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Differential Autonomic Responses of Autistic and Normal Children[1]

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The autonomic responses of 10 autistic and 10 normal children were compared using auditory stimuli varying in social relevance. Consistent differences in heart rate response and skin conductance level were found between the groups. The results suggest that the autistic subjects exhibited deficits in psychophysiological reactivity to a range of environmental stimuli. Findings are discussed in terms of the information-processing capabilities of autistic children, and probable physiological correlates. Implications for treatment are considered.

A commonly observed characteristic of autistic children is selective unresponsivity to environmental stimuli. In particular, unresponsivity to auditory stimuli is so prevalent a characteristic of autistic children that deafness is often suspected. Perhaps because adults are unable to attract the child's attention by calling the child's name or speaking to him, autistic children have been described as living "in a shell." On the other hand, it has been observed that the same children may sometimes react violently to

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barely audible sounds, such as a distant siren or a dog's barking (Anthony, 1958; Goldfarb, 1956). Fluctuations of sensory responsivity within an individual are perhaps most dramatically illustrated in an example provided by Wing (1972), who described an autistic child who failed to blink when a stack of plates was dropped directly behind him, yet who shortly thereafter oriented toward the sound of a piece of candy being unwrapped across the room.

Unlike most normal children, the autistic child's verbal reports cannot be relied upon in obtaining data about responsiveness to or preference for various types of environmental stimuli. Hence, autonomic measures of attention, which require little or no instructed response and minimal amounts of behavioral compliance, provide a potentially rich source of information about the degree to which the child's nervous system has registered a stimulus and an effector reaction has occurred (Bernal & Miller, 1970). Moreover, interpreting autonomic response data in terms of orienting and defensive responses (Graham & Clifton, 1966; Sokolov, 1963), may provide a better understanding of the nature of the fluctuations in responsiveness and social withdrawal characteristic of autistic children.

A well developed body of research supporting Sokolov's (1963) orienting theory has shown that differential physiological responses are evoked by nonsignal auditory and visual stimuli of varying physical intensities. Graham and Clifton (1966) report that stimuli of moderate physical intensity evoke cardiac deceleration and an increase in skin conductance; these reactions are considered to be an index of an orienting response (OR). In contrast, stimuli of high intensity elicit heart rate accelerations and skin conductance increases, and these changes are consistent with a defensive response (DR). The OR pattern has been interpreted as a correlate of attentional *receptivity* to environmental input, while the DR is considered to reflect a pattern of *rejection* of environmental stimuli (Lacey, 1967).

Several investigations have extended these empirical findings and theoretical formulations to include differential responsivity to stimuli varying along the dimension of psychological intensity. For example, a recent study by Klorman, Weissberg, and Wiesenfeld (1977) found that subjects preselected for specific high fear of mutilation reacted to gruesome photographic slides with DRs, while low fear subjects responded to these same stimuli with ORs. Clinical observations of withdrawal in autistic children led us to hypothesize that social situations represent a high degree of psychological intensity for this group of children.

In the present study, the physical intensity of stimuli was held constant, and stimuli were varied along a dimension of social relevance. In an earlier investigation of autistic children's heart rate and electrodermal reactivity to a variety of physical stimuli, Bernal and Miller (1970) found that the electrodermal reactivity of the autistic subjects was lower than that of a group of age-matched normal subjects on early experimental trials, but that patterns of response habituation to a series of stimulus repetitions failed to differentiate the two groups of children. No reliable between-groups differences were found in cardiac reactions to stimulation.

The purpose of the present study was to investigate autistic and normal children's heart rate and electrodermal responses to three stimuli: socially meaningful speech, nonsense speech, and tones. It was predicted that normal children would react with cardiac deceleration (orienting responses) to all stimulus types, whereas autistic children would display diminished orienting to the socially irrelevant stimuli (tones and nonsense speech) and cardiac acceleration (defensive responses) to the socially relevant speech stimulus.

METHOD

Subjects

The autistic group consisted of 10 males between the ages of 5.8 and 10.0 years ($\bar{X}$ = 7.56 yrs., *SD* = 1.71 yrs.). The autistic subjects were students at the Douglass Developmental Disabilities Center at Douglass College, Rutgers University, a day training, research, and educational facility. All of the 10 autistic subjects met Ornitz and Ritvo's (1976) criteria for diagnosing autism; i.e., they manifested irregularities in development and disturbances in the modulation of sensory input, social relatedness, and language prior to 3 years of age. The mean number of items for each autistic child from the National Society for Autistic Children's working definition of autistic children was 6.1 (*SD* = 1.7). Five of the autistic subjects' IQ scores placed them in the mildly retarded intellectual range, two in the moderately retarded range, and three in the moderate to severe category. Seven of the autistic children were Caucasian, two were Asian-Americans, and one was Black.

Ten males matched to the autistic subjects by approximate chronological age and race constituted the normal group. The mean age of the normal subjects was 7.7 years (*SD* = 1.4 yrs.). Inclusion in the normal group required the absence of any known mental, physical, or emotional disability and age-appropriate achievement in school. As was the case with the autistic group, seven were Caucasians, two were Asian-Americans, and one was Black.

Written parental permission for the participation of each child was obtained after the goals and procedures of the experiment were verbally explained. Each normal subject received an age-appropriate explanation of the experiment, and each child was advised that he was free to terminate participation at any time without penalty. All subjects completed the procedure without complaint.

Apparatus and Physiological Recording

All subjects were tested individually in a sound-attenuated room (2X 3.2 m). A small air-circulating fan provided a low level of background noise in the experimental chamber. The ambient noise level of the experimental chamber was below 60dB sound pressure level (SPL). The subject was seated in a comfortable chair, and his legs were supported on a wood and foam-cushioned platform to facilitate quiet, motionless sitting. Two Beckman miniature biopotential electrodes filled with Cambridge electrode jelly were placed bilaterally on the lower rib cage for detection of the electrocardiogram (EKG). The EKG was transduced by an electronic cardiotachometer into heart rate in beats per minute. Two Beckman standard biopotential electrodes were placed in the center of the plantar surface of the right foot to monitor skin conductance. The skin conductance electrodes were filled with Unibase saline solution (Lykken & Venables, 1971) and secured with an electrode collar and surgical tape. The child's sock was put on over the electrodes on the right foot in order to minimize awareness or manipulation of the apparatus. Skin conductance was measured by means of a constant voltage circuit with a maximum sensitivity of .01 micromho/mm. A Grass model E34DS silver earclip was attached to the subject's right ear to serve as a ground.

EKG and skin conductance were continuously minotored and written out on a Grass model 5D polygraph at a paper speed of 15 mm per second.

All of the physiological recording equipment and apparatus for stimulus presentation (except for a loudspeaker) was located in a room adjacent to the experimental chamber.

Stimuli

Three varieties of stimuli were included: (1) a 5-sec 500-Hz pure tone of uncontrolled rise time generated by a Hewlett Packard 200 AB audio oscillator (tone), (2) a spoken phrase of nonsense words ("sponzel nirem, shern") inflected as a normal declarative sentence (nonsense), and (3) the spoken phrase "Listen to me,   " (the subject's first name was inserted). This phrase served as the socially relevant stimulus (meaningful). The nonsense and meaningful stimuli were spoken by an adult female. All stimuli were presented at a peak level of 75 dB (SPL) by means of a Sharp RD 708 tape recorder through a loudspeaker positioned 2.1 meters high on a wall 1.7 meters in front of the subject's head.

The three stimulus types were arranged in six counterbalanced orders to control for sequence effects. Within each order, five consecutive trials of each stimulus type were presented, for a total of 15 trials. Intertrial intervals varied randomly from 30 to 60 seconds, with the provision that if the subject was moving, stimulus presentation was delayed until the child resumed quiet sitting for a period of at least 10 seconds.

Measurement and Scoring of Physiological Activity

Heart rate data were hand-scored from the polygraph record for each individual trial for 1 second prior to and 10 seconds following stimulus onset, and converted to average heart rate per second (Graham, 1978 a,b). Skin conductance was scored from each subject's polygraph record with regard to *level* at the onset of each stimulus, and for maximum amplitude change from baseline for a period of 10 seconds poststimulus onset, i.e., skin conductance *response.* Finally, spontaneous fluctuations in skin conductance were tallied for the first 20 seconds of each interstimulus interval (10 seconds poststimulus onset to 30 seconds poststimulus onset).

Procedure

Acclimation Phase. A behavioral shaping procedure was administered to facilitate the adjustment of the autistic children to the laboratory setting and experimental conditions, i.e., sitting quietly and wearing electrodes. The number of acclimation sessions required to reach a criterion of sitting quietly for a period of 30 seconds or more while wearing electrodes ranged from 4 to 11 sessions per subject (Mean = 8.1 sessions). Acclimation sessions ranged in length from 5 to 25 minutes, with the typical session lasting approximately 15 minutes. The acclimation process consisted of a series of goal-oriented steps beginning with acquaiting the experimenter and individual subjects, helping the subject to sit comfortably in the experimental room, and finally, helping to shape quiet and comfortable sitting while wearing electrodes. No stimuli were presented via the loudspeaker prior to data collection, which occurred on the day after criterion was reached. In addition, the autistic subjects were tested during their regular school day in the familiar surroundings of their school. Data from normal children were recorded on their first visit to the lab on days when their school was not in session. This differential procedure was implemented for the sole purpose of minimizing the stressfulness of the experimental situation for the autistic group.

Because pilot testing indicated that normal children quickly adapted to the laboratory situation, normal subjects did not receive acclimation training. Upon arriving at the lab the normal subjects were introduced to the experimenters and given an explanation of the psychophysiological measures to be recorded during the experiment. Each subject was instructed to relax, to sit as quietly as possible throughout the procedure, and not to reply to any of the sounds from the loudspeaker. All subjects were informed that they could stop participating in the experiment at any time without penalty.

RESULTS

Cardiac Data

An overall analysis of variance (ANOVA) for the second of time preceding the onset of the three stimuli indicated that baseline heart rates were comparable for the two groups ($F(1,18) < 1$, n.s.) and for all of the stimulus types ($F(1,18) < 1$, n.s.). Visual examination of plots of the two groups' average cardiac responses indicated that the heart rates had returned to prestimulus rates by 6 seconds poststimulus onset. Hence, analyses were conducted on cardiac data representing the prestimulus second and 6 poststimulus onset seconds. An overall ANOVA of the prestimulus second and the first 6 seconds poststimulus onset yielded significant types X groups ($F(4,36) = 4.34, p < .02$) and seconds X groups ($F(6,108) = 4.13, p < .001$) interactions. Therefore, individual analyses of linear, quadratic, and cubic trends of seconds were conducted for each stimulus type to assess each group's wave form of cardiac response.

In response to the tone, the autistic children exhibited slight acceleration above baseline, which was not significant (all trends of seconds, $F(1,9) < 1.48$, n.s.). In contrast, the normal group's response to the tone was deceleratory, reaching a trough at 1 second poststimulus onset (seconds quadratic $F(1,9) = 6.57, p < .03$; seconds cubic $F(1,9) = 6.02, p < .04$). Figure 1 depicts the two groups' cardiac response to the tone expressed as difference scores from the prestimulus second. A comparison of the two groups' reactions to the tones indicated that the normal group's deceleration differed from the cardiac response of the autistic group (seconds quadratic X group $F(1,18) = 5.92, p < .03$).

Figure 2 depicts the cardiac response data for the nonsense stimulus (socially irrelevant speech). In response to the nonsense speech, the autistic

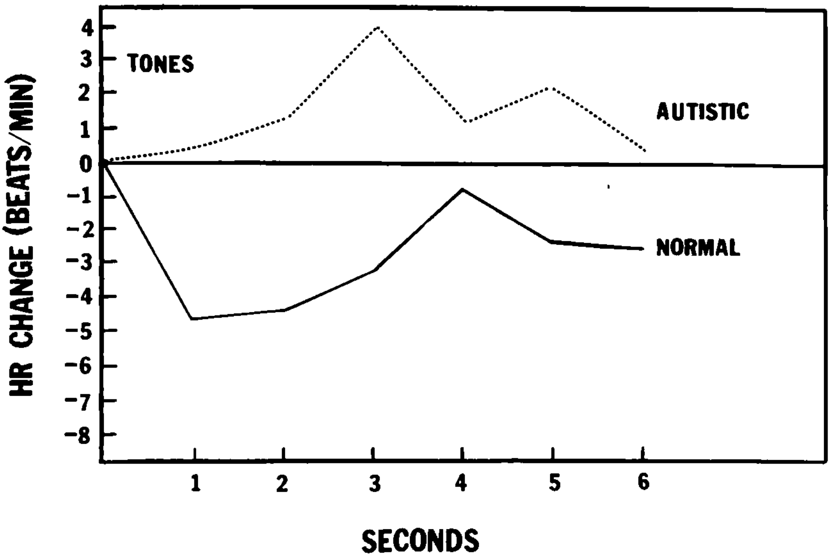

Fig. 1. Mean cardiac response of the autistic and normal groups to the 500-Hz tone expressed as differences from the prestimulus values.

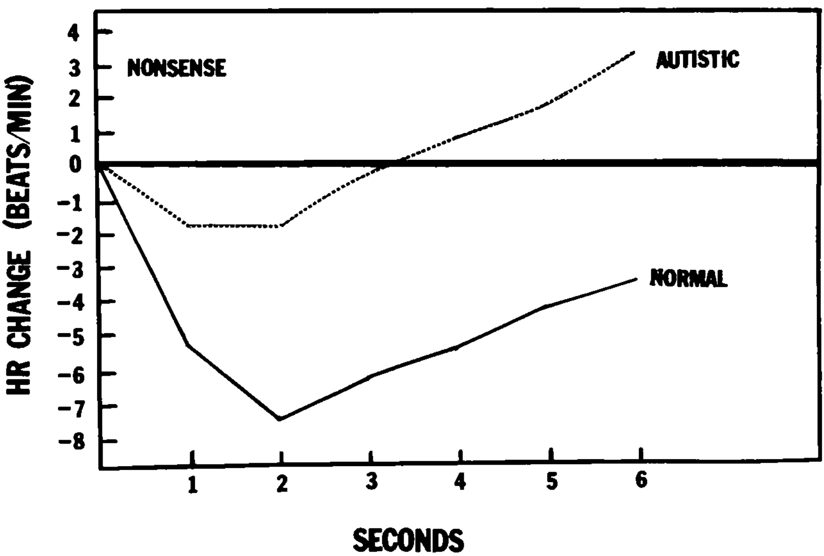

Fig. 2. Mean cardiac response to the nonsense phrase (socially irrelevant speech) plotted by group.

group displayed a biphasic response including an initial deceleration of heart rate that was greatest 1 second after the onset of the stimulus, followed by acceleration above baseline. This acceleratory response was reflected in a significant linear ($F(1,9) = 8.78$, $p < .02$) trend of seconds. The normal group's response was characterized by a sharp deceleration (seconds quadratic $F(1,19) = 13.00$, $p < .006$), which reached a trough at 2 seconds poststimulus onset. A comparison of the two groups' responses indicated that the deceleratory limb of the normal group's heart rate change was more pronounced than that of the autistic group's (seconds linear X group $F(1,18) = 6.66$, $p < .02$).

The cardiac data for the meaningful (socially relevant) speech stimulus are displayed in Figure 3. The autistic group reacted with a slight deceleratory heart rate response to the meaningful stimulus, with the greatest slowing at 1 second after the onset of stimulation and followed by a secondary acceleration above baseline. This biphasic response is reflected in the quadratic trend of seconds ($F(1,9) = 6.55$, $p < .03$). The normal group's reaction was characterized by a sharp deceleration at 1 second poststimulus onset and a gradual return to baseline over the next 5 seconds. The quadratic ($F(1,9) = 11.45$, $p < .008$) and cubic ($F(1,9) = 14.97$, $p < .004$) trends of seconds were significant in the normal group's wave form. Statistical comparison of the two groups' wave forms failed to yield a significant effect (linear, quadratic, and cubic trends all $F < 2.72$, n.s.), although

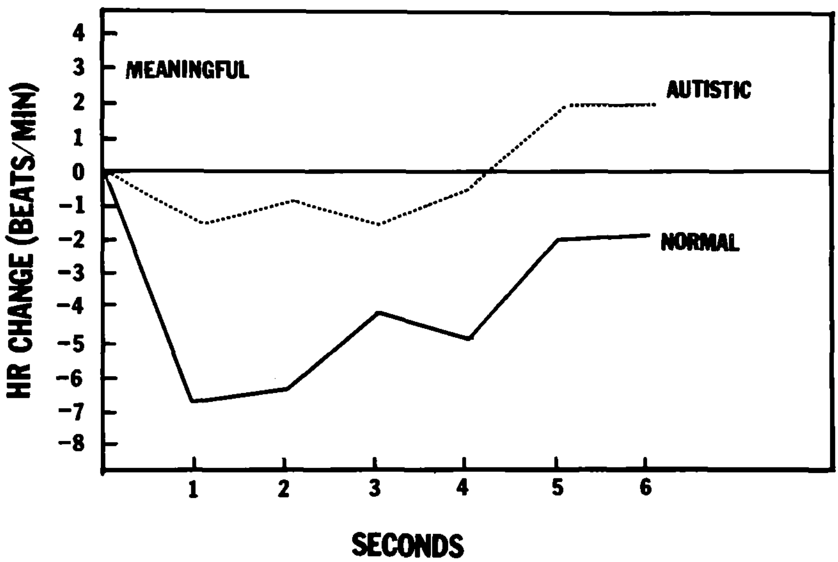

Fig. 3. Mean cardiac response to the meaningful (socially relevant speech) stimulus.

the normal group's heart rate response showed a trend toward greater complexity than the autistic group's (seconds quadratic X group $F(1,18) = 4.05$, $p < .059$).

Analyses of variance failed to yield any significant interactions of seconds with trials or seconds X trials X groups, indicating no evidence of response habituation for any of the stimulus types. Hence, no further analyses were conducted upon the trials data.

Electrodermal Data

The mean skin conductance level of the autistic subjects was significantly greater than that of the normal group (9.25 micromho vs. 3.39 micromho, respectively; $F(1,18) = 16.58$, $p < .001$). This between-groups difference was also significant when analyses were performed on log-transformed skin conductance levels ($F(1,13) = 11.39$, $p < .003$). The analyses failed to disclose significant interactions of groups with trials or types. Table I displays the mean raw and log-transformed electrodermal levels of the autistic and normal groups. Visual examination of Figure 4 suggests that there was very little overlap in the individual scores of subjects between the groups.

Although a highly significant difference was found in the two groups' resting skin conductance levels, the overall magnitude of electrodermal

Table I. Mean Group Skin Conductance Levels as a Function of Stimulus Type and Trial

		Raw scores[a]		Transformed scores[b]	
Stimulus type	Trial	Autistic	Normal	Autistic	Normal
Tone	1	9.84	3.35	.91	.46
	2	9.48	3.36	.89	.46
	3	9.51	3.14	.88	.44
	4	9.89	3.13	.91	.40
	5	9.51	3.29	.89	.44
Nonsense	1	8.45	3.20	.83	.39
	2	8.97	3.10	.86	.39
	3	9.41	3.05	.88	.38
	4	9.25	2.90	.88	.36
	5	9.65	2.80	.89	.35
Meaningful	1	9.47	3.62	.89	.49
	2	10.09	3.38	.91	.47
	3	9.74	3.44	.90	.47
	4	10.05	3.33	.92	.45
	5	9.89	3.34	.91	.44

[a] Scores represent micromho.
[b] Scores transformed to $\log_{10}$.

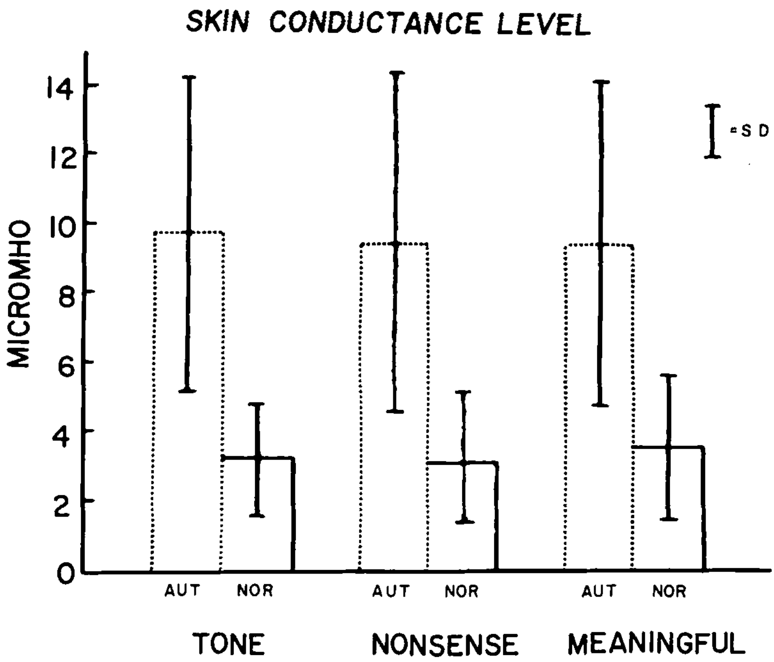

Fig. 4. Mean group skin conductance levels at the onset of the first trial of the tone, nonsense, and meaningful stimuli.

response to the stimuli failed to differentiate the groups' mean response (.57 micromho vs. .20 micromho for the autistic and normal groups, respectively; $F(1,18) = 2.57$, n.s.). No group by type nor type X trial interactions were significant.

In a total of 140 intertrial intervals (per group) the autistic group had a frequency of 223 spontaneous skin conductance responses as compared to the normal group's 45 responses. A chi-squared analysis of these data indicates a group difference that is highly significant ($\chi(1) = 118.22$, $p <$ .001).

DISCUSSION

The results indicated that whereas the normal children demonstrated cardiac slowing in response to all three stimuli, the autistic children responded with primarily accelerative changes to the nonsense and meaningful stimuli. Moreover, the autistic children's decelerative heart rate changes tended to be of lower magnitude than the normal children's. Heart rate deceleration has been associated with attentional processes reflecting environmental intake (Graham & Clifton, 1966). The normal children responded to all of the stimuli with cardiac deceleration that was maintained over the five trials. Hence, it may be concluded that the normal children's attentional response to the stimuli was relatively greater than the autistic children's, especially in response to the nonsocial (tone) stimuli.

In an earlier investigation of psychophysiological reactions of normal and autistic children (Bernal & Miller, 1970), no between-groups cardiac or resting electrodermal level differences were found. In contrast, marked autonomic group differences existed in the present investigation. The autistic children's decelerative cardiac response to the auditory stimuli was less pronounced than that of the normal children, regardless of stimulus type or trial. In the case of the tone, the autistic children did not evidence a significant heart rate response, whereas the normal subjects oriented to the sound.

Our results suggest that the autistic children studied in this experiment exhibited deficits in psychophysiological reactivity to a range of environmental stimuli in comparison to normal children. Because the autistic children's response to the socially relevant stimulus was least discrepant from that of our normal sample, we suspect that the autistic group's response may reflect the benefit of behavioral training in attending to adults. This kind of training is a basic ingredient in social learning treatment programs such as those employed at the Douglass Center. Phrases such as "listen to me" are common attention-elicitors for these children. As such, the socially relevant stimulus may have represented a cue to prepare for information intake for the autistic group. On the other hand, the tone, a socially irrelevant stimulus, may be novel for normal children but appeared to be irrelevant as an environmental stimulus for autistic children. This interpretation of our data is consistent with the theoretical formulations espoused in several related investigations. Johnson (1976) has suggested that the orienting reflex is "better conceptualized as a response correlated with input of information rather than a response correlated with novelty (p. 135). Lewis (1978) has more strongly stated that a stimulus is novel because it provides relevant information to the organism, not necessarily because of specific physical characteristics. In conclusion, any particular stimulus may fail to evoke an OR for either of two reasons: (1) it contains a minimum of information, or (2) the information that it does contain is of no relevance to the organism (Johnson, 1976).

Our findings suggest that the autistic children tend to respond autonomically with defensive patterns to stimuli that are greater in social relevance. That is, the autistic subjects exhibited heart rate accelerations to the two speech stimuli. The acceleratory climb of the autistic subjects' response to the tone was not a significant change from baseline. This finding supports our hypothesis that austic children exhibit defensive responses to social stimuli.

The electrodermal level data suggest that the disturbed children experienced a state of autonomic hyperarousal relative to the normal children. The most parsimonious explanation for the finding of the higher skin conductance levels in the autistic children would be the existence of more movement artifact in the autistic group. However, this possibility is highly unlikely, because trials where movement occurred within a 10-second period prior to stimulus onset were excluded from the analysis. In fact, relatively few trials showed evidence of preonset movement (seven and four trials for the autistic and normal groups, respectively).

Fluctuations in arousal level may also be related to the overall differences in skin conductance level described above. It can be seen that the variance in the autistic group's resting level was considerably greater than that of the normal group. This finding is consistent with models of increased arousal and greater fluctuations of arousal in autistic as compared to normal children (i.e., based on these models one would expect to find a higher overall mean skin conductance level with greater variance as a result of greater lability). Further, a measure of the two groups' spontaneous fluctuations in skin conductance indicated that the autistic group manifested a far greater number of phasic changes than the normal group did. Katkin (1975) has reported that the presence of spontaneous fluctuations in skin conductance is correlated with arousal level. As such, the electrodermal findings provide convergent evidence for the findings of Hutt and Hutt (1965) and Sroufe and Waters (1977) indicating relatively greater arousal in autistic children. The evidence of electrodermal hyperarousal coupled with a decrement of the heart rate component of the orienting response in the autistic group suggests an autonomically based correlate of certain behavioral manifestations and learning deficits among autistic children. Although between-groups differences in amounts of gross bodily movement did not exist, the possibility remains that the stimuli tended to differentially evoke greater amounts of subtle phasic somatic activity in the autistic group (such as muscle tension). This possibility should be explored in future research. An alternative hypothesis is that autistic children experience a high degree of internal "noise" relative to which environmental stimuli have diminished impact.

As noted above, all of the autistic subjects were characterized by some degree of mental retardation. Data that provide divergent evidence that autistic children's autonomic responses differ from those of other diagnostic groups of children (e.g., retarded children) are needed before speculation is warranted concerning mechanisms underlying diminished cardiac responsivity. There appear to be some discrepancies in the existing literature concerning the relationship between mental retardation and the OR. The Russian literature (cf. Luria, 1963) reports that the stimuli that elicit an OR in normal children frequently fail to do so in a group of retarded children matched by chronological age. In a review of the American literature, Heal and Johnson (1970) cited research that has not consistently supported the hypothesis of a weak OR in retarded children. Unpublished data provided by Elliot and Johnson (reported in Johnson, 1976) indicate that when comparing the ORs of mentally retarded and normal subjects, the intensity of the chosen stimulus and the IQ of the subjects determines which group demonstrates the stronger OR. Johnson (1976) concluded that it "appears impossible to make the general statement implied by the Russians that retarded subjects have a weak OR" (p. 134). It is possible that the findings of the present study apply only to the subgroup of autistic children who can discriminate between speech and nonspeech stimuli.

It is highly likely that differences in autonomic responsivity are accompanied by physiological as well as behavioral manifestations. Lynn (1966) has reported that abnormalities consisting of a weakness or absence of the orienting response are presumably due to an inhibition of the reticular formation. The weakened cardiac orienting exhibited by the autistic group would suggest, therefore, that reticular inhibition may be etiologically involved in this group of autistic children. A substantial amount of evidence points toward the ascending reticular activating system (ARAS) as the central transactional core of the central nervous system (Magoun, 1958). Evidence that the ARAS plays an important role in the sleep and waking cycles as well as acting as a circuit breaker of inner or outer stimuli is overwhelming (Cairns, Oldfield, Pennybacker, & Witteridge, 1941; Penfield, 1954; Denny-Brown, 1962; Olds, 1958). As such, defects within the ARAS could lead to fluctuations in attention and responsivity characteristic of autistic children.

We are now conducting further investigations of autistic and normal children's reactions to a variety of environmental stimuli across several sensory modalities. In addition, we are investigating the question of whether autistic children may be especially responsive autonomically to particular varieties of stimulation (e.g., objects that may precipitate stereotyped behaviors).

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