, not unexpected.

The important finding is the significant group x condition interaction. This indicates that the two groups performed differently for the various intensities of light. This was further explored by a trend analysis for the linear and quadratic components of the group x condition interaction (Table 8). The findings indicate that the quadratic component, i.e., the difference in curvature of trends for the two groups, is significant ($F = 7.34$, df = 1 and 40, $p<.01$), while the linear component is not ($F = 3.30$, df = 1 and 40, $p<.10$).

TABLE 6

Two Measures of Performance by Normal and Autistic Children on Five Intensities of Light (ftL) in Increasing Order

	REINFORCEMENTS					TOTAL RESPONSES				
GROUP	.01	.1	1	10	100	.01	.1	1	10	100
NORMAL										
PN	25	53	61	40	45	36	99	110	67	59
ST	21	39	36	48	18	30	50	44	80	36
MN	7	60	150	127	147	11	89	285	213	194
JN	47	160	164	144	143	73	264	267	253	191
RA	54	70	77	154	163	135	175	230	569	536
JA	45	38	90	111	70	71	57	140	188	113
Mean	33.2	70.0	96.3	104.0	97.7	59.3	122.3	179.3	228.3	188.2
S.D.	18.2	45.8	50.5	48.8	61.1	44.2	82.5	96.0	182.5	182.5
AUTISTIC										
JR	106	99	48	59	108	224	211	84	86	213
DM	13	70	44	24	63	21	131	75	41	107
JB	87	54	36	95	126	127	99	54	138	193
WJ	46	40	38	16	69	96	60	76	33	131
SZ	10	69	71	77	129	18	99	134	152	228
RF	30	30	69	15	36	60	42	87	27	48
Mean	48.7	60.3	51.0	47.7	88.5	91.0	107.0	85.0	79.5	153.3
S.D.	39.7	24.6	15.3	34.3	38.0	77.7	59.9	26.6	55.0	69.9

TABLE 7

Analysis of Variance of Reinforcements Obtained by Normal and Autistic Children for Five Intensities of Light

Source of Variation	SS	df	MS	F	p
Between Groups	6,615.0	1	6,615.0	1.40	n.s.
Error	47,125.1	10	4,712.5		
Condition	17,389.8	4	4,347.4	5.19	<.01
Group X Condition	10,323.8	4	2,580.9	3.08	<.05
Error	33,493.8	40	837.3		
Total	114,947.5	59			

TABLE 8

Trend Analysis of the Linear and Quadratic Components of the Group X Condition Interaction* of Reinforcements Obtained by Normal and Autistic Children on Five Intensities of Light

		INTENSITY (ftL)							
		.01	.1	1	10	100	df	F	P
ORTHOGONAL	Linear	-2	-1	0	+1	+2	1,40	3.30	<.10
COEFFICIENT	Quadratic	+2	-1	-2	-1	+2	1,40	7.34	<.01
GROUP	Normal	199	420	578	624	586			
SUMS	Autistic	292	362	306	286	531			

*Edwards, 1968, 282-284

Inspection of group reinforcement curves (Figure 1) indicates that normal children yield an increasing, but decelerating pattern as light intensities of greater luminance are presented as reinforcers. This curve reaches its peak at 10 ftL and decreases slightly with a 100 ftL stimulus. In contrast, the group of autistic children exhibit relatively unchanging performance to each of the four dimmer intensities and a twofold increase in rate to the 100 ftL intensity. The group's performance on this brightest intensity closely approaches that of the normal children.

A breakdown of the individual reinforcement patterns for the six children in each group is illustrated in Figure 3. Four of the six normal children clearly demonstrate the inverted U-shaped relationship between performance and stimulus intensity. The rate for one child (MN) reaches a peak at 1 ftL, decreases at 10 ftL, then increases again at 100 ftL. Another child (RA) exhibits a continuously increasing rate across the 5 intensities used.

Inspection of the individual reinforcement patterns of autistic children indicates that three autistic children reach their peak performance at 100 ftL, as demonstrated by the group curve. Two children showed two peaks,

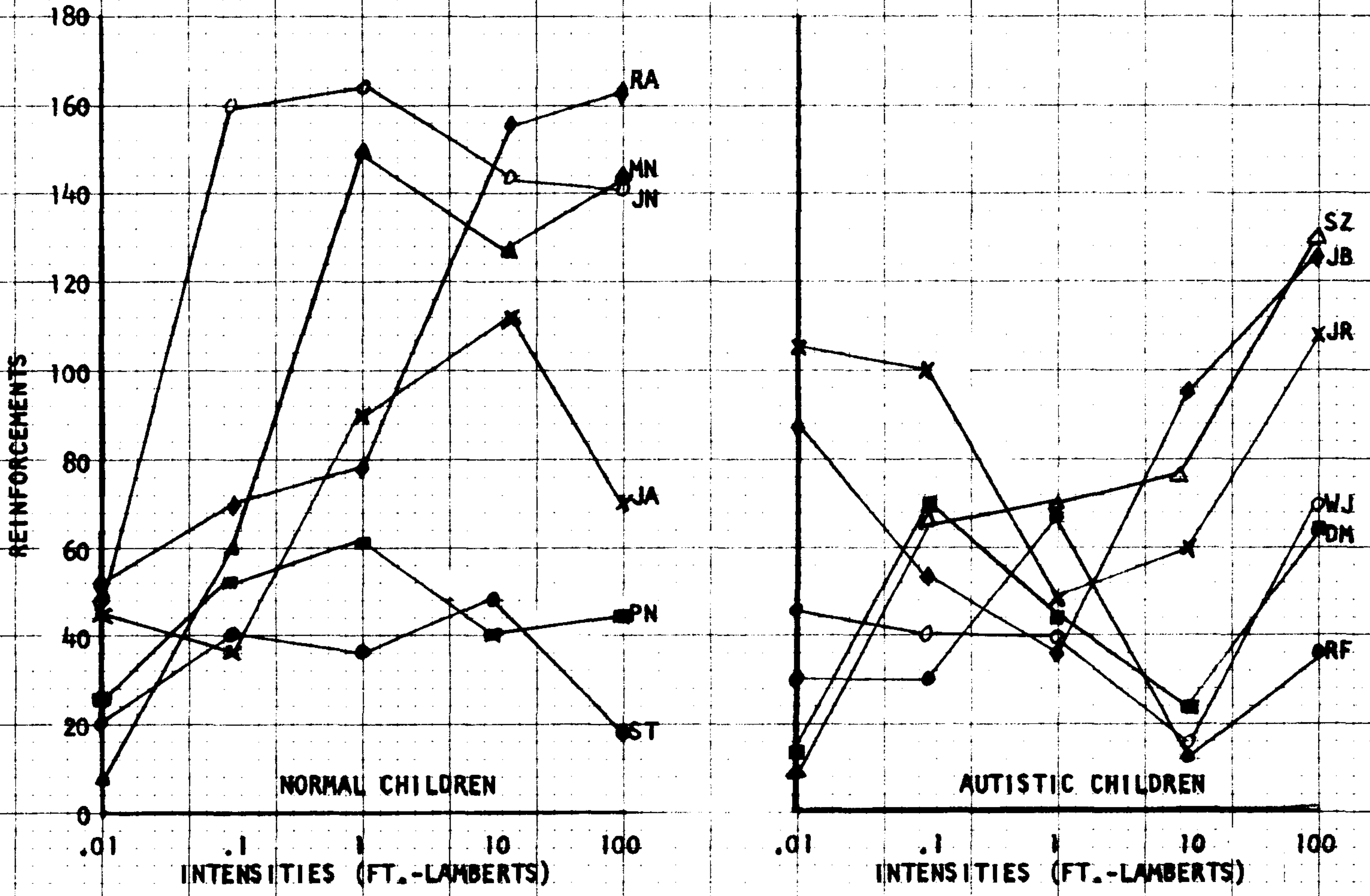

Figure 3. Number of reinforcements obtained on five intensities of light by individual normal and autistic children.

one child at 100 ftL and .01 ftL, resulting in a U-shaped curve,[1] and another child at 100 ftL and .1 ftL.

The second performance measure, total responses, is included in Table 5. An analysis of variance of the group means for normal and autistic children on the five intensities of light (Table 9) showed that:

(a) Differences between groups are not significant
(b) The condition effect is significant
(c) The group x condition interaction is significant

Both performance measures, reinforcements obtained and total responses, yield similar findings in this study of light intensity, as underscored by comparison of Figures 1 and 2. The overall difference between groups in the study of stimulus complexity, found only in the measure of total responses, was not replicated in the study of light intensity.

Analysis of extraneous responses per reinforcement period:

The difference between the two measures, total responses and reinforcements, is a measure of the extraneous

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[1] In fact, evidence of U-shaped performance patterns appears for three autistic children (JB, WJ, & JR). However, since the group's performance was not significantly different at the lower intensity because of large individual differences, the interpretation of no differences from .01-10 ftL (see Figure 1) is used throughout.

TABLE 9

Analysis of Variance of Total Responses by Normal and Autistic Children for Five Intensities of Light

Source of Variation	SS	df	MS	F	p
Between Groups	41,081.6	1	41,081.6	1.33	n.s.
Error	306,959.2	10	30,695.9		
Condition	65,722.1	4	16,430.5	3.17	<.05
Group X Condition	57,422.4	4	14,855.6	2.86	<.05
Error	207,263.7	40	5,181.5		
Total	678,449.0	59			

responses emitted by a child during the 10 sec. period while the window is open in the study of stimulus complexity, and the 3 sec. of illumination in the study of light intensity. The mean number of extraneous responses per reinforcement period is presented in Table 10. Again, the group difference during training is not significant ($t = 1.434$, $df = 10$, $p<.20$).

Independent analyses of variance were made of the data for the two studies. The one significant finding (Table 11) was the difference between groups in the stimulus complexity study. This difference, as well as the similarities between groups in the second study and the absence of condition effects in both studies is illustrated in Figure 4. Normal children emitted twice as many extraneous responses per reinforcement period on each condition of the study of stimulus complexity.

The difference between the two measures in the first study is completely accounted for by the greater number of extraneous responses emitted by normal children during each 10 sec. reinforcement period. The absence of a condition effect indicates that this response rate is stable for each group and is not influenced by the level of stimulus complexity.

The failure of the normal children to make a greater

TABLE 10

Extraneous Responses per Reinforcement Period by Normal and Autistic Children during Training and Two Studies of Visual Reinforcement

GROUP	VIEWS				INTENSITIES (FT.-LAMBERTS)				
	E	A	B	C	0.01	0.1	1	10	100
NORMAL									
PN	0.27	1.71	1.11	0.85	0.44	0.87	0.80	0.68	0.31
ST	1.56	3.47	2.37	3.61	0.43	0.28	0.22	0.67	1.00
MN	3.46	5.47	3.63	4.44	0.57	0.48	0.90	0.68	0.32
JN	1.78	1.10	2.03	1.41	0.55	0.65	0.63	0.76	0.34
RA	2.25	3.38	2.64	1.67	1.50	1.50	1.99	2.69	2.29
JA	1.75	2.40	2.15	1.70	0.58	0.50	0.56	0.69	0.61
Mean	1.845	2.921	2.321	2.280	0.678	0.713	0.850	1.028	0.811
S.D.	1.034	1.553	0.824	1.410	0.407	0.432	0.605	0.814	0.771
AUTISTIC									
JR	1.46	1.48	0.47	1.26	1.11	1.13	0.75	0.46	0.97
DM	0.80	1.89	1.36	0.90	0.62	0.87	0.70	0.71	0.70
JB	0.79	0.58	0.59	0.46	0.46	0.83	0.50	0.45	0.53
WJ	1.61	1.31	2.60	1.76	1.09	0.50	1.00	1.06	0.90
SZ	0.26	0.91	0.66	0.72	0.80	0.43	0.89	0.97	0.77
RF	1.91	1.54	1.63	1.37	1.00	0.40	0.26	0.80	0.33
Mean	1.138	1.285	1.218	1.078	0.846	0.693	0.683	0.741	0.700
S.D.	0.621	0.470	0.820	0.474	0.266	0.294	0.268	0.253	0.238

TABLE 11

Independent Analyses of Variance in Two Studies of Visual Reinforcement for the Number of Extraneous Responses per Reinforcement Period by Normal and Autistic Children

STUDY	SOURCE OF VARIATION	SS	df	MS	F	p
Three Levels of Stimulus Complexity	Between Groups	15.536	1	15.536	6.090	<.05
	Error	25.509	10	2.550		
	Condition	1.197	2	0.598	2.178	n.s.
	Group X Condition	0.438	2	0.241	0.879	n.s.
	Error	5.494	20	0.274		
	Total	48.219	35			
Five Intensities of Light	Between Groups	0.104	1	0.104	0.116	n.s.
	Error	8.940	10	0.894		
	Condition	0.213	4	0.053	0.789	n.s.
	Group X Condition	0.349	4	0.087	1.288	n.s.
	Error	2.710	40	0.067		
	Total	12.316	59			

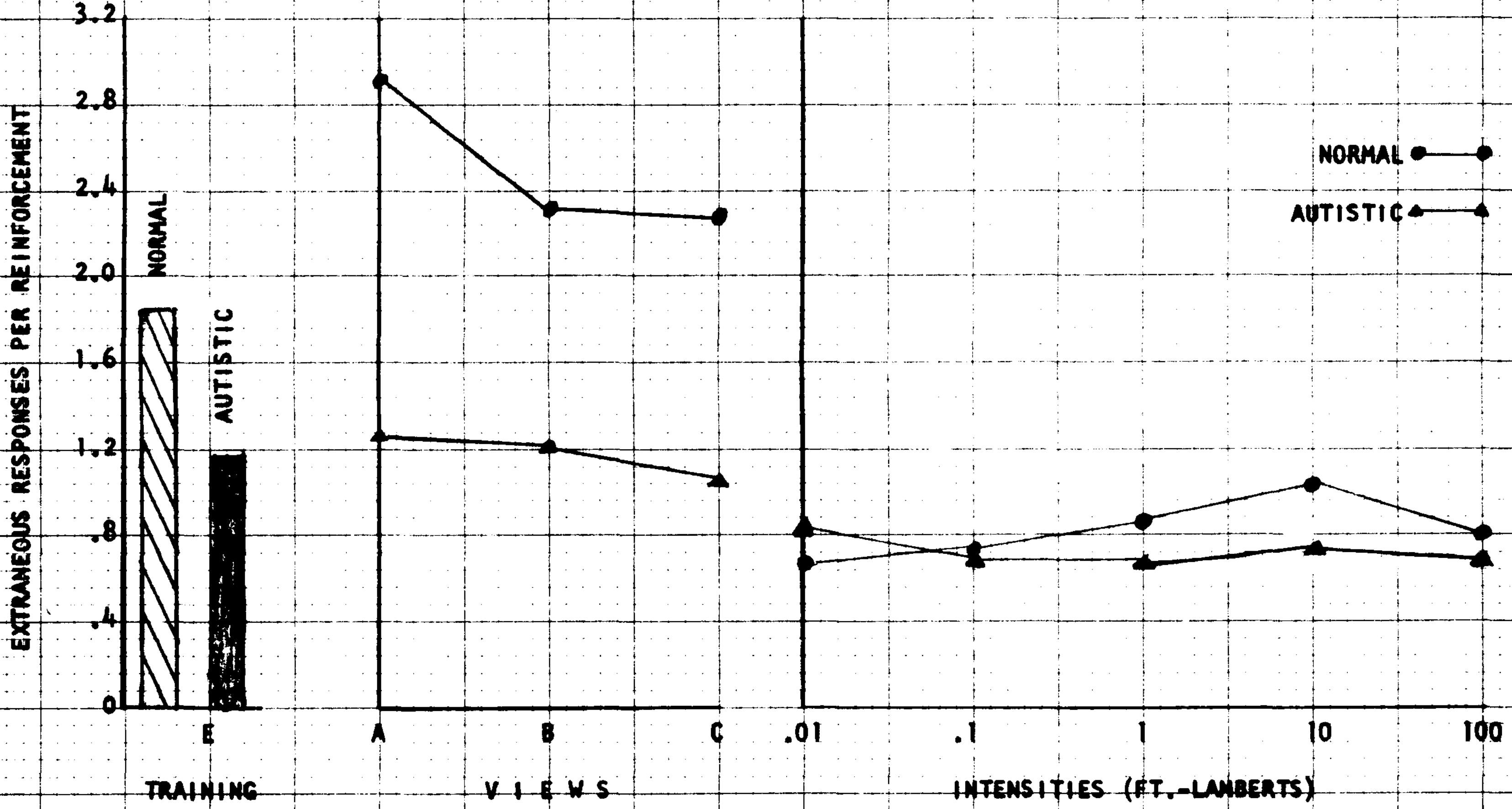

Figure 4. Mean extraneous responses per reinforcement period by groups of normal and autistic children during training and two studies of visual reinforcement.

number of extraneous responses per reinforcement period in the study of light intensities is evident from the data and also from inspection of Figure 4. It should be noted, however, that while the reinforcement period for views is 10 sec., the reinforcement period for intensities is only 3 sec. of illumination.

DISCUSSION

The two parametric studies of visual reinforcers with normal and autistic children yielded support for two of the original four hypotheses.

Hypothesis 1: For normal children, there will be an increasing, monotonic relationship between stimulus complexity and its effectiveness as a reinforcer of free-operant behavior. The results of the first study indicate that for normal children there does exist a monotonic relationship between rate of reinforcement and stimulus complexity. Total responses, a second free-operant measure, are similarly related to stimulus complexity. Normal children emit the greatest number of responses for the view of maximal complexity and the fewest responses for the least complex view. The data support the original hypothesis.

Hypothesis 2: For normal children, the relationship between light intensity and its effectiveness as a reinforcer of free-operant behavior is in the form of an inverted U-shaped function. The average reinforcement rates of normal children increase at a decelerating rate from a low at .01 ftL to a maximum at 10 ftL followed by a decrease at 100 ftL. The individual performances of four of the six children clearly demonstrate the inverted U-shaped function; such a function is also indicated in a fifth child. The data of this study support the hypothesis.

Hypothesis 3: The response rates for autistic children will be higher than for normal children for each of the three conditions of stimulus complexity used under Hypothesis 1. Like their normal counterparts, autistic children demonstrate an increasing monotonic relationship between performance and increasing stimulus complexity. Again, this finding is consistent for both performance measures. Mean reinforcement rates are similar for the two groups. However, the autistic children emit significantly *fewer* total responses than normal children at each level of stimulus complexity. The results of this study fail to support Hypothesis 3. In fact, the measure of total responses is in the opposite direction to that predicted.

Hypothesis 4: The absolute rate of response under Hypothesis 2 will be higher for autistic children than for normal children, within the optimal range of intensities. Both performance measures yield identical results. The group of autistic children exhibit a flat performance curve up to that intensity at which normal children reach their peak reinforcement rate (10 ftL). Their rates suddenly rise to approach the descending response curve of normal children at 100 ftL. Thus, within the normal optimal range of 1-10 ftL, the autistic children respond at lower rates; the reverse of Hypothesis 4.

The findings of these two studies will be analyzed with the purpose of relating them to the literature reviewed earlier. The present data are occasionally open to more than one interpretation. This is typical of studies of autistic children, since most previous work with this group has been clinical rather than experimental. Although the clinical descriptions of autistic behavior may be valid, the conditions under which such behavior has been observed and the stimuli controlling behavior have not often been controlled. Since theories of etiology are often vague, attempts to relate them to the experimental work of others or to the findings of this study may suffer. Nevertheless, the results of this study do elucidate the functional relationships between two parameters of visual reinforcement and free-operant behavior of normal children, and provide a firm basis of comparison for defining the abnormal sensitivity to sensory stimulation reported for autistic children.

Previous studies with infants found that their relative preferences in two choice tasks was a function of stimulus complexity. Given a choice of two designs differing in some component of complexity, children reliably chose the more complex. Theorists (Berlyne, 1966; Kish, 1966) predict that more vigorous exploration occurs with stimuli of greater complexity. They suggest that free-operant behavior is a function of this parameter. However, Caron (1967) correctly claimed that discrete two-choice studies of such parameters at best limit their findings to statements of <u>relative</u> preferences. The possibility that free-operant behavior might be unrelated to stimulus complexity cannot be rejected. For example, in the present study children are given the choice of facing a closed window or responding for a view outside that window. Since the open window might be considered always preferable to the closed window (or the window movement, per se, might be the reinforcer) response rates might remain high and constant across views. Thus, free-operant rates of response may not be a function of the stimulus complexity of the view.

In the first of the two studies, exposure to one of three views which differed qualitatively in stimulus complexity was made contingent upon contact with a non-moving manipulandum. The most complex view (A), that of a moving train and toy accessories, presented movement in addition to pattern and color. The second view (B), with the train stationary, omitted only movement as a component of stimulus complexity. The minimally complex view (C) had the train and accessories removed from the scene, with a resultant reduction in pattern and color. Thus, the three views were qualitatively different in the amount of stimulus complexity they presented to the viewer.

The findings of this study are conclusive. The free-operant behavior of normal children is monotonically related to the stimulus complexity of the view (within the limits tested), so that a greater number of responses were emitted with views of greater complexity.

A number of experimental studies conducted with animals indicate that free-operant rates are related to light intensity in a curvilinear fashion. Berlyne (1967) believes that the reward value of light intensity is related to arousal potential in an inverted U-shaped function. He suggests that initial increases in stimulus intensity activate a CNS reward mechanism. Subjects should therefore exhibit increased response rates as stimulus intensity increases. Beyond a certain point, however, further increases in intensity also activate a CNS aversion mechanism. A decrease in performance would then be expected. Between these two extremes lies an optimal range of stimulus intensities which effectively function as sensory reinforcers. Work with animals supports the premise of an inverted U-shaped relationship between reward values and intensities.

In the present study, four of the six normal children exhibit the predicted inverted U-shaped function. The relationship was also suggested by the performance of a fifth child. As each subject was tested only once at each intensity, the consistency of the individual response patterns are all the more impressive. The sixth child exhibited an increased rate to the maximum intensity used.

The response rates for normal children might have further decreased if more intense lights had been used in this study. However, ethical considerations precluded the use of stronger, possibly aversive stimuli with children. The 100 ftL stimulus was produced by a 500 watt light projected to a Plexiglas diffusion glass three feet away, with children seated on the other side of the glass. Although 100 ftL is well below intensities causing damage to the visual system, it was unclear at what level of intensity bright lights would become aversive to children. Nevertheless, the significant curvature of the group data and the inverted U-shaped performance patterns for four (or five) of the six normal children provide clear support for a curvilinear relationship between light intensity as a reinforcer and free-operant behavior.

Various interpretations of the abnormal responses of autistic children to sensory stimuli have been noted in the literature. Autistic children have been described as withdrawing from normal levels of sensory stimulation because such stimulation is aversive to them (Fraknoi and Ruttenberg, 1971; Moore and Shiek, 1971; Spitz, 1964); as experiencing random fluctuations in arousal and being unable to maintain "perceptual" constancy because of a CNS dysfunction (Ornitz & Ritvo, 1968); or as being constantly involved in stimulus-seeking activity or self-stimulating behavior (Fraknoi and Ruttenberg, 1971). The latter interpretation is based on clinical observations of autistic behavior, and suggests that autistic children would be more responsive than normal children to visual reinforcers.

The data demonstrate that the performance of autistic children is related to stimulus complexity in a monotonic function, similar to that of normal children. More importantly, both groups obtain a similar number of reinforcements for each stimulus condition. These data fail to conform with any of the above interpretations of the autistic child's abnormal sensitivity to sensory stimulation. They seem neither less nor more responsive to this parameter of visual reinforcement than normal children. Finally, their performance is as much a function of the absolute complexity of the view as it is for normal children.

On the other hand, the autistic children emitted only half as many extraneous responses in the complexity experiment as normal children during the 10 sec. reinforcement period. The rate of these responses was constant for the two groups across conditions. Interpretation of the group differences in extraneous responses is difficult without additional experimentation. A number of possibilities suggest themselves. First, since they emit fewer of these non-functional and unreinforced extraneous responses, autistic children could be said to perform more "efficiently" than normal children. Second, perhaps the autistic children are better coordinated than normal children. Neither interpretation seems plausible to anyone familiar with these children.

A more likely hypothesis is that autistic children are less "excitable" than normal children (Supposition I). The latter respond before the window is fully closed in excited anticipation of the next reinforcement. Autistic children fail to be excited and thus emit fewer extraneous responses. Unfortunately, such a hypothesis would also predict that the autistic child will obtain fewer reinforcements. This is not borne out by the data. One would also expect excitation to act as a function of stimulus complexity. However, the extraneous responses yield a non-significant condition effect.

A final suggestion is that the autistic child may produce self-stimulating behavior which competes with extraneous responses. The reward value of the view is sufficient to suppress interfering responses, so that functional responses are not interfered with. Such a hypothesis, discussed in greater detail below, would require close observation of the performance of the children during testing. Such observations are, unfortunately, not now available.

Stimulus complexity is only one parameter of sensory reinforcement. Our failure to find group differences on this parameter does not imply that such differences are not present on other parameters. However, these findings do indicate that observations of autistic behaviors as either withdrawn or, alternately, stimulus-seeking are not borne out by this experimental evidence. Greater definition of the responses described as "autistic" and of the stimuli controlling such behaviors is required.

The performance of autistic children in the second study of light intensity as a parameter of sensory reinforcement failed to support our original hypothesis that they would exhibit elevated response rates at the optimal range of intensities, relative to normal children. However, the findings can be interpreted in support of one of our original suppositions (III) that autistic children may be stimulus-seeking.

Although our autistic children were not more responsive within the "optimal" range of stimulus intensities than normal children, it is possible that they seek more intense sensory stimulation. This would lead to a displacement of the curve to the right of that of normal children, a possibility previously suggested (p.34). In fact, the average rates for the autistic children remain relatively low at the four dimmer intensities and then increase twofold at 100 ftL, that intensity at which the performance of normal children decreases. Inspection of individual response patterns indicates that autistic children were consistent in preferring the brightest intensity to the dimmer ones, while normal children demonstrated a preference for an optimal range of intensities more to the left (less intense stimuli). Thus, the data suggest that autistic children are most reactive to intense stimuli, while normal children are more responsive to the less intense stimuli.

Moore and Shiek (1971) and others have suggested that autistic children are in a state of chronic cortical hyperarousal. Other theorists suggest that they alternate between subnormal and supranormal arousal levels (Ornitz & Ritvo, 1968), or that they are chronically underaroused (Bettelheim, 1967; Fraknoi & Ruttenberg, 1971). Berlyne (1969), in clarifying the relationship between arousal levels and reward values of stimulus parameters such as light intensity, suggests that either subnormal or supranormal arousal levels will result in displacement of the inverted U-shaped function to the left (the dimmer intensities). He states, "In other words, an animal will be most inclined to welcome arousing stimuli when its capacities for dealing with them are at their peak but will prefer less challenging and troublesome stimulation when arousal level is too high or too low for full efficiency." (p. 208). The performance of autistic children to light intensity as a parameter of sensory reinforcement supports neither theories of increased or decreased arousal, nor theories of fluctuating arousal.

Theories of arousal have been relatively neglected in our discussion of the differences between autistic and normal children. The reason for this is that the relationship between subject arousal and arousal potential of a rewarding stimulus has not yet been worked out. Tapp (1969) reviewed arousal theories and concluded, "Berlyne has argued that if a reward can move the subject to an optimal level of arousal, it will reinforce. The arousal potential of a reward, as Berlyne has also suggested, is a function of the arousal level of the subject. This gives the theory too much freedom and consequently little predictive value." (p. 392). This same conclusion was reached by Hinde (1970), in his review of arousal theories. Therefore, it was decided not to pursue implications of theories of impaired arousal in autistic children.

Even if theories of autism are ignored, there remain conflicting descriptions of the autistic child as either withdrawn or hyperreactive to sensory stimulation. The study of light intensity as a parameter of reinforcement provides data which might explain this seeming paradox. All of the autistic children exhibited preferences for bright lights rather than those in the optimal range preferred by normal children. For the autistic child, this can be interpreted to mean that any act which greatly increases light intensity will be reinforced. In contrast, normal children are reinforced for acts which increase or decrease light intensity, bringing it toward the moderate "optimal range." Thus, compared to the normal child, the autistic child may seem withdrawn when he fails to respond to intensities within the normal range, or hyperreactive when he acts to increase light intensity above that considered normal. Such an interpretation focuses on the preferences of autistic children as contrasted to those of normal children. It resolves the seeming conflict between observations of hyperreactivity to and withdrawal from sensory stimuli which appear in the literature. Thus, we suggest that the autistic child might appear withdrawn in situations in which the available visual stimulation would be within the "optimal range" for normal children, and might appear hyperreactive when the environment offers the opportunity to greatly increase light intensity beyond the normal child's "optimal range."

Early sensory deprivation has been suggested as etiological in the development of autism (Freedman, 1968; Moore and Shiek, 1971). There exist two opposing theories concerning the effects of varied early stimulation on the development of later reactivity to sensory stimulation. The first are the popular "optimal arousal" theories of Schultz (1965) and of Fiske and Maddi (1961), which claim that the effectiveness of two parameters of sensory stimuli as reinforcers, complexity and intensity, are direct functions of the organism's past experience. Berkowitz (1970) interpreted this as suggesting that a sustained period of decreased visual stimulation should decrease sensory reinforced behavior. Schultz (1965) supplied a similar interpretation of the optimal-arousal theory for developing organisms:

> It is suggested that the optimal level or range of stimulus variation within which the adult organism is able to function effectively is influenced in great part by the stimulation provided at the neonate stage. Contact with a rich sensory environment would facilitate the development of differentiation of cue functions, of sensory modalities, and of events within modalities. An impoverished sensory environment would prevent such differentiation and the fuller use of cue functions later in life (p. 26).

Since early sensory deprivation results in a lowered level of activation, Schultz suggests that a lowered drive for sensory reinforcement (which he calls Sensoristasis) will develop. If early sensory deprivation does produce autism, an optimal arousal theory would predict that this population should demonstrate decreased Sensoristasis, or a lowered response rate for sensory reinforcement.

A deficit-oriented theory directly opposed to the above optimal arousal theory (Berkowitz, 1970) suggests that, "Deprivation of stimulation would motivate the organism to seek out more stimulation as a monotonic function of the severity and duration of the deprivation." (p. 192). This theory would predict that if autistic children have been sensory-deprived, they should prove to be stimulus-seeking.

The data favor neither hypothesis. Autistic children are neither more nor less responsive than normal children to the parameter of stimulus complexity. In the analysis of the study of light intensity, the between groups difference is not significant. Rather, the two groups yield different response curves over the range of light intensities tested. While an interpretation of the behavior of autistic children as stimulus-seeking was suggested, this was defined as a preference for more intense stimulation and not as greater responsivity to all levels of stimulation.

Rimland (1964) suggested a relationship between respiratory trauma and autism. Waizer et al. (1972) found that neonatally asphyxiated monkeys were more responsive than controls to views of greater stimulus complexity. The performance of autistic children in the present study, however, was comparable to normal children on all levels of stimulus complexity. A hypothesis of neonatal respiratory trauma in autistic children is therefore not supported by this data.

A relationship between reduced maternal contact and autism has been suggested by many theorists (Bettelheim, 1967; Fraknoi and Ruttenberg, 1971; Kanner, 1943), who also see the autistic child as less responsive to his environment than are normal children. Green and Gordon (1964) found monkeys reared in isolation to be significantly less responsive to stimulus views than maternally-reared monkeys. Autistic children in the present study, however, were not less responsive to stimulus views than were normal children.

A theory provided by Prescott (1971) suggests an alternate interpretation of the Green and Gordon study. He supports the claims that sensory deprivation results in increased stimulus-seeking behavior, but that:

> ...sensory deprivation during early development leads to stimulus-seeking behaviors that are related to the sensory system that has been deprived; furthermore, that hyperactivity, hyperreactivity, and increased violent-aggressive behavior commonly reported following maternal-social deprivation in mammals represent forms of stimulus-seeking behavior which are attributable to somato-sensory deprivation and not to deprivation of the other sensory systems. (p. 189).

Green and Gordon (1964) describe maternally deprived animals as evidencing continuous repetitive movements, rocking, hair-pulling, clasping, and a high rate of "fear" vocalizations, while ignoring the lever in the test chamber. Prescott (1971) interpreted these abnormal behavior patterns as self-stimulating. He attributed them to the specific deprivation of somatosensory stimulation suffered during infancy and not to the deprivation of other sensory systems. Since these animals suffered somatosensory deprivation, they seek primarily vestibular and kinesthetic stimulation through rocking, clasping, and even hair-pulling. These stereotyped performances interfere with the lever pressing response. According to Prescott, early sensory deprivation does lead to increased sensorily reinforced behavior for the deprived sensory system - an interpretation which conforms to other sensory-deprivation data and supports a deficit-arousal theory. In addition, it also explains the otherwise "abnormal" home cage motor stereotypies and hyperactivity of maternally deprived monkeys.

Using this argument, the fewer extraneous responses per reinforcement period by autistic children compared to normal children might be due to the interference of stereotyped self-stimulating behaviors. Rocking, hair-pulling, hand-flapping, and ear-flicking are all behaviors commonly observed in autistic children and they did occur in the children studied here. The similarity of the reinforcement rates for the two groups may be due to the fact that this parameter of visual reinforcement has high reward value, and that the performance of autistic children for views is not interfered with by the self-stimulating behaviors.

On the other hand, in keeping with this model one would have to assume that the motor stereotypies of autistic children more easily interfered with responses to stimuli varying in intensity than in complexity. However, the reinforcement period for the intensity study was 3 sec. of illumination, versus 10 sec. of view in the first study. The shorter reinforcement period might have been more sensitive to the interference of such stereotypies. Finally, the elevated responses for autistic children at the brightest intensity might be explained by the possibility that bright lights are highly arousing and may satisfy the autistic child's need for stimulation. The findings in the present study are concordant with Prescott's theory. However, since no systematic observations were made of the specific activities of children during testing, the support for Prescott is by no means compelling.

This study has demonstrated that autistic children are less responsive than normal children to lights of moderate intensity, and that they are most responsive to bright lights. Compared with normal children, autistic children appear unresponsive to (withdrawn from) lights within the moderate range of intensities and appear hyperreactive as defined by their preference for intense over moderate levels of brightness. In addition, autistic and normal children obtained similar numbers of reinforcements for views of varying stimulus complexity, while the former emitted significantly fewer extraneous responses.

Theories of neonatal asphyxiation and of visual deprivation in autism fail to account for these observations, although the data are concordant with Prescott's theory of maternal deprivation. Furthermore, clinical descriptions of autistic children as withdrawn from and/or hyperreactive to visual stimuli lack sufficient specificity to predict these findings. As demonstrated by the present study, the "abnormal" responsiveness of autistic children to sensory stimuli as either "withdrawn" or "hyperreactive" can be understood, if defined under properly controlled conditions.

SUMMARY

The performances of normal children under both parameters of visual reinforcement confirmed the predictions of the first two hypotheses. The free-operant rates of normal children were directly related, in a monotonic function, to the stimulus complexity of the visual reinforcer. Also, the free-operant rates of normal children were related to light intensity in an inverted U-shaped function.

Free-operant rates of autistic children were directly related to stimulus complexity, as were those of their normal counterparts. However, while the groups were similar with respect to number of reinforcements obtained, they differed significantly in the number of extraneous responses emitted per reinforcement period. One suggestion considered more likely than others is that the motor stereotypies observed in autistic children interfered with the emission of extraneous responses.

Unlike those normal children, the free-operant rates for the group of autistic children remained unchanged over the four dimmer intensities tested, and doubled at the fifth and brightest intensity. Inspection of their individual performance curves illustrates that most autistic children obtained the greatest number of reinforcements at the brightest intensity. This suggested a possible displacement of the curve to the right of that of the normal subjects, i.e., autistic children are responsive to a range of more intense stimuli than are normal children. This can explain why their behavior is often interpreted as stimulus-seeking.

The results of the second study were also successful in resolving conflicting descriptions of autistic children as simultaneously withdrawn and hyperreactive to sensory stimulation. It appears that autistic children prefer light increments from dim to very intense rather than from dim to moderately intense as preferred by normal children. On the other hand, they might appear less responsive to moderate levels of light intensity. This would conform with and resolve the conflicting descriptions of autistic behavior.

Theories of early sensory deprivation or oxygen deprivation are not supported by the present findings with respect to autistic children. A theory of tactile or maternal deprivation, interpreted by Prescott's (1971) deficit oriented model, can explain the data but is difficult to test.

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