PREDICTION OF HEARING THRESHOLDS BY MEANS OF THE ACOUSTIC REFLEX WITH AUTISTIC AND NORMAL SUBJECTS

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This study concerns audiometric evaluation and prediction of hearing loss in the autistic child based on information derived from acoustic reflex thresholds. Two groups (autistic males and normal children) of five subjects each were utilized. Results indicated that the acoustic reflex method consistently predicted significantly higher hearing thresholds for autistic subjects than operant pure-tone audiometric procedures. Furthermore, the acoustic reflex thresholds were significantly less sensitive in the autistic group than in the normal group, suggesting that the acoustic reflex response is somehow altered in autistic individuals. These findings are consistent with earlier work which hypothesized that autistics manifest an organic brain lesion which interferes with the propagation of auditory information.

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The present study addresses the problems of audiometric evaluation and prediction of hearing loss in the autistic child. It has been found that the visual and auditory perceptual systems are particularly important to normal child development and that adequate hearing is essential for normal language development (Cruishank, 1967, Kephart, 1960; Kirk & Kirk, 1971). Researchers in the field of language and learning disabilities have come to the conclusion that developmental lags and deviant behavior may occur as a result of perceptual deficits. Audiological research, however, has indicated that valid and reliable audiometric data were most often difficult to obtain in children with severe behavioral disorders, retardation, aphasia, and other language handicaps (Lloyd, Spradlin, & Reid, 1968).

This difficulty in obtaining reliable audiometric data has often occurred in the case of the autistic child. His bizarre behavior, aggressiveness, hyperactivity, self-destructiveness, or his lack of responsiveness has made difficult the acquisition of even gross audiological information. Because of the unresponsiveness to sensory stimuli (Rimland, 1964; Wing, J., 1966), the autistic child has been often misdiagnosed as having an auditory or visual impairment when in fact audition and vision have been normal

(Rimland, 1964). Misdiagnoses may have occurred in another way as well. That is, a highly disruptive child with deficits of language and communication may have been diagnosed as autistic rather than sensorily impaired due to the presence of certain autistic-like behaviors.

Additional confusion has arisen when an autistic child has had a hearing loss in conjunction with the characteristic autistic behaviors. Several studies have indicated large deficits in the autistic's auditory functioning (Davis, 1967; Hoberman & Goldfarb, 1963; Rutter, 1966a; Wing, L., 1966, 1969). Such findings have indicated the significance of accurate audiological assessment and its relevance to treatment. It has been generally agreed that an early and accurate conception of the child's problem, in most cases, was an essential prerequisite to the differential treatment of that problem. Kanner and Eisenberg (1955) found that if an autistic child had not acquired the use of language by the age of 5 years, it was highly unlikely that language would be acquired thereafter; thus, the prognosis for the child's future was poor.

Traditional pure-tone hearing examinations have been very difficult to administer to the autistic child primarily because of an inability to communicate. Special audiometric testing procedures often have been necessary when other behaviors diagnostic of the autistic syndrome accompanied this characteristic lack of communicative ability. Operant audiometric testing procedures have been found to be very effective with nonverbal populations such a neonates, small children, retarded individuals, aphasics, and autistic children (Bricker & Bricker, 1969a, 1969b; Dahle & Daly, 1974; Fulton & Spradlin, 1971; Lloyd et al., 1968; McReynolds, 1966; Meyerson & Michael, 1960; Suzuki & Ogiba, 1961). Unfortunately, it has not always been possible to obtain early valid hearing assessment for many autistic children. This difficulty of assessment has often been the case since operant testing procedures frequently require expensive programming equipment, individuals trained in operant methodology, and additional or lengthy visits to the clinic for conditioning to take place.

Another test has become available, however, which has offered the promise of applicability to the problems of differential diagnosis and treatment of audiological disorders with the autistic population. Impedance audiometry has been a method of measuring auditory acuity by means of a reflexive response of the tensor tympani and the stepedius muscle within the middle-ear. The reflex involved has been generally referred to as the acoustic reflex. A functional relationship has been shown to exist between hearing thresholds obtained from standard pure-tone assessment and hearing thresholds obtained through measurement of the acoustic reflex in normal-hearing persons and patients suffering from sensori-neural hearing loss (Niemeyer & Sesterhenn, 1974).

The relationship between threshold of audibility and threshold of the acoustic reflex for pure-tones and broadband noise has been used as an objective measure of hearing sensitivity of neonates, cleft-palate children, and young children (Bess, Lewis, & Cieliczka, 1975; Jerger, 1970; Robertson, Peterson, & Lamb, 1968; Terkildsen, 1960; Wedenberg, 1963) and also to determine the existence and magnitude of nonorganic hearing impairment (Harper, 1961; Jepsen, 1953, 1963; Lamb & Peterson, 1967; Lamb, Peterson, & Hansen, 1968; Terkildsen, 1964; Thomsen, 1955a, 1955b; Wilmot, 1969). Jerger (1974) found that by using acoustic reflex thresholds for pure-tones and white noise he could objectively predict the severity (categorical) of audiometric loss in 1043 ears with sensori-neural hearing loss. Serious errors occurred in only 4% of these cases.

No study has been published which has attempted to predict hearing level from measurement of the acoustic reflex in the autistic population or which has tested for differences in the ability of impedance audiometry to predict actual hearing thresholds in autistic and normal populations. The present study was an attempt to test for differences in the predictive ability of impedance audiometry between samples of the autistic and normal populations.

An investigation of the usefulness of impedance audiometry with the autistic population has been shown to be important for several reasons. An objective measure of hearing acuity was important to the differential diagnosis of children suspected of being autistic since many of these children at times appeared to be deaf. However, reliable and objective measures of hearing were most difficult to obtain in these children since they typically had very little or no functional language, appeared to be highly selective in their attention to the environment, and behaved in quite bizarre and disruptive ways. Operant pure-tone audiometric procedures have been demonstrated to be effective for testing the hearing of autistic children, but several difficulties have arisen in the actual clinical use of these procedures. With the autistic child, appropriate stimulus control was difficult to achieve even under optimal conditions. Thus, it was necessary for a clinician skilled in operant methodology to be available for the conditioning procedure which took many hours, days, or even weeks in some cases. It was frequently not feasible for the parents or the clinician to make accommodations for the protracted time involved. Further, for conditioning to occur most efficiently and quickly special electronic programming equipment for the automatic and systematic control of stimulus and consequence presentation was required. These factors have combined with the net result that a quick, reliable, and highly objective evaluation has not been generally available for the audiological diagnosis of children suspected of being autistic. For this reason a measure of hearing sensitivity which met these criteria and was more widely available was found to be greatly needed. Acoustic impedance audiometry has been demonstrated to be very useful in the diagnosis of auditory pathology.

A review of the literature revealed that this procedure could be highly suitable for use with autistic children. First, it did not require that the subject be able to speak or to understand instructions since the child was required only to sit quietly for a few minutes. Secondly, no stimulus-response conditioning was required in order to obtain measurements of the acoustic reflex; the results were not dependent upon an operantly conditioned response. Thus, stimulus control was not a critical factor as it was in an operantly conditioned auditory discrimination task with autistic children. Finally, the entire procedure need not take more than 10-30 minutes except for very disruptive children.

The present study explored the relationship between threshold of audibility for pure-tones and broad-band white noise as measured by changes in dynamic acoustic impedance resulting from induced reflexive contraction of the middle-ear muscles and threshold of audibility for pure-tones as measured by standard and operant audiometric procedures in samples of the autistic and normal populations. Based on the autistic child's peculiar responsiveness to auditory stimuli and recent research bearing on the etiology of autism, there was found to be reason to suspect a difference in the relationship between pure-tone hearing thresholds and acoustic reflex thresholds for autistic and normal children. Thus, the hypothesis under investigation was that there was no significant difference between the autistic and normal populations in predictability of hearing sensitivity from threshold measurement of the acoustic reflex.

The literature pertaining to the present study was classified according to three major content areas: (a) characteristics and etiology of autism; (b) prediction of hearing loss from threshold measurement of the acoustic reflex; and (c) operant pure-tone audiometric procedures with difficult-to-test subjects.

Characteristics and Etiology of Autism

Childhood autism has been a separate diagnostic category only since 1943 when Dr. Leo Kanner first used the term to describe children exhibiting certain characteristics which he felt constituted a separate syndrome from the other childhood psychoses (Kanner, 1943). Researchers were not certain how long the syndrome had existed, but it was believed that several historical accounts of deviant children from earlier times were descriptions of children we would now diagnose as autistic (Haslam, 1809; Itard, 1801, 1807; Vaillant, 1962; Witmer, 1930). Prior to 1943 autistic children were generally diagnosed as mentally retarded (Copel, 1967; Rutter, 1968).

Childhood autism was considered to be a major syndrome of childhood psychoses along with childhood schizophrenia and symbiosis. Many authors used the terms childhood psychosis and autism interchangeably since autism was considered to be the most important type of childhood psychosis (Kessler, 1966). The autistic syndrome has been confirmed as a viable diagnosis by many psychologists and educators (Copel, 1967; Pronovost, 1961; Rimland, 1964; Ritvo & Provence, 1953) and has been variously termed early infantile autism, early childhood autism, and childhood autism (Rimland, 1964).

As noted earlier, at one time most of the children presently included in the classification of childhood autism were considered mentally retarded (Rutter, 1968). Seventy to 80% of autistic children were found to be functionally retarded. On standard intelligence tests and social behavior inventories they were found to function in the retarded range (Lockyer & Rutter, 1970; Rutter, 1965a). However, Rutter (1968) believed that autism could not be considered another variety of mental retardation since 1/3 to 1/4 of these children scored average or above average on nonverbal intelligence tests (Lockyer & Rutter, 1970; Rutter, 1965b). Retarded children generally showed a flat or rather uniformly depressed intelligence profile, whereas, autistic children typically scored high in some categories and low in others (Rutter, 1968). In addition, J. Wing (1966) found that the severe interpersonal deficiencies and aberrations of the autistic such as isolated play, no bonds of friendship, and lack of human eye contact occurred less frequently and less intensely in the retarded population. Few autistic children showed the delays in motor development typical of the retarded child and many autistics were quite agile, graceful, and attractive (Rimland, 1964).

Autism did, however, occur in conjunction with retardation and other problems in about 50% of all cases. This was frequently a complicating factor in the diagnosis of the syndrome. Convulsive disorders, mental retardation, cerebral palsy, brain damage, and disorders of hearing and vision were some of the more common afflictions which have been found to accompany the autistic syndrome (Wing, J., 1966).

Autism has been shown to be a relatively rare condition with the general incidence being about 4.5 in every ten thousand children. The syndrome has been found to occur about four times more frequently in males than females. The reasons were unknown but most conditions in which language problems were found to be important seemed to be more prevalent in males (Wing, L., 1974). Early studies indicated that most autistic children were found in families of above average intelligence and above average socio-economic status (Lotter, 1967). However, these studies have been criticized because of small sample size and narrowness of the definition of the syndrome (Wing, L., 1976).

A child was diagnosed as autistic based upon a rather unique profile of behaviors (Rimland, 1964; Wing, J., 1966). Disorders of speech were a major distinguishing characteristic of the autistic child (Pronovost, Wakstein, & Wakstein, 1966; Rimland, 1964; Rutter, 1968; Wing, J., 1966). Approximately 50% of these children never acquired any functional speech (Eisenberg, 1956; Kanner & Eisenberg, 1955; Lockyer & Rutter, 1969; Rimland, 1964; Rutter, 1966a, 1966b). Speech failed to develop or the child went through a period of apparently normal language acquisition and then suddenly ceased further development or even partially or completely lost that which had already taken place (Wing, J., 1966). Those autistic children who did acquire speech had marked aberrations and retardation in speech development (Kanner, 1943; Pronovost et al., 1966; Rimland, 1964; Rutter, 1965b, 1966a; Wing, J., 1966). Echolalia was one of the more common deviant speech patterns (Pronovost et al., 1966; Rutter, 1965b, 1966a; Wing, J., 1966). Expressive spontaneous speech when present in the autistic child was also invariably disordered in some manner (Pronovost et al., 1966; Rimland, 1964; Rutter, 1965b; Wing, J., 1966). A variety of speech abnormalities was common. Autistic children displayed pronominal reversal, special voices, articulation deficits, formal language, over-concrete language, confusion of words, fragmented speech, and incorrect word order and syntax (Kanner, 1943; Rutter, 1965a, 1966a, 1966b; Wing, L., 1969). Pronovost et al. (1966) noted several common aberrant features of the speech of the verbal autistic children in their study: monotonal speech with frequent high-pitched sounds, extreme variations in intensity range, and disordered voice qualities such as hoarseness, harshness, and hypernasality interspersed with the normal voice. They also reported that most of the children's speech was inappropriate to the situation in which it was expressed.

The level of speech development appeared to be prognostic of the autistic child's later functioning (Brown, 1960; Kanner & Eisenberg, 1955; Rutter, 1966b). Kanner and Eisenberg (1955) found that the autistic child who reached the age of five without developing speech continued to perform at a very primitive level of socialization in later years.

Understanding speech often was as difficult as producing it for these children (Wing, L., 1976). Autistic children appeared to be unresponsive to the spoken word (Hermelin & O'Connor, 1963; Pronovost et al., 1966; Rutter, 1966a; Wing, L., 1976). These children's responses to commands were inconsistent and when they did respond to commands, other ancillary cues were frequently present (Wolf & Ruttenberg, 1968). Pronovost et al. (1966) found that when these children did respond to the auditory aspects of the commands, their responses were controlled by situational cues or gestures rather than by the specific words. On the basis of data gathered from parents, L. Wing (1966) reported that all the autistic children in her study at one time had difficulties comprehending speech.

Perceptual deficits, particularly in the auditory mode, often resulted in severe behavior deficits such as lack of speech expression and reception (Strauss & Kephart, 1955). In general, investigators found that the auditory responses of the autistic child were indeed aberrant (Davis, 1967; Hoberman & Goldfarb, 1963; Rutter, 1966a, 1968). J. Wing (1966) stated that failure to respond to noise was typical at some stage of development. Rutter's population (1966a) evidenced a marked lack of response to sound. The most striking difference between a subnormal control group and the psychotic group in Rutter's study was the failure of the psychotic group to respond to sound. Rutter found that the psychotic children were even more unresponsive to the spoken word than to sound in general. Pronovost et al. (1966) found that the responses to both nonspeech and speech sounds of the mute autistic children in their study were either absent or markedly depressed. L. Wing (1969) reported that all of the autistic children in her study evidenced deviant responses to sound sometime in their development. Davis (1967) found that even in an environment in which auditory stimuli were structured, the most advanced skill that 2/3 of the autistic children in her study displayed was localization of sound. In a second study of autistic children, Davis (1970) found that in a structured environment, these children could localize sound but could not match sounds of simple noise-makers. In an unstructured environment, the children failed to respond to either speech or nonspeech sounds. The autistic child's unawareness of sound was often so pronounced that speculation about a hearing loss at some point during development was common (Hoberman & Goldfarb, 1963; Kessler, 1966). One-third of the psychotic children in Rutter's study (Rutter, 1966a; Rutter & Lockyer, 1967) had been thought to have been deaf at sometime.

According to Hoberman and Goldfarb (1963) unawareness of sound was not the only aberrant auditory response characteristic of autistic children. They reported aberrations in auditory behavior ranging from complete unawareness of sound to over-alertness, obvious distress, fear, and apprehension. J. Wing (1966) stated that avoidance of auditory stimuli, particularly loud noises or speech was common. Rutter (1966a) found several psychotic children in his population who reacted excessively to sound. Goldfarb (1964) stated that the autistic child's response to sound varied from an extreme reaction to soft sounds, to the total exclusion of loud ones. Goldfarb (1963) indicated that hypersensitivity and hyposensitivity to sounds were ordinarily found in the same child. At one time a child would cover his ears in reaction to the rustling of leaves and at another time would ignore a shattering noise. According to Wolf and Ruttenberg (1968), one of the most obvious symptoms of childhood autism was this aberrant response to environmental sounds. Their study of the auditory responses of 34 autistic children disclosed a great variability and inconsistency within the response patterns of each child. Responses varied from total lack of awareness of sound to reacting appropriately to words in familiar contexts and in the company of auxiliary cues, such as gestures. Hoberman and Goldfarb (1963) and Wolf and Ruttenberg (1968) further contended that aberrant responses to sound were the first indicators to parents of autistic children that something was wrong.

Some investigators found evidence that the autistic child's visual perceptual skills were also disordered (Hermelin, 1966; Hermelin & O'Connor, 1964, 1965; O'Connor & Hermelin, 1967; Wing, L., 1966, 1969). Occasionally an autistic child was suspected of being blind at some stage in his development, but this was uncommon (Wing, L., 1966). Autistic children characteristically demonstrated a preference for peripheral vision over central vision. Thus, the autistic child tended to look past objects and people, twist his fingers to one side of his face in the periphery of vision, and recognize moving objects more readily than stationary ones (Wing, L., 1966, 1969). The investigators cited above believed that these tendencies reflected visual perceptual disorders.

There was evidence, however, that at least some autistic children did not have visual perceptual deficits but rather possessed compensatory strengths in this mode. Some autistic children demonstrated superior functioning in form perception (Kessler, 1966). In their study of six autistic children, Ritvo and Provence (1953) found that these children had advanced form perception. It was without exception the highest area of performance and was equivalent to, or above, age level norms. Kanner (1943) reported high performance on the Sequin Form Board in his autistic population. Mittler (1966) stated that many autistic children have been reported as showing exceptional skills in working jigsaw puzzles. Kessler (1966) contended that autistic children worked puzzles efficiently by attending to form.

The other senses--olfactory, gustatory, and tactile--have received only very limited attention from researchers in the field of childhood autism (Wing, J., 1966). Rutter (1966a) reported that autistic children often have been observed to touch or smell new objects. Also, the autistic child often has exhibited unusual tastes and interests in certain smells (Wing, J., 1966). In a 1964 study, Hermelin and O'Connor found that if given the choice of responding to a tactile stimulus versus a visual stimulus, autistic children tended to select the tactile stimulus over the visual stimulus more often than did the subnormal controls.

Lovaas and his associates conducted two studies concerning the tendency of the autistic child to selectively respond to one dimension of a multidimensional stimulus. Using a stimulus complex with three sensory dimensions--auditory, visual, and tactile--Lovaas, Schreibman, Koegel, and Rehm (1971) found that autistic children selectively responded to one dimension of a multiple sensory stimulus complex. The stimulus complex in the second study had only two dimensions: auditory and visual (Lovaas & Schreibman, 1971). Results from both studies indicated that the autistic children responded mainly to one sensory dimension of a multi-dimensional stimulus. Normal children responded to all the dimensions equally. A preference for one type of stimulus over others was not evident in the autistic population. Some autistic children attended more to the auditory stimulus while others attended more to the visual stimulus. The nonfunctional stimulus acquired discriminative properties when it was trained in isolation as the discriminative stimulus.

The inability to produce or understand language along with disturbed perceptual functioning appeared to be the most salient diagnostic features of autism but there were other indicators, any or all of which could be present in various degrees at various times in the child's life (Wing, J., 1966). The signs characteristic of autism were found to be present at birth or sometimes later, but usually within the first three years of life (Wing, 1974). Wing noted that other disorders of speech and behavior occurred in children after the age of three years, but these disorders usually did not resemble the autistic syndrome closely enough to be diagnosed as autism.

The most disturbing aspect of the autistic child's behavior was found to be his abnormal interpersonal behavior manifested by an indifference toward people, an inability to communicate with others, aloofness, and lack of emotion. The typical autistic child exhibited an impaired or complete lack of relatedness and appeared socially inaccessible to children, parents, and other adults (Wing, J., 1966). He seemed to lack the desire or need for affection and did indeed shun attempts to coddle or embrace him (Rimland, 1964; Rutter, 1968; Wing, J., 1966). The autistic child was found to express extreme distress such as crying or throwing tantrums for no readily discernable reason or he was observed to show inappropriate affect or extreme emotional responses (Rimland, 1964; Wing, J., 1966; Wing, L., 1976). These features often coincided with lack of intellectual development or retardation in certain areas, sometimes accompanied by normal or superior abilities in other areas (Rimland, 1964;

Rutter, 1965b; Wing, J., 1966; Wing, L., 1976). Many authors have noted the autistic child's inappropriate use of toys and objects. He frequently used the toy or object at hand in a very repetitive and peculiar manner, often with similar repetitive and peculiar body motions such as incessant rocking or ritualism (Rimland, 1964; Wing, J., 1966; Wing, L., 1976). The autistic child's unusual reaction to perceptual stimuli often took the form of seeming not to hear certain sounds and overreacting to others, "looking-through" objects, excessive touching and rubbing of textures, excessive smelling of things, or peculiar preferences and dislikes for foods (Rimland, 1964; Wing, J., 1966; Wing, L., 1976). Hyperactivity or passivity was often evidenced along with an apparent insensitivity to pain. J. Wing (1966) found few impairments in motor behavior among autistic children. Motor skills such as walking were seldom delayed (Rimland, 1964). Kessler (1966) was of the opinion that the motor coordination of autistic children was normal. Most of the children were agile and graceful (Kanner, 1943; Rimland, 1964; Wing, J., 1966).

A pattern of ritualistic, compulsive behavior was often evidenced in the autistic child (Kanner, 1943; Rutter, 1966a; Wing, J., 1966). Many of the children exhibited compulsive behavior and became very upset if someone prevented them from completing their routines. This behavior frequently took the form of an abnormal attachment to certain objects or toys, or an abnormal preoccupation with one behavior such as incessant shaking and twirling of any object (Rutter, 1966a). The autistic child's inability to adjust to change was evidence of this propensity to compulsion. Kanner (1943) referred to this aspect as the child's "insistence on sameness." Overactivity and poor attention during early and middle childhood were prevalent (Rutter, 1966a). Temper tantrums and self-injurious behavior such as head banging, biting oneself, or clawing oneself were more prevalent in this population than in others (Rutter, 1966a; Wing, J., 1966).

The cause or causes of autism have not yet been isolated but several theories have been proposed. One of the problems related to the discovery of etiology has been an inability to clearly delineate the syndrome. It has been easily possible to recognize children who have had the classic syndrome described by Kanner, but the borderline of the condition have been unclear (Wing, L., 1976). L. Wing (1976) maintained that the classic syndrome was easily differentiated from an equally classic developmental receptive speech disorder, but that between these two lay a range of children with some elements of both syndromes. Wing summed up the difficulty by stating that "the only rational way of dealing with problems of this kind, which abound in psychiatry, is to adopt operational definitions pending the discovery of the aetiology and pathology" (p. 20).

Although the autistic child has been found to exhibit aberrant behavior and many deficits, it was his abnormal interpersonal responses which consumed the interest of the first clinicians involved in the study of autistic children (Kanner, 1943; Kanner & Eisenberg, 1956). However, concurrent with recent developments in the study of children with specific learning and language disabilities, the focus of most investigators in the area of childhood autism has changed to an analysis of the autistic child's perceptual functioning (Lovaas, Litrownik, & Mann, 1971; Lovaas, Schreibman, Koegel, & Rehm, 1971; Rutter, 1966a, Wing, J., 1966; Wing, L., 1969). Most recent theories of etiology have pointed to organic possibilities for the autistic child's behavior (Wing, L., 1976). L. Wing characterized autism as a severe learning disorder, possibly the most severe type, which impeded or prevented the normal development of language skills. She further postulated that the basic problem arose at some stage during the process of interpreting sensory information.

There has been substantial recent evidence linking autism with brain damage. Several conditions which damage the central nervous system have been shown to precede the development of the autistic pattern of behavior (Wing, L., 1976). Chess (1971) found that the prevalence of autistic behavior following maternal rubella was 10 times greater than the expected rate in the general population. L. Wing (1975) found that an early history of encephalitis or meningitis and conditions such as tuberose sclerosis and phenylketonuria were associated with the autistic pattern of behavior. Rutter (1970) reported that by the time of adult life, one-third of a group of autistic children who were followed from early childhood to adolescence and early adult life had at some time had epileptic seizures. Follow-up studies have also shown that EEG abnormalities, seizures and other signs of neurological dysfunction increased as the children grew older even in those who appeared to have no additional handicaps when first diagnosed (Creak, 1963; Rutter, 1970). In his epidemiological study, Lotter (1966, 1967) found that nearly one-third of the children he identified as autistic had recorded evidence suggestive of neurological abnormality.

Most brain damaged children, however, were not found to be autistic. Therefore, investigators believed that if there was an abnormality of brain structure of function in autism, it was very localized and specific in nature. There was no firm evidence as to the possible site or nature of this hypothesized abnormality, although some suggestions were made. Tanguay (1976) grouped the neurophysiological theories of autism into three categories: (a) theory of perceptual inconstancy, (b) theory of a defect in cross-modal associations, and (c) theory of a central cognitive defect.

The theory of perceptual inconstancy (Ornitz & Ritvo, 1968a) was based upon clinical observations which suggested that autistic children suffered from a defect in the homeostatic regulation in sensory input and motor input. Ornitz, Ritvo, and their colleagues (Ritvo, Ornitz, Evitar, Markham, Brown, & Mason, 1969; Ornitz, Forsythe, & de la Pena, 1973; Ornitz, Brown, Mason, & Putnam, 1974) have concentrated their electrophysiological work upon phenomena whose occurrence has been found to be mediated by the vestibular nuclei in the brain stem. They presented several findings to support this theory. They discovered that when waking autistic children were subjected to vestibular stimulation by whirling in a Baronay chair in a lighted room, their vestibular reactivity as measured by the duration of ocular nystagmus was markedly diminished in comparison with normal subjects. This reduction in vestibular reactivity was not seen when autistic children were whirled in the dark. Ornitz et al. (1974) believed that the reduction in duration of ocular nystagmus in autistic children was not a result of their fixating on objects in the lighted room, but was a result of abnormal interaction between the light and vestibular stimuli.

An additional finding by these investigators concerned the occurrence of rapid eye movements during dreaming sleep. These rapid eye movements (REM) have been found to be mediated by the medial and descending vestibular nuclei and have been thought possibly to be influenced by higher centers of the brain. These investigators found that in autistic children, there was a significant reduction in the tendency of the rapid eye movements of REM sleep to cluster into bursts (Ornitz, Ritvo, Borwn, LaFranchi, Parmelee, & Walter, 1969). Thus, two-to-five year old autistic children resembled normal six-to-twelve-month old babies in this regard. Additionally, Ornitz et al. (1973) have shown the increase in eye movement burst duration seen as a result of mild vestibular stimulation during sleep in normal subjects to be deficient in autistic children. These workers suggested that the mechanism, which, in normal people, regulated the episodes of phasic excitation and inhibition in REM sleep, was disrupted in autistic children and that this disruption broke into the waking life of the children, in the form of behavioral hyperexcitation alternating with inhibition.

Four additional studies have tended to support the theory of perceptual inconstancy by suggesting an impairment in the operation of homeostatic brain stem reflexes. Ornitz and Ritvo (1968b) have suggested that an impairment of these reflexes may underlie perceptual inconstancy. In a study by Piggott, Ax, Bamford, and Fetzner (1973) psychotic children were noted to have less well-coordinated mechanisms for the regulation of sinus arrhythmia. MacCulloch and Williams (1971) have noted that autistic children appeared to have a defect in the homeostatic mechanism which regulates heart rate. MacCulloch and Sambrooks (1972) considered the possibility of a lesion in and around the head of the nucleus of the tractus solitarius in the posterior brain stem which was known to be a bulbar inhibitory center. They postulated that such a lesion could have released from damping much of the ascending reticular formation's activity. This could have led to disturbances of perceptual processes and to cortical arousal which would have produced many behavioral abnormalities. They also postualted that the brain stem lesion could have affected the vestibular system, thus linking their hypothesis with that of Ornitz and Ritvo.

One final study was found to support the theory that autistic traits were due mainly to an organic brain lesion. Student and Sohmer (1978) recorded the responses of the auditory nerve and brain stem auditory nuclei in autistic and normal subjects. This technique has been successfully used as an objective test of hearing in infants and children with uncertain diagnosis. Since the electrical responses of several brain stem auditory nuclei were recorded, the technique also was being used in the diagnosis of brain stem lesions. Latencies and amplitudes of each of five waves were measured and those of the autistic group were compared to those of the control group. Previous studies have shown the first wave to be the compound action potential of the auditory nerve and the following waves to be the responses of the successive brain stem auditory nuclei: wave two from the region of the cochlear nucleus, wave three from the region of the superior olivary complex, and waves four and five from the region of the inferior colliculus. The values obtained from the autistic children were different from those of the control group. Five of the autistic subjects (N = 15) did not have any responses: that is, they had a profound peripheral hearing loss in addition to autistic traits. From the remaining subjects, responses were obtained from the auditory nerve and the brain stem auditory nuclei with response thresholds within the normal range. However, there were differences in several aspects of the wave form between the autistic group and the normal group. One difference was a greater response latency of the first wave, i.e., the peak of the compound cochlear action potential appeared with a longer latency after the auditory stimulus compared to the control group. In addition, brain stem transmission time (wave 4) was significantly longer in the autistic group than in the control group.

These findings of hearing loss in some autistic subjects and in others a longer latency of the auditory nerve response along with a delayed brain stem transmission seemed to indicate the presence of an organic brain lesion at least in that part of the brain concerned with propagation of auditory information. Since the latency of the auditory nerve response and brain stem transmission time have been shown to be longer in younger infants these results were interpreted as supporting the theory that autistic traits were due to an immaturity in the development of certain brain stem mechanisms (Tanguay, Ornitz, Forsythe, & Ritvo, 1976). Student and Sohmer stated that these results proved nothing about whether they were obtained due to a peripheral-cochlear lesion, a synaptic lesion, and /or a decreased nerve conduction velocity.

A second theory which attempted to explain the symptoms of autism postulated that autistic children suffered from a defect in cross-modal associations. This theory noted that normal children were easily able to receive information in one mode (auditory, visual, tactile, etc.) and respond in another. Lovaas et al. (1971) have noted that when normal children were reinforced for responding to a complex stimulus involving auditory, visual and tactile cues, all three cues assumed stimulus control properties over the response, so that on later presentation of any one of the cues, the response occurred. However, while autistic children could be conditioned to respond to all three cues given at once, when the cues were presented singly no more than one of the three cues was found to control this response. Bryson (1970) has shown that when presented with stimuli delivered in one mode (either visual or vocal), autistic children had great difficulty in responding in a different mode from that in which the stimulus was presented.

The work of Lelord, Laffant, Jusseaume, and Stephant (1973) was interpreted as providing some electrophysiological substantiation of the above observations. Lelord employed average evoked responses recorded using standard computer techniques. He noted that when normal subjects received auditory stimuli, their evoked response measured from the occipital region was small and variable. When each auditory stimulus was followed 300 msec. later by a strong flash stimulus, the auditory evoked responses were considerably enhanced. This enhancement could not be produced in autistic children, suggesting that the interaction between auditory and visual pathways in autistic subjects was defective.

A third theory has been proposed to explain the etiology of autism based on the autistic child's inability to comprehend or to use communicative speech. Rutter, Bartak, and Newman (1971) have postulated that autistic children have suffered from a central cognitive defect which presumably prevented them from using language. It has been demonstrated that autistic children had a great deal of difficulty with encoding or decoding in the auditory mode and to a lesser extent, in the visual mode. Frith (1970) has shown that when speaking autistic children were presented with short sentences made up solely of random words, their recall was as good as that of normal children matched for mental age. When presented with the sentences in which the same words had been rearranged into a meaningful message, the recall rate of autistic children did not increase, while that of normal children did so markedly. Investigations by Shapiro, Chiarandine, and Fish (1974) and Shapiro, Fish, and Ginsberg (1972) have suggested that when autistic children did learn speech, their morphological competence was often in advance of their communicative competence. Tubbs (1966) found that autistic children had difficulty encoding information in both the auditory and visual modes. Two studies have been published which suggested that autistic children had special difficulty in processing material whose information was encoded as a sequential or linear pattern. One, by

Hermelin (1972), showed that autistic children were quite insensitive to temporally patterned visual material, while the other by DeMyer, Alpern, Barton, DeMyer, Churchill, Hintgen, Bryson, Pontius, and Kimberlin (1972) showed that autistic children were unable to reproduce a sequence of bodily movements.

No research has yet produced conclusive evidence confirming any one of the theories of etiology presented here or confirming a particular site of lesion, damage or malfunction in the central nervous system of autistic children. However, research is continuing and it is hoped that with increased interest in the problems of the autistic child greater light will be shed on the cause, or causes, of the syndrome.

Prediction of Hearing Loss from Threshold Measurement of the Acoustic Reflex

Acoustic reflex threshold measurement was found to be one of three tests used in an audiological technique known as impedance audiometry. Impedance audiometry has proven to be an objective means of assessing the integrity and function of the peripheral auditory mechanism. Acoustic impedance was defined as a ratio of a sound pressure averaged over a given surface to the rate of volume displacement (or volume velocity) through that surface. The concept of acoustic impedance was reported to be analogous to the concept of electrical impedance which was defined as the complex ratio of voltage and current across a circuit element. Measurement of absolute acoustic impedance was expressed in acoustic ohms

(Fulton & Lloyd, 1969). In order to explain acoustic impedance researchers have demonstrated what happens when sound enters the human ear. Upon entering the ear canal, sound pressure waves have been shown to impinge upon the surface of the eardrum resulting in a displacement of this membrane. This displacement has been shown to equal a given volume of space. The rate at which the displacement took place was referred to as the volume velocity. To an extent the membrane has proven to be resistant to movement opposing the sound pressure changes, thus affecting the rate of volume displacement. This opposition to change has been termed the acoustic impedance of the ear. Acoustic impedance, thus, has been shown to represent opposition by a surface to the flow of acoustic energy through that surface. The acoustic impedance of the ear has been found to be dependent primarily upon the mobility of the middle-ear system. In the normal ear, the conductive middle-ear mechanism has been demonstrated to be a highly efficient system with little sound energy lost in transmission. However, a certain amount of energy has been shown to always be reflected from the membrane back into the ear canal regardless of the efficiency of the system. The frequency of the reflected wave has proven to be the same as the incident wave, but the amplitude and phase have been found to be dependent upon the impedance encountered at the eardrum. This, in turn, has been found to be controlled by the characteristics of the membrane, the ossicular chain, the ligaments and muscles of the middle-ear, the two cochlear windows, the middle-ear cavity and air spaces, and by the mechanical properties of the inner-ear. Thus, sound waves reflected from the tympanic membrane have been used to gather information regarding characteristics of the membrane and the functional status of the middle-ear which was measured with an electroacoustic impedance meter (Fulton & Lloyd, 1969, Jerger, 1970; Lilly, 1973; Northern & Downs, 1974).

The three tests employed in impedance audiometry have been tympanometry, static acoustic impedance (or static acoustic compliance), and dynamic acoustic impedance (or acoustic reflex thresholds). Tympanometry has been utilized as an objective technique for measuring the complaince, or mobility of the tympanic membrane as a function of mechanically varied air pressures in the external auditory canal. The term tympanometry has been used to refer to methods and techniques for measuring, recording, and evaluating changes in acoustic impedance with systematic changes in air pressure. Tympanic membrane mobility was of particular interest since almost any pathology located on, or medial to, the eardrum would influence its movement. The complaince of the tympanic membrane at specific air pressures has been plotted on a graph known as a tympanogram and has yielded information regarding the presence of effusion within the middle-ear cavity, the integrity of the tympanic membrane, the patency of pressure-equalization tubes, air pressure within the middle-ear cavity, the effects of atropic scars on the tympanic membrane, equalization pressure prior to measuring changes in acoustic impedance at the tympanic membrane, and an estimate of the magnitude of static acoustic impedance at the tympanic membrane (Lilly, 1973).

Static acoustic impedance measurements were made with ambient (atmospheric) air pressure in the external auditory canal and with the middle-ear muscles in a state of normal tonus. Measurements of static acoustic impedance at the tympanic membrane were of primary value in differential diagnosis of conductive lesions. These measurements reflected directly the transmission characteristics of the middle-ear system (Lilly, 1973; Northern & Downs, 1974).

Dynamic acoustic impedance measurements (or acoustic reflex thresholds) were obtainable as a result of the fact that in the normal ear certain intensities of sound produced reflexive contractions of the intraaural muscles, stapedius, and tensor tympani that alterred the impedance of the ear. The measurement of changes in dynamic acoustic impedance while the stapedius muscle or tensor tympani muscle was contracted by auditory, electrical, or tactile stimuli yielded an objective measure of loudness recruitment, a validation of nonorganic hearing loss, a validation of conductive hearing loss, a differential diagnosis of conductive hearing loss, and an objective inference of hearing sensitivity (Northern & Downs, 1974).

This investigation was concerned with a determination of acoustic reflex threshold and prediction of hearing sensitivity based on information derived from reflex thresholds. Niemyer and Sesterhenn (1974) found that hearing threshold levels could be predicted from a consideration of the relation between acoustic reflex thresholds for pure-tones and broad-band noise. In a series of 223 ears with varying degrees of sensori-neural hearing loss, they showed that the average hearing threshold level over the range from 550 Hz to 4000 Hz could be predicted from the difference between reflex threshold levels for white noise and for pure-tones (averaged from 500 Hz to 4000 Hz) with an accuracy of ±10 dB in 73% of patients and at least ±20 dB in 100% of patients. These researchers used the following formula to derive the average hearing threshold level used for prediction: hearing threshold = SRT tones - 2.5dl2. Where SRT tones = stapedius reflex threshold for tones of 0.5 - 4 kHz (mean) and dl2 = difference level between SRT tones and SRT white noise.

Following a similar procedure, Jerger, Burney, Mauldin, and Crump (1974) used acoustic reflex thresholds for pure-tones and white noise to predict severity of audiometric loss in 1043 ears with sensori-neural hearing loss. Serious error occurred in only 4% of the cases. Jerger and his associates attempted to predict four degrees of hearing sensitivity: grossly normal, mild-moderate loss, severe loss, or profound loss. They noted that for children it was usually not necessary to attempt to predict sensitivity loss in decibels since it was sufficient for differential diagnosis and treatment to place the child in one of these four categories. These workers used as a basis for their prediction a combination of (a) differences between reflex thresholds for pure-tones and noise and (b) the absolute sound pressure level (SPL) of the reflex threshold for noise. A difference score, D, was defined as the average difference between threshold for noise and three different weightings of the reflex thresholds for pure-tones in the 500 Hz - 2000 Hz range.

Jerger and his associates predicted normal hearing if D exceeded 20 dB, a mild-to-moderate loss if D fell between 10 dB and 19 dB, and a severe loss if D was less than 10 dB. Profound loss was predicted if no reflex was observed. The exact prediction was modified, however, by the absolute level of the reflex threshold for broad-band noise (BBN). If the BBN SPL was 80 dB or less, it offset a D in the 15-19 range. Similarly, if BBN SPL was 89 dB or less, it offset a D below 10 dB. Subjects' actual hearing thresholds were categorized as having normal hearing if pure-tone audiometric thresholds (PTA) were less than 20 dB HL (Hearing Level), mild/moderate hearing loss if they were 20 dB HL to 49 dB HL, severe hearing loss if they were 50 dB HL to 84 dB HL, and profound hearing loss if they were 85 dB HL or greater.

Predictive errors were analyzed in such a way that if prediction and actual result agreed, there was no error. If an actual result diverged by only one scale position, then the error was considered moderate. If prediction and actual result diverged by two or more scale positions, then the error was considered serious. Perfect agreement occurred in

60% of all cases, moderate errors occurred in 36% of the cases, and serious errors occurred in only 4% of all cases. Analysis of the 41 ears in this latter group (serious errors) indicated that 35 were cases in which the prediction was severe and the actual result was normal. In only six ears (0.6% of total cases) was the prediction normal in the case of actual severe loss. Jerger noted that the latter error was the more serious of the two types of errors in that the consequences of a false positive (prediction of hearing loss when none existed) were not as detrimental to the client as the consequences of a false negative (prediction of normal hearing when a loss existed).

In another study, Keith (1976) compared three different formulae used in predicting hearing level form acoustic reflex data with 74 normal and hearing impaired persons: the Niemeyer-Sesterhenn, the Jerger weighted, and the Jerger unweighted methods. The Niemeyer-Sesterhenn and Jerger weighted formulas have been described earlier. In the Jerger unweighted method, the difference between the pure-tone and white noise acoustic reflex thresholds were calculated and compared to differences obtained in studies on patients with hearing in each of the four categories: normal, mild-moderate, severe, and profound.

Keith's results indicated that the Niemeyer-Sesterhenn and Jerger unweighted formulae yielded comparable results and were preferable to the Jerger weighted formula. A review of the results of the Niemeyer-Sesterhenn and Jerger unweighted formulae indicated that either one did a good job of separating normal ears from those with hearing impairment. However, the different formulae yielded results which predicted more accurately in some hearing categories than others. Keith found that the Niemeyer-Sesterhenn data appeared to have less pronounced fluctuations in correct predictions of the four categories and, therefore, suggested that this formula was more attractive for clinical use.

In another study Bess et al. (1975) used acoustic impedance measurements in cleft-palate children as pertinent supportive information to routine pure-tone audiometric testing and encouraged the use of impedance measurements in examinations of this population.

Operant Pure-Tone Audiometric Procedures with Difficult-to-Test Subjects

Conventional or standard pure-tone audiometry, in which the subject was asked to raise his hand or press a signal button when he heard a sound, used verbal reinforcement (Lloyd, 1966). The audiologist has developed highly reliable techniques for evaluating the hearing of persons who could follow verbal instructions and who were influenced by verbal feedback and reinforcement. However, reliability and validity of audiometric techniques were greatly reduced when the subject did not respond to verbal instructions (Lloyd et al., 1968). Operant audiometric techniques have been tested, however, which yielded objective, valid, and reliable results employing a variety of responses and reinforcers (Lloyd et al., 1968).

These studies proved that it was possible to condition difficult-to-test subjects to respond to auditory stimuli so that their hearing could be evaluated, even if they could not make intelligible vocal responses or finite motor responses to auditory stimuli (Fulton & Lloyd, 1969). Most of these methods used positive reinforcement through instrumental techniques. The reinforcements which have been used have included: electrical toys (D'Asaro & Grey, 1964; Fulton, 1962; Fulton & Graham, 1964; Wolf & MacPherson, 1959), edible foods (LaCrosse & Bidlake, 1964; Lloyd et al., 1968; Meyerson & Michael, 1960), slides and filmstrips (Lloyd, 1965; Weaver, 1965), trinkets (Knox, 1960; Meyerson & Michael, 1960), and lights (Wolf & MacPherson, 1959). Several response modes have also been employed: standard hand raising or button pressing (Lloyd, 1966); ear choice or modified ear-choice (Lloyd & Melrose, 1966); play responses such as putting pegs in holes, putting rings on a peg, hitting a peg board, hitting a drum, stacking blocks, putting marbles in a box, and putting blocks in a box (Barr, 1955; Donnelly, 1965; Frisina, 1962; Fulton & Lloyd, 1969; O'Neill, Oyer, & Hillis, 1961); and lever pressing (Bricker & Bricker, 1969a). Thus, the application of the operant paradigm to evaluation of the hearing of behaviorally difficult populations was not new. Many researchers and clinicians have applied the principles in various forms (Bricker & Bricker, 1969a, 1969b; Dahle & Daly, 1974; Fulton, 1974; Fulton & Lloyd, 1969; Fulton & Spradlin, 1971; Lloyd et al., 1968; McReynolds, 1966; Meyerson & Michael, 1960; Schell, Stark, & Giddan, 1967; Suzuki & Ogiba, 1961).

Fulton (1974) pointed out that the problem in audiology has been obtaining a different rate or probability of responding when a tone was present than when the tone was not present. The problem, therefore, was one of stimulus control (Fulton & Lloyd, 1969). Thus, an operant audiometric procedure was viewed basically as an instance of discrimination training in which the discriminative stimulus (S^D) was the auditory signal (pure-tone, white noise, voice, etc.) and the non-discriminative stimulus (S^Δ) was the absence of the auditory signal (Fulton, 1974; Fulton & Lloyd, 1969). Responses in the presence of the S^D were reinforced and responses in the presence of the S^Δ went unreinforced (extinction procedure). The objective was to have the subject making some discernible response only when the tone was present and not making that particular response when the tone was absent. One hundred percent correct responding was found to be desirable; however, most clinicians defined some lower criterion for an acceptable measure of hearing threshold (Fulton, 1974). Researchers employing this basic paradigm have made consistent improvements in the discrimination procedure (Fulton, 1974).

Meyerson and Michael (1960) found that mentally retarded subjects could easily be brought under auditory stimulus control by initially using a light as an extra-stimulus cue when paired with the tone presentation and then gradually reducing the intensity of the light over a number of trials until the subject was responding on the basis of the auditory stimulus only (fading procedure). The authors also concluded that the most effective auditory discrimination procedure involved two responses. One response was reinforced when the tone was present; the second response was reinforced when the tone was absent. Thus, an indication of the child's ability to hear was obtained by observing if and when the child switched from one response to the other. Accidental reinforcement of incorrect responding was controlled by using a change-over-delay (COD) procedure. Accidental reinforcement of incorrect responding could occur if the child was responding on the incorrect response button (and not being reinforced) when the stimulus interval changed (tone present to tone absent or tone absent to tone present). The child would, in this case, be reinforced for repeated responding on the incorrect response button rather than being reinforced for switching from one response button to the other when cued by the stimulus change. Therefore, a penalty was implemented whereby responses on the incorrect button delayed the onset of the next stimulus condition repeatedly until a response on the correct button was obtained.

The following steps were usually included in operant audiometric procedures: determining an effective reinforcer, initial response training, bringing the response under stimulus control, earphone training, auditory discrimination training, discriminative stimulus generalization, intensity generalization, and threshold assessment. Additional steps were necessary in the event that additional stimuli were presented as an aid in establishing auditory discrimination. In general, these operant audiometric procedures have been found to be highly valid and reliable in the measurement of hearing thresholds in retarded, autistic, and other difficult-to-test populations, especially when automatic electronic programming equipment was employed to control stimulus presentation and reinforcement presentation (Fulton, 1974).

Fulton (1974) has described an operant audiometric procedure with which he and his associates have been able to evaluate the hearing of a variety of difficult-to-test populations including nonverbal retarded and autistic children. Fulton employed a specially designed response-reinforcement delivery apparatus which was automatically programmed and operated with electronic programming equipment. Fulton achieved a high degree of control and reliability in the systematic presentation of stimuli and reinforcement to achieve a high degree of auditory stimulus-response control with his subjects.

Fulton (1974) and others (Bricker & Bricker, 1969b) have suggested that the following steps be followed in the audiometric conditioning of difficult-to-test subjects:
(a) a reinforcer should be determined for the subject generally by trying several types and testing to determine if the desired response can be conditioned satisfactorily;
(b) procedures for the nonreinforcement of behaviors inappropriate to the audiometric procedure should be implemented;

(c) initial response training with the use of prompts, differential reinforcement, shaping, fading, and attenuation of the reinforcement schedule when necessary; (d) earphone training using prompts, shaping, and fading procedures; (e) discrimination training; (f) discriminative stimulus generalization training; (g) intensity generalization; (h) unilateral generalization; (i) pure-tone threshold assessment.

These authors have pointed out that several points should be considered closely in the discussion of an operant audiometric procedure. A reinforcer was usually defined as anything which, when made contingent upon a response tended to increase the probability of that response occurring again in the future. Thus, a reinforcer was defined by the way in which it acted upon a response and any potential reinforcer was first tested on the response in question to insure that it would function as a reinforcer. Reinforcers were edible, social, toys, activities, or anything which had the desired effect on the response. However, in order to be maximally effective in the context of an auditory discrimination procedure, a potential reinforcer had also to be easily and quickly dispensed, and had also to be consumed or partaken rather quickly so as not to interrupt the training procedure unduly. Also, the potential reinforcer had to be one which could be consumed or partaken repeatedly without noticeable satiation effects during the time frame of the procedure.

Behaviors which were found to be inappropriate to the discrimination procedure included self-stimulation, crying vocalizations, responding with some inappropriate part of the body, or incorrect responding (as in the case of two response buttons). Withholding reinforcement or penalizing the subject by the use of a change-over-delay was usually sufficient to reduce this type behavior such that it had minimal effect on the outcome.

Initial response training was achieved in a number of ways. Shaping (the differential reinforcement of closer approximations to a terminal response) was used; however, it was generally somewhat slow in achieving the desired results. A faster method was to use verbal (when feasible) or physical prompts (as in guiding the subject's hand to the response button) and to gradually reduce the prompts over a number of trials until the subject was responding on his own (fading the prompt). Once a stable rate of responding had been obtained using continuous reinforcement (CRF), the schedule of reinforcement was attenuated in order to insure that the subject would not quickly satiate during the audiometric procedure. This also insured that incorrect responses would be tolerated by the subject without extinction of responding.

Earphone training was especially necessary when the subject was fearful of wearing the headset or when he attempted to play with the headset. The subject was trained to accept the wearing of the headphones, usually through a fading procedure, whereby he was reinforced for responding on the manipulanda while the headset was gradually brought closer to the subject until he finally continued to respond while wearing it.

A discrimination training procedure involved the presentation of a discriminative stimulus (S^D) for a defined period of time and reinforcing the subject on some established schedule of reinforcement for responding during this S^D period. Likewise, a period was presented in which the stimulus in question was not present and the subject was either reinforced for switching his responding to another manipulandum or his responding on the original manipulandum went unreinforced (extinction procedure) depending on the manner in which the discrimination task was arranged. These different stimulus periods were found to be presented alternately or in a randomized fashion. The duration of the stimulus periods was usually varied within certain parameters in order to control for temporal responding by the subject in the case of alternating presentation of S^D and S^Δ periods. The period durations were not varied when the stimulus periods were presented randomly. In both cases a COD was used to control for accidental reinforcement of incorrect responding. The initial discriminative stimulus was presented binaurally in order to control for unilateral hearing loss and consisted of a pure-tone stimulus of 500 Hz, 750 Hz, or 1000 Hz at sufficient intensity that the tone could be heard even when some impairment existed, usually 50 dB-70 dB hearing level (HL) or 40 dB above estimated threshold (Fulton, 1974). Subjects were trained to respond to the presence or absence of a signal or to respond to a change in signal. Fulton (1974) taught subjects to respond to the presentation of a pure-tone signal over a constant background narrow-band signal centered at 750 Hz. This allowed for other, more specialized hearing tests to be administered. For simple pure-tone audiometry, however, it was sufficient to have the subject respond to the presence or absence of the signal.

Discriminative stimulus generalization was necessary in order to insure that the subject would continue to respond when the frequency of the auditory discriminative stimulus signal was varied during the audiometric examination. The subject was trained to respond to different frequencies including 250 Hz, 500 Hz, 750 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz.

Intensity generalization was also necessary to insure that the subject would continue to respond when the intensity of the tone was varied during audiometric testing. The subject was trained to respond to reduced intensities of one frequency, usually in small decrements of 5 dB-10 dB. This procedure was sometimes repeated with all other training frequencies.

Unilateral generalization was required in order to be able to obtain thresholds for each ear individually. The subject was trained to respond to unilateral presentation of the signal, usually beginning with a constant frequency and intensity and then gradually changing the frequencies and intensities. This procedure was performed for both ears. Unilateral hearing losses could be discovered at this point.

Established audiometric procedures were used at this point to find thresholds for each frequency and each ear. Fulton and Spradlin (1971) found that ascending or descending techniques of threshold assessment could be used without producing differential results. However, it should be noted that the subject was exposed to different schedules of reinforcement in the two techniques depending on the responses required of the subject. If the subject was required to respond during the presentation of tone and refrain from responding during its absence, then an ascending technique would allow fewer reinforced trials. This was due to the fact that stimulus presentation was begun below threshold, and the intensity of the stimulus was gradually increased in increments until the subject began to respond to signal presentations, hence, ascending. The signal was then lowered to a level below threshold and the procedure repeated until thresholds were obtained for all frequencies. For any one frequency, threshold was typically defined as that level of intensity at which the subject responded 50% of the time. An intermittent schedule of reinforcement was requisite to the use of this type of procedure when using the one-response mode, since there was only one reinforced response in each ascending series. This was noted during initial training and attenuation of the schedule of reinforcement. The other system of stimulus presentation, the descending technique, involved presenting the stimulus above estimated threshold and gradually reducing the intensity until the subject failed to respond to stimulus presentations. The intensity was then returned to above threshold and the procedure repeated until threshold was determined; again defined as that point at which the subject responded 50% of the time. It was apparent that when using the one-response mode this procedure presented multiple opportunity for reinforcement in each descending series, whereas there was only one opportunity for reinforcement in each ascending series. The two-response mode wherein the subject was responding and obtaining reinforcement within both stimulus conditions differed in that attenuation of reinforcement schedules was based on factors of satiation rather than on stimulus presentation design.

Method

Subjects

Two groups of five children each were used in the study; one group consisting of autistic males and the other group consisting of normal children. The groups were matched by age. Children in each group ranged in age from 6 years-1 month to 12 years-1 month.

Autistic subjects were selected from a private treatment center where each was receiving intensive behavior modification treatment 5 hours per day, 5 days per week. Normal subjects were selected from among clients of a private audiology clinic who were receiving routine audiological screening.

Each subject of the autistic group had been previously diagnosed as autistic by at least two independent agencies or clinicians. Every autistic subject had received at some time in his history an audiological examination, the results of which were inconclusive in all cases. Audiological histories of the subjects in the normal group indicated no prior hearing difficulties or clinical problems.

For this study the ears of each subject were considered separately, since the investigation concerns peripheral rather than central loss of hearing; thus, the total N for each group equaled 10. Participation in the study was voluntary. Parents or guardians of the subjects gave their informed consent for subjects' participation in the research with the full knowledge that the parents or guardians were allowed to remove subjects from the study at any time.

Apparatus

Dynamic acoustic reflex measurement was accomplished with a Madsen ZO-72 impedance bridge using Telephonics TDH-140 headphones cushioned with MX-41/AR cushions. In this procedure an airtight seal of the external auditory meatus was obtained with a probe tip containing three tubes encased in a rubber tip. One tube was connected to a loudspeaker which emitted a tone generated by a 200 Hz oscillator into the sealed cavity of the ear canal. A second tube was connected to a tiny probe microphone which measured the sound pressure level (SPL) of the reflected 220 Hz tone via a bridge circuit and a balance meter. The sound pressure level could be varied utilizing a potentiometer over a range corresponding to an equivalent volume of 0.2-0.5 cubic centimeters. The third tube was connected to an air pump and manometer capable of varying air pressure in the sealed cavity from +400 mm/H_20 to -400 mm/H_20.

Small rubber hoses connected the receiver and probe microphone to the probe tip. Air was delivered to the probe tip via a third rubber hose. These were then mounted at the end of the headband. Affixed at the opposite end of the headband was a conventional earphone. When connected to an appropriate sound source and the impedance bridge, accurate measurements of middle-ear function could be obtained (see Figure 1). Prior to obtaining any measurements, the headset was properly positioned on the subject,with the probe tip sealing one ear and the earphone placed over the opposite ear.

For the acoustic reflex threshold measurement, the electroacoustic bridge was used to show relative changes in the impedance of the middle-ear system. With the balance meter nulled to zero, an acoustic signal was delivered to the nonprobe ear at various intensities. If sufficiently loud, a bilateral contraction of the stapedius muscle would occur, causing an impedance change at the tympanic membrane. This resulted in an upward deflection of the balance meter.

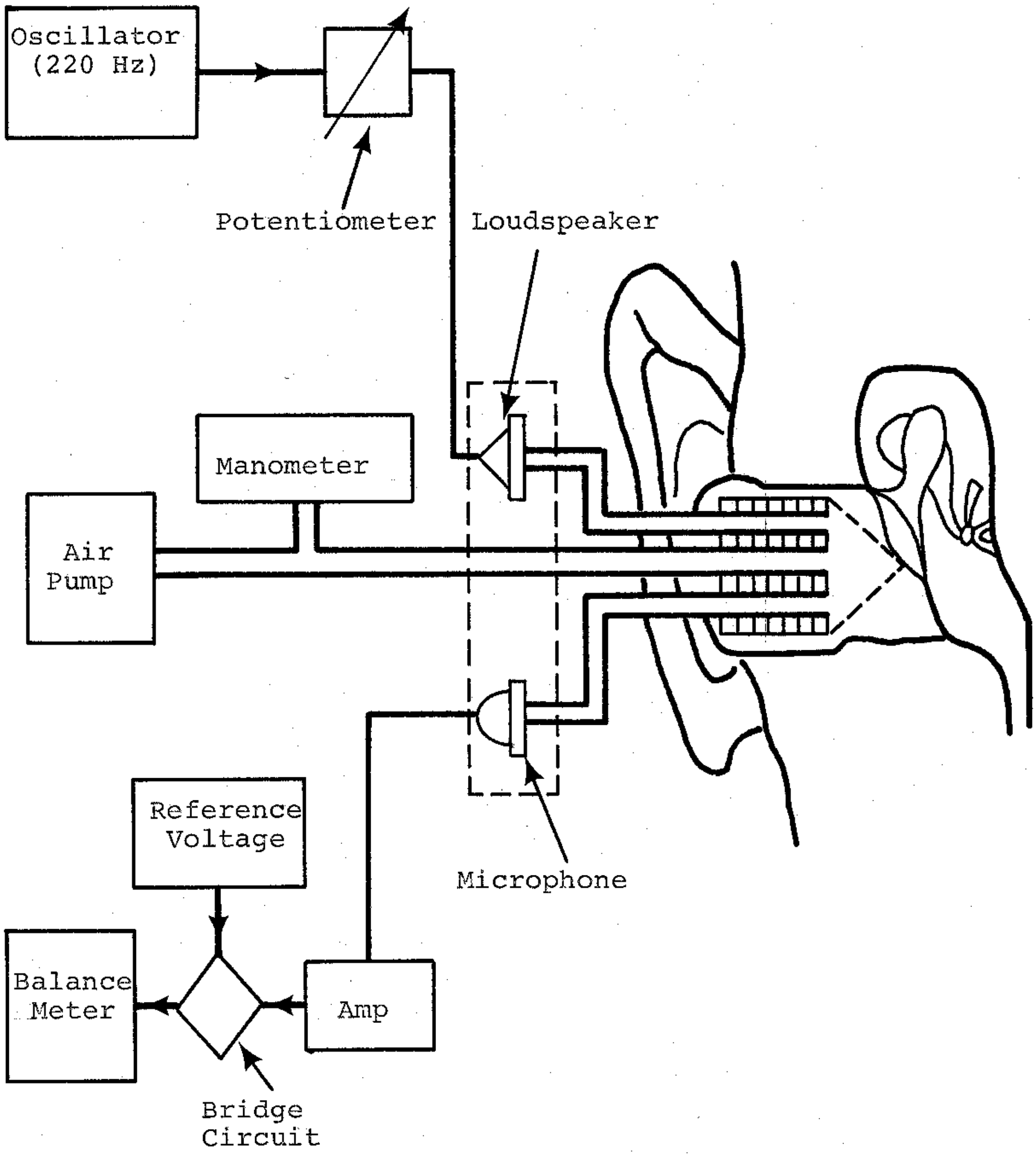

Figure 1. Impedance bridge circuit.

The lowest signal level capable of eliciting this deflection was the acoustic reflex threshold.

Auditory discrimination training prior to pure-tone threshold assessment was accomplished with a portable audiometer, Beltone Model No. 12-D. Other apparatus consisted of a small wooden block, a tin can, and a stopwatch.

Pure-tone threshold assessment was accomplished in a double-walled two room sound suite, Industrial Acoustics Company (IAC) 1204-A-CT. The auditory stimuli were generated by a Rachor RA-115 audiometer using Telephonics TDH-39-10 ohm earphones with MX-41/AR cushions. The test room of the sound suite contained two chairs and a small wooden table. One wall of the suite was fitted with a window so that the audiologist could observe the subject's responses while remaining acoustically insulated from the testing environment. All equipment employed during testing--with the exception of the earphones, wooden table, tin can, and wooden block--was located in the control room.

Calibration of all tests signals was achieved at the beginning of the experiment. In addition, checks of the SPL output for all tests stimuli were made prior to testing (see Appendix A for calibration information).

Procedure

The experimental procedure consisted of three phases for both the normal and autistic groups: (a) acoustic reflex threshold measurement, (b) auditory discrimination training, and (c) pure-tone threshold assessment.

It was known that almost any pathology located on or medial to the tympanic membrane would influence the movement of the membrane and thus any threshold measurement made of the acoustic reflex. Therefore, all prospective ears were first screened for continuity by obtaining tympanograms using the impedance bridge. Ears which were found to have such a pathology and those found to have tubes implanted in the tympanic membrane for the drainage of effusion were not considered for inclusion in this study. All subjects selected for this study passed this screening procedure.

Acoustic reflex threshold measurement. The acoustic reflex threshold of all subjects was measured by a certified audiologist. The subject was seated in a chair and fitted with the headset. If the subject was unwilling to wear the headset or wanted to handle or play with it, he was reinforced with a verbal "Good boy" for not touching the headset after placement on the head. An edible reinforcer which had been determined previously to be an effective reinforcer was presented in addition to verbal praise with autistic subjects. The final behavior of quietly sitting while wearing the headset was shaped using the method of reinforcing successive approximations.

Once the subject was seated and wearing the headphones, the probe tip was inserted into the ear which was to be evaluated and an airtight seal obtained as indicated by the balance meter on the impedance bridge. If the subject opposed the insertion of the probe tip, the trainer employed a shaping procedure for obtaining the desired response of sitting quietly with probe inserted. When the subject was sitting quietly with the probe tip inserted into the test ear, a constant tone (220 Hz) was then presented through the probe and further adjustments were made on the impedance bridge to obtain a balance between the sound reflected from the eardrum and a comparison signal of the same frequency. When a null was observed, indicating that balance between the signals had been achieved, test stimuli were introduced to a contralateral ear via the headphone. Test stimuli were broad-band white noise and pure-tone frequencies of 500 Hz, 1000 Hz, and 2000 Hz. The intensity of each stimulus was varied until a reflex threshold was obtained for each stimulus. Reflex threshold was defined as the lowest sound level producing an observable deflection of the balance meter of the impedance bridge. This same procedure was repeated for the opposite ear; then the subject was excused from the testing room.

Auditory discrimination training. Auditory discrimination training differed for the two groups due to the fact that the subjects of the normal group were verbal and could be given instructions, and the subjects of the autistic group were not communicative. This made necessary a discrimination conditioning procedure for the autistic group. In conventional pure-tone audiometry, the subject raised a hand or pressed a signal button when he heard a sound. The subject was given verbal instructions and a brief demonstration of this task. An appropriate response was followed by social reinforcement such as a smile, nod of the head, or pat on the back to communicate the appropriateness of the response. All subjects of the normal group were given this instructional training prior to pure-tone threshold measurement.

Subjects of the autistic group were given auditory discrimination training in a 3.65 X 4.87 m. carpeted school room of the private facility where all were receiving treatment. Training consisted of the following sequential phases: (a) determination of an effective reinforcer, (b) initial response training, (c) auditory discrimination training, (d) discriminative stimulus generalization, and (e) intensity generalization training.

An effective reinforcer was determined for each child from existing behavioral program data available at the facility. An edible reinforcer was chosen if it had proven to be effective for language or self-help programs in which the child was participating.

A simple and discrete response of dropping a wooden block into a tin can was selected as the response which was to come under auditory stimulus control. The subject was seated at a small table with the experimenter seated to his right. The wooden block and tin can were placed on the table directly in front of the subject. The subject was then physically prompted to place the block in the cup and was reinforced with a small bit of edible reinforcer immediately upon completion of the response. The prompt consisted of the experimenter manipulating the subject's hand in such a manner that the subject was performing the response, but somewhat passively. After the initial prompted response, the experimenter gradually reduced the amount of active physical prompting on each successive trial until the experimenter was only tapping the subject's arm, elbow, shoulder, and finally the middle of his back each time the response occurred. The experimenter removed the block from the cup after each response. The discriminative stimulus for the response consisted of a tap in the center of the subject's back. The exact response was defined as dropping or placing the wooden block into the tin can. Reinforcement occurred after each response. A limited-hold contingency existed on each trial such that the reinforcement was only forthcoming for a response if it occurred within 3 seconds of the discriminative stimulus as timed on a hand-held stopwatch. The intertrial intervals ranged randomly from 3 seconds to 15 seconds as timed by a stopwatch. A random schedule was generated for intertrial time intervals for 200 trials prior to training by numbering cards 3-15, shuffling the deck, and drawing a card 200 separate times. This prearranged schedule was followed during the training. For those subjects requiring more than 200 trials to reach training criterion, the schedule was followed again from the start. The procedure was considered complete when the subject responded correctly to 18 of 20 stimulus presentations or 90% correct responding.

For the auditory discrimination training phase, the subject was again seated at a small table with a wooden block and tin can placed directly in front of him. The experimenter was seated directly behind the subject and an assistant was seated to the subject's right. The assistant was responsible for delivering reinforcement to the subject.

The headphones were placed on the subject's head and correctly adjusted. The subject was differentially reinforced for sitting quietly without touching or removing the headset. If the subject expressed fear of the headphones or was reluctant to have them placed on his head, he was reinforced for allowing the headphones to be brought successively closer, gradually having him touch them and finally having them placed on his head.

The subject at this point was required to perform ten consecutive response trials successfully as defined in the initial response training phase. The schedule of reinforcement was attenuated from CRF to a fixed-ratio two (FR-2). After ten successful trials an auditory signal of 500 Hz was presented to the right ear at 70 dB HL for 3 seconds duration; the onset occurring simultaneously with the tactile discriminative stimulus, the tap in the center of the back. Ten additional consecutively correct responses were required for each ear prior to the next step in the training sequence.

Next, the auditory stimulus was presented to the right ear for a number of trials while the force of the tap on the back was gradually reduced until it was minimal. The auditory stimulus at this point became the only discriminative stimulus for the response. Criterion for moving to the next phase of training was defined as 18 correct responses of 20 trials. A 3-second limited-hold contingency was maintained throughout training and testing, and the intertrial interval continued to be randomly varied from 3 seconds to 15 seconds as timed by the hand-held stopwatch. If the subject failed to reach criterion on this step, the procedure was repeated with an increase of 5 dB in auditory stimulus intensity for each series of repetitions until criterion was reached or until five unsuccessful series had been completed. The training procedure was terminated on the right ear and repeated with the left ear when the subject either met criterion or failed to reach criterion after five series repetitions (at which time the intensity of the stimulus had reached 95 dB). Failing to meet criteria for auditory stimulus-response control for both ears required dropping the subject from the study. If criterion was achieved for one or both ears, the subject remained in the study and advanced to the next training step.

The next phase in training was discriminative stimulus generalization. A tone generalization procedure was performed with each ear. The purpose of this procedure was to generalize stimulus control from 500 Hz to other frequencies used in testing. Seven additional frequencies were used in this phase: 250 Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, and 4000 Hz. Criterion for each frequency was required before the next frequency was presented. In the event of failure to meet criterion for any one frequency, that frequency was repeated in another series of five trials while increasing intensity 5 dB each series until criterion was met or a total of five series had been attempted for that frequency. If criterion still had not been achieved, the 500 Hz frequency was presented until criterion was met. The problem frequency then was attempted once again in the previous manner. Failing to meet criterion at this point moved the subject to the next scheduled frequency and generalization training was attempted in the same way. If responding had not generalized to all frequencies, the entire procedure was repeated once on that ear. If responding had not generalized to all frequencies at this point, the problem frequencies were duly noted and training continued to the next phase. Frequency generalization was performed with each ear.

During the intensity generalization procedure, the subject was requried to respond to a 500 Hz signal as the intensity was reduced in 10 dB steps from the training level of 70 dB HL or from the intensity at which stimulus control had previously been achieved. This was continued until the subject failed to respond on three consecutive stimulus presentations or until normal sensitivity levels were reached. This procedure was repeated for all trained and generalized frequencies on all ears. Failure to respond to a reduction in intensity for any frequency was noted and training continued. No autistic subjects were lost in this study due to failure to achieve auditory discrimination training criteria.

Pure-tone threshold measurement. Pure-tone threshold assessment for all subjects was accomplished in sound suite under the supervision of a certified audiologist. A descending schedule of threshold assessment was used (Carhart & Jerger, 1959). Threshold was defined as the lowest intensity level at which the subject maintained a 50% response rate for a minimum of six trials.

For the autistic subjects, as in the training phase, the subject and assistant were seated together in the suite. The examiner was seated outside the suite and could view the subject and assistant through the observation window. The examiner operated the controls of the audiometer and the assistant visually cued the audiologist to present the signal using the inter-stimulus interval randomization schedule and a stopwatch. The visual cue consisted of a slight hand movement, and was shielded from the view of the subject so as to prevent the occurrence of any cues other than the auditory stimulus. When thresholds for all trained frequencies had been obtained, the subject was excused from the testing room.

Subjects of the normal group were seated in the sound suite, fitted with the earphones and instructed to raise the right hand when they thought they heard something. Threshold measurement proceeded in the same manner as for the autistic group.

Results

The data consist of average hearing thresholds measured in hearing level (ANSI, 1969) for both types of hearing tests (pure-tone and acoustic reflex) with both groups (autistic and normal). The average pure-tone threshold values are derived by averaging threshold values for pure-tone at octave frequencies from 500 Hz through 4000 Hz. The acoustic reflex thresholds are used to calculate an average predicted hearing threshold level by employing the formula used by Niemeyer and Sesterhenn (1974).

The means and standard deviations of the calculated average thresholds for the two groups and the two hearing tests are as follows: normal group/pure-tone test, 3.90 dB, 2.08, normal group/acoustic reflex test, 9.46 dB, 9.14; autistic group/pure-tone test, 4.40; dB, 4.04; autistic group/acoustic reflex test, 25.47 dB, 11.41. Data for each subject is reported in Appendix B. Actual threshold results for each subject are reported in Appendix C.

A 2 X 2 analysis of variance with repeated measure is used to compare the variables of type of hearing test and type of subject and their appropriate interactions. The variable of type of subject is significant, F (1, 18) = 35.53. The Group X Test interaction is also significant, F (1, 18) = 12.50. A test of simple main effects reveals no significant difference between average hearing thresholds obtained by the two types of hearing test for subjects of the normal group, F (1, 18) = .02. There is no significant difference between average pure-tone thresholds obtained for the autistic and normal groups, F (1, 18) = 3.10. A significant difference at the .01 level is obtained between the two types of hearing tests for the autistic group, F (1, 18) = 21.86. A significant difference at the .01 level is also obtained between hearing thresholds measured with the acoustic reflex test for the autistic and normal groups, F (1, 18) = 44.48.

Several observations of the data are of clinical significance. First, based on pure-tone threshold data, all ears of both autistic and normal subjects are found to have hearing in the normal range. Based on acoustic reflex data all ears in the normal group are predicted to have normal hearing while five ears in the autistic group are predicted to have mild-moderate hearing loss. The average difference between thresholds calculated from the acoustic reflex data and thresholds obtained through pure-tone audiometry is approximately three times greater for the autistic group (21.1 dB) than for the normal group (7.4 dB). Also, the difference is in the direction of predicting greater hearing loss using acoustic reflex data than is actually found with the pure-tone data.

In all cases with the autistic subjects, when a difference exists between thresholds obtained from the two tests it is in the direction of predicting less sensitive hearing thresholds from the acoustic reflex results than those finally obtained through pure-tone audiometry. In one case the error is as great as 38 dB.

Further, it is found that in the autistic group the predicted threshold (calculated from the acoustic reflex data) differs from the actual threshold (calculated from the pure-tone data) by more than ±10 dB in 90% of cases, and by ±30 dB or more in 30% of cases. In the normal group the predicted and actual thresholds differ by more than ±10 dB in 30% of the cases, and by more than ±20 dB in 10% of the cases. No differences as great as ±30 dB are observed in the normal group.

Discussion

The initial impetus to conduct this research is a result of the author's experience in attempting to teach language skills to autistic children. Often there exists confusion among professionals as to an autistic child's ability to hear. In some cases professionals find it difficult to determine if a very young child is autistic, autistic with hearing loss, simply hearing-impaired, or has one of several other developmental disorders the symptoms of which sometimes overlap those of the autistic syndrome. For these reasons an objective diagnosis of hearing in autistic children is valuable to the diagnostician as well as to educators and therapists charged with the responsibility of helping them to lead more normal lives.

It was the hope of this author that the acoustic reflex could be used as an accurate predictor of hearing threshold in autistic subjects to the degree that it is used with normal subjects. However, the results of this investigation suggest that threshold of the acoustic reflex cannot be used to predict hearing level in autistic individuals. The author realizes the difficulty in generalizing results from such small samples. Nonetheless, the data are interesting in several respects and suggest clearly a need for further investigation in this area.

Pure-tone hearing thresholds are generally taken as the actual hearing thresholds and other types of hearing measurements are compared to the pure-tone test to indicate accuracy of prediction. The results of this study indicate that there is no significant difference between the threshold values of the acoustic reflex prediction method and the pure-tone threshold values of the normal subjects. This suggests that the acoustic reflex measure may be used to predict pure-tone hearing level for these subjects. It is sufficient for audiological diagnostic purposes to be able to predict actual hearing thresholds within ±10 dB HL. In the normal group the predicted and actual thresholds differ by more than ±10 dB in 30% of the cases. This finding is consistent with the findings of Niemeyer and Sesterhenn (1974) who found that they could predict pure-tone thresholds using the acoustic reflex prediction formula within ±10 dB in 73% of their cases (predicted and actual thresholds differed by more than ±10 dB in 27% of the cases).

The results of this study further indicate that there is no significant difference in pure-tone thresholds between the autistic and normal groups. All subjects have hearing thresholds within normal limits.

A significant difference appears between pure-tone and acoustic reflex thresholds of the autistic subjects. This indicates that the acoustic reflex prediction formula cannot be used with confidence to predict pure-tone hearing thresholds for autistic subjects. The data further suggest that the acoustic reflex prediction method consistently predicts less sensitive hearing thresholds than are obtained by pure-tone audiometry. The predicted thresholds differ from actual thresholds by more than ± 10 dB in 90% of the cases.

A significant difference also appears between acoustic reflex thresholds of the autistic and normal groups. Again the acoustic reflex thresholds are less sensitive in the autistic group than in the normal group. This finding suggests that the acoustic reflex response is somehow altered in autistic individuals.

Since it is the acoustic reflex thresholds of the autistic children which are so incongruous, an examination of factors possibly influencing these data is necessary to this discussion. Factors which could influence obtained acoustic reflex thresholds include the following: test procedure; instrumentation; peripheral hearing sensitivity; middle-ear function, and central nervous system function.

Acoustic reflex thresholds for the autistic and normal subjects were obtained using different impedance bridges.

However, both instruments were of the same manufacturer and model and calibration was closely checked for each bridge prior to testing. Test data indicated that both impedance bridges were performing within acceptable limits (see Appendix A). With the knowledge of the characteristics of autistic children it seemed possible that the acoustic reflex threshold data could be altered by emotional responses of the autistic subjects to the testing situation. No subject appeared to be upset by the testing, yet it was possible that autistic subjects could have experienced a change in autonomic functioning as a result of the testing situation and procedure which could have had some effect on the obtained acoustic reflex thresholds. If this were the case, however, one might have expected that the acoustic reflex response would have also been affected by sedation of the subject. Light, Ferrell, and Sandberg (1977) and Stelmachowicz, Bowling, Taylor, and Norris (1974) have reported that sedation of subjects had no significant effect on measured parameters of the acoustic reflex. Light et al. concluded the acoustic reflex was not of myogenic origin. It would be possible in future investigations to expose each autistic subject to the testing environment and procedure several times prior to the collection of acoustic reflex threshold data in order to control for this possibility.

The peripheral hearing of all subjects is found to be well within normal limits. It should be noted that the pure-tone testing procedure utilized with the autistic group insures adequate stimulus control and valid thresholds by defining a discrete motor response to be observed in the presence of the auditory stimulus. Procedural methods were employed to control for temporal responding, responding to unintended visual cues, and accidental reinforcement of incorrect responding. Further, the autistic subjects, because they were nonverbal and noncommunicative, were required to participate in an auditory discrimination training procedure in order to learn to respond reliably in the pure-tone testing situation.

The normal subjects were verbal and therefore were given simple instructions on how to respond in the testing situation. This procedural difference between the groups could possibly introduce some variance in pure-tone hearing thresholds. However, no differences are observed on this measure between the groups. In addition all ears were screened for normal tympanograms prior to inclusion in the study. The presence of normal tympanograms and the fact that acoustic reflexes were obtained for all ears suggests middle-ear function was within normal limits.

It is possible that in autistic subjects the acoustic reflex arc is somehow compromised centrally. The effect is subtle, however, since the reflex does exist but at higher thresholds than for normals. Elevated acoustic reflex thresholds in the absence of peripheral hearing loss or middle-ear disorder has been demonstrated in subjects with brain stem lesions (Jerger & Jerger, 1977). At least one of the recent theories of autism postulates that autistic traits are due mainly to an organic brain lesion (Ornitz, Ritvo, Panman, Lee, Carr, & Walter, 1968).

The finding of the present study that the acoustic reflex occurs at higher threshold levels in autistics than in normals is consistent with the findings of Student & Sohmer (1978). These researchers concluded that an organic brain lesion must exist in the part of the brain concerned with the propagation of auditory information in autistics. This conclusion was based on their findings of hearing loss in some autistic subjects and in others, a longer latency of the auditory nerve impulse suggesting a delay in brain stem transmission. Therefore it is plausible that the observed differences of acoustic reflex thresholds between the autistic and normal subjects are another manifestation of this brain stem pathology. Further research in this area with a greater number of subjects is necessary to verify these findings.

It is possible, based on the results of this and other investigations that acoustic reflex threshold data along with brain stem evoked response audiometry could be used as an additional diagnostic indicator of the autistic syndrome. The absence of peripheral hearing loss in the presence of elevated acoustic reflex thresholds and prolonged auditory brain stem response latencies may provide objective evidence to compliment behavioral observations.

It is hoped that the present study is a contribution to the growing body of knowledge about autism as well as the knowledge of the diagnostic uses of the acoustic reflex. It is apparent that no firm conclusions can be drawn from this study due to the small number of subjects used. However, others may extend this research in order to better understand the autistic syndrome and perhaps contribute to its alleviation.

Appendix A

Impedance Calibration

Make: Madsen Model: Z072I Serial: 5016S

Headphone Type: TDH-140 Test Group: Normal

Frequency (Hz)	Oscillation (Hz)	Air Conduction AT 70 dB SPL	
		Standard dB SPL	Actual dB SPL
500	503	81.5	81.7
1000	1013	77.0	77.2
2000	2034	79.0	79.1
4000	4030	79.5	79.4
White Noise	--	90.0	91.0
Probe Tone (220)	--	85.0	85.0

Make: Madsen Model: Z0-72 Serial: 6904

Headphone Type: TDH-140 Test Group: Autistic

Frequency (Hz)	Oscillation (Hz)	Air Conduction AT 70 dB SPL	
		Standard dB SPL	Actual dB SPL
500	496	81.5	82.0
1000	1008	77.0	77.0
2000	2009	79.0	80.0
4000	4006	80.5	81.0
White Noise	--	90.0	90.5
Probe Tone (221)	--	85.0	85.0

Audiometer Calibration*

Make: Trachor Model: RA-115 Test Group: Normal

Frequency (Hz)	Intensity Limits	Right Phone	Left Phone
500	81.5 78.5-84.5	83.5	79.0
1000	77.0 74.0-80.0	77.0	75.0
2000	79.0 76.0 82.0	79.5	80.0
4000	79.5 75.5 83.5	80.5	80.5

Make: Trachor Model: RA-115 Test Group: Autistic

Frequency (Hz)	Intensity Limits	Right Phone	Left Phone
500	81.5 78.5-84.5	81.5	81.5
1000	77.0 74.0-80.0	77.1	77.0
2000	79.0 76.0-82.0	78.5	79.0
4000	79.5 75.5-83.5	79.5	79.5

*70 dB HL input.

Appendix B

Average Hearing Thresholds Obtained from Pure-Tone Audiometric Evaluation and Acoustic Reflex Threshold Evaluation for Autistic and Normal Subjects

	Normal		Autistic	
	AR[1]	P-T[2]	AR[1]	P-T[2]
Subject 1				
Left ear	6.9 dB	3.8 dB	18.8 dB	1.3 dB
Right ear	3.1 dB	2.5 dB	33.1 dB	1.3 dB
Subject 2				
Left ear	13.8 dB	5.0 dB	31.9 dB	15.0 dB
Right ear	1.3 dB	6.3 dB	21.3 dB	6.3 dB
Subject 3				
Left ear	21.3 dB	5.0 dB	43.8 dB	5.0 dB
Right ear	25.0 dB	3.8 dB	31.3 dB	2.5 dB
Subject 4				
Left ear	17.5 dB	6.3 dB	3.8 dB	3.8 dB
Right ear	1.3 dB	5.0 dB	17.5 dB	2.5 dB
Subject 5				
Left ear	3.1 dB	1.3 dB	33.8 dB	3.8 dB
Right ear	1.3 dB	0.0 dB	19.4 dB	2.5 dB

AR = Acoustic Reflex
P-T = Pure-Tone

Appendix C

Hearing Thresholds Obtained from Pure-Tone Audiometric Evaluation and Acoustic Reflex Threshold Evaluation for Autistic and Normal Subjects

Pure-Tone Thresholds of Normal Subjects

	Threshold (dB HL)	
	Left Ear	Right Ear
Subject 1		
500 Hz	5	0
1000 Hz	0	0
2000 Hz	5	5
4000 Hz	5	5
Subject 2		
500 Hz	5	5
1000 Hz	0	5
2000 Hz	5	5
4000 Hz	10	10
Subject 3		
500 Hz	5	0
1000 Hz	5	5
2000 Hz	5	5
4000 Hz	5	5
Subject 4		
500 Hz	5	5
1000 Hz	5	5
2000 Hz	5	0
4000 Hz	10	10
Subject 5		
500 Hz	0	0
1000 Hz	0	0
2000 Hz	5	0
4000 Hz	0	0

Pure-Tone Thresholds of Autistic Subjects

	Threshold (dB HL)	
	Left Ear	Right Ear
Subject 1		
500 Hz	5	5
1000 Hz	0	0
2000 Hz	0	0
4000 Hz	0	0
Subject 2		
500 Hz	25	15
1000 Hz	20	0
2000 Hz	15	5
4000 Hz	0	5
Subject 3		
500 Hz	10	5
1000 Hz	5	5
2000 Hz	5	0
4000 Hz	0	0
Subject 4		
500 Hz	10	0
1000 Hz	5	5
2000 Hz	0	0
4000 Hz	0	5
Subject 5		
500 Hz	5	5
1000 Hz	5	5
2000 Hz	5	0
4000 Hz	0	0

Acoustic Reflex Thresholds of Normal Subjects

	Threshold (dB HL)	
	Left Ear	Right Ear
Subject 1		
500 Hz	85	85
1000 Hz	85	85
2000 Hz	80	85
4000 Hz	85	90
White Noise	75	75
Subject 2		
500 Hz	85	90
1000 Hz	85	85
2000 Hz	90	85
4000 Hz	90	90
White Noise	80	75
Subject 3		
500 Hz	80	80
1000 Hz	80	80
2000 Hz	85	80
4000 Hz	85	80
White Noise	80	80
Subject 4		
500 Hz	85	85
1000 Hz	80	90
2000 Hz	85	90
4000 Hz	90	85
White Noise	80	75
Subject 5		
500 Hz	85	85
1000 Hz	85	90
2000 Hz	90	90
4000 Hz	85	85
White Noise	75	75

Acoustic Reflex Thresholds of Autistic Subjects

	Threshold (dB HL)	
	Left Ear	Right Ear
Subject 1		
500 Hz	95	95
1000 Hz	95	90
2000 Hz	95	90
4000 Hz	85	90
White Noise	85	90
Subject 2		
500 Hz	85	85
1000 Hz	85	85
2000 Hz	80	80
4000 Hz	85	80
White Noise	85	80
Subject 3		
500 Hz	95	95
1000 Hz	85	90
2000 Hz	90	95
4000 Hz	100	90
White Noise	95	90
Subject 4		
500 Hz	75	80
1000 Hz	75	80
2000 Hz	75	80
4000 Hz	85	100
White Noise	70	80
Subject 5		
500 Hz	85	85
1000 Hz	85	85
2000 Hz	85	80
4000 Hz	80	80
White Noise	80	85

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