Recognition of Environmental Sounds in Autistic Children

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Abstract. Environmental sound recognition was tested in children with an autistic disorder, along with recognition of spoken words for the same target items, using a picture-matching task. No overall difference between sound and word recognition scores was observed for either autistic or normal subjects. However, those autistic children found to achieve high scores on the sounds also scored highly on a visual pattern matching task. Thus, a pattern-matching ability was found across two modalities, visual and auditory, in this subgroup of children with an autistic disorder. Possible relevance of this finding to hemispheric dominance (as reflected by handedness studies) in autism, and to the putative inabilities of these children to recognize affectual cues, are considered. These findings also have implications for clinical assessment, indicating that tests of pattern-matching may provide more specific information about preserved skills in the individual child with an autistic disorder. *J. Am. Acad. Child Adolesc. Psychiatry*, 1988, 27, 4:423–427. **Key Words:** autism, affectual cues, pattern-matching ability.

This study examines the relative abilities of children with an autistic disorder to recognize two kinds of auditory pattern: words (processed in the left hemisphere of normal right-handed individuals) and environmental sounds (nonverbal auditory patterns, generally associated with right hemisphere processing). Auditory pattern-recognition abilities have not been systematically assessed in autistic children; however, clinical observations suggest that relatively preserved cognitive abilities of these children may extend to auditory phenomena. For example, children with an autistic disorder are reported to attend to noises (e.g., bells), to be attracted to stereotyped vocal expressions such as television commercials, and to prefer music to spoken language (Blackstock, 1978), although they are generally less responsive to verbal commands and questions than normal children (Tonick, 1981). In fact, musical abilities in a small group of higher functioning children with an autistic disorder were demonstrated to exceed linguistic skills (Applebaum et al., 1979).

Although children with an autistic disorder are deficient in the production and perception of speech and language (despite apparently normal hearing), they often show relatively intact abilities for *visual* pattern recognition. For example, on the Wechsler scale, scores for Block Design (Tymchuk et al., 1977) and Object Assembly (Lockyer and Rutter, 1970) have been shown to be generally higher than verbal IQ scores; and on the Merrill-Palmer Test, scores on the Seguin formboard (De Myer et al., 1972) and Decroly Matching Game (Tonick, 1981) are higher than would be predicted from overall IQ scores. This relative preservation of visual pattern recognition abilities in autistic disorders, along with the nonverbal auditory pattern recognition abilities that have been observed, led the authors to hypothesize that the sound recognition performance of autistic subjects would exceed their performance on a word recognition task. Surprisingly, only one published paper mentions formal testing of "response to sound" within a battery of tests administered to several clinical populations (Wing, 1969); an autistic group was reported to be less impaired in understanding the meaning of some sounds than was a receptive aphasic group.

Many of the above nonverbal processing abilities have been associated with the right hemisphere in normal adults (e.g., Bogen, 1969; Bryden, 1982; Levy, 1974) and children. For example, right hemispheric specialization for meaningful, nonverbal sound recognition has been shown for adults in clinical and experimental studies using dichotic listening (Assal and Aubert, 1979; Carmon and Nachshon, 1973; Curry, 1967; King and Kimura, 1972); more relevant to the present study, Knox and Kimura (1970) demonstrated a left ear advantage by age 5 for recognition of environmental sounds in children, and Geffen (1976) has shown that lateralization of language to the left hemisphere is fully established by that same age.

The present study thus bears on the debate over left-hemisphere impairment in autistic disorders. The discrepancy between communicative and perceptual responses of children with autistic disorders has previously been considered in light of brain lateralization (Blackstock, 1978; Hermelin, 1976; Hoffman and Prior, 1982; Prior, 1979; Prior and Bradshaw, 1979; Wing, 1969); however, the view of autism as a left-hemisphere disorder has recently been challenged (e.g., Arnold and Schwartz, 1983; Damasio, 1984; Fein et al., 1984). For example, Dawson et al. (1982) found in an EEG study of hemispheric asymmetry for verbal and spatial tasks that verbal IQ for autistic subjects was correlated with the *degree* of brain lateralization, *independent* of side.

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Although the site of cerebral impairment in classic autism remains unclear, it is generally agreed that certain behavioral systems—and hence certain cerebral systems—are affected, while others are relatively intact (Damasio, 1984). Left, right, bilateral, and limbic systems have all been implicated as impaired, but no one anatomical deficit has been demonstrated in autistic groups (Damasio and Mauerer, 1978; Prior et al., 1984). In autistic populations, some subgroups with anomalies in some CAT-scan studies have been reported (Campbell et al., 1982; Damasio et al., 1970; Hier et al., 1979); however, another CAT-scan study showed no brain abnormality associated with diagnostic groups (Caparulo et al., 1982), and a neuropathological analysis failed to find clues to the autistic disorder (Williams et al., 1980). Most researchers now agree that autism arises from multiple etiologies and that autistics constitute a heterogeneous group (Coleman, 1979; Darby, 1976).

Subgroups of subjects with an autistic disorder have been identified successfully using hand preference measures. Satz et al. (1985) found three distinct subgroups within the autistic population with respect to handedness: A predominantly right-handed group, a predominantly left-handed group, and an ambiguous group (showing no measurable hand preference). The left-handed group constituted a higher percentage than would be found in the normal population; the ambiguous group constituted about 40% of both autistic populations studied.

In summary, many children with an autistic disorder score at moderate to mild retardation levels in formal testing but perform within normal ranges on visual pattern matching tasks. The experiments described in this paper have extended these observations to testing of auditory pattern recognition. Given that pattern recognition processes in both the visual and the auditory modalities have been associated with right hemisphere specialization in normal adults, there is an obvious interest in investigating the nature of such abilities in children with an autistic disorder, since subgroups of this clinical population may be made up of individuals in whom abnormal lateralization of function or failure to lateralize neuropsychological functions has occurred.

Method

Subjects

Twenty-five children with an autistic disorder, 22 male and 3 female, with a mean chronological age (CA) of 8.1 years and a mean mental age (MA) of 5.17 years, and 25 normal children with a mean age of 5.35 years, participated as subjects. Control subjects were matched for mental age and sex to the autistic subjects. Mental ages were measured within 6 months of testing (using the Merrill-Palmer Test and the Wechsler Preschool and Primary Scale of Intelligence). Normal control subjects differed from autistic subjects in CA-MA matched pairs by no more than 6 months.

The autistic children were seen and diagnosed by the Child Psychiatry Clinical Research Center at UCLA's Neuropsychiatric Institute. Each child received an extensive evaluation, including a detailed developmental history using a questionnaire, a videotaped psychiatric assessment, psychological and linguistic testing, pediatric and neurological examination, and audiological assessment. Examinations were carried out by a professional team of child psychiatrists and child psychologists, language pathologists, an audiologist, a social worker, and a pediatrician, all expert in dealing with psychotic children. A diagnosis of early infantile autism was reached only if at least all but one of the members of the team agreed that the child's condition met all of the criteria for early infantile autism listed in the DSM-III. Children whose developmental quotient or IQ was less than 40 on a standardized psychological assessment were rejected (Tanguay et al., 1982).

Stimuli and Procedure

Stimuli were 40 tape-recorded 2-second environmental sounds, consisting of (1) human vocalization (e.g., laughter, crying); (2) animal vocalization; and (3) inanimate noises, such as object sounds (e.g., bell, hammer) and event sounds (e.g., traffic, playground), and 40 tape-recorded words for the same target items. The sounds and corresponding words were divided into two forms (A and B). Two stimulus tapes were prepared; one was composed of form A sounds and form B words, and the other of form A words and form B sounds. Each response sheet contained line drawings of the target and three foils (an animate sound-maker, an inanimate sound-maker, and a nonsounding foil (e.g., cactus, box)). Examples are given in Figure 1.

A practice tape was also prepared with five examples of environmental sounds. The response sheet for the first practice item had only one drawing. The sheet for the second sound had two drawings, the target and one foil; the third had three drawings; and the fourth and fifth had four drawings. Thus, these practice items began with simple sound-picture associations and ended with a target sound and four choices.

All subjects heard the same practice tape at the beginning of the session, and, if necessary, were prompted to point to the correct drawing. The criterion for continuation of the task following the practice was a response to the last practice item

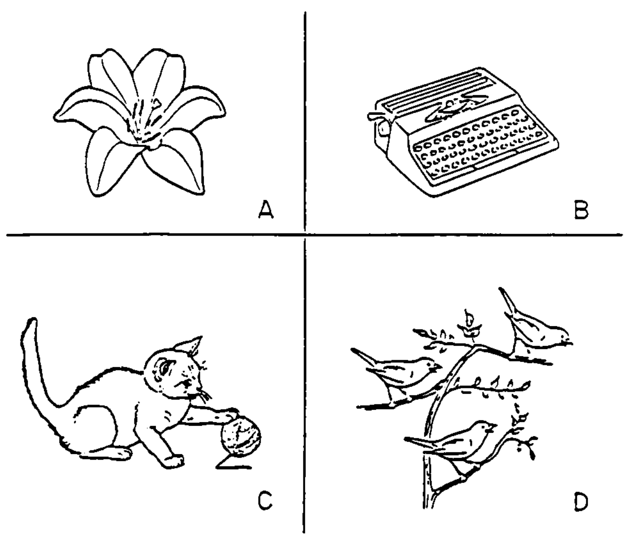

FIG. 1. An example of the response materials. Stimulus was 2 seconds of birds chirping; the cat (animate sound-maker), typewriter (inanimate sound-maker), and flower (nonsounding) are foils.

without physical prompting. The order of presentation of sound and word tasks was alternated between subjects.

Results

All results reported are significant at the 5% level, unless otherwise stated; and all t tests have 24 degrees of freedom, unless otherwise stated.

Scores for normal and autistic subjects, matched by MA, are shown in Table 1. Normal children made remarkably few errors on both tasks. Subjects with an autistic disorder performed significantly worse overall on both sounds and words than did age- and sex-matched normals (matched pairs t tests; sounds: $t = -3.33$; words: $t = -3.26$). However, using the sounds-to-words error ratio found for normals (10.48/8.35; see Table 1) to predict the autistics' error rate on sounds from their word error rate (21.48) gives a predicted mean error rate of 26.96%. This is quite close to the observed mean error rate on sounds (26.66%), suggesting no difference in relative abilities between groups.

Contrary to our hypothesis, both autistic and normal groups overall performed slightly but not significantly better on word stimuli than on sounds (matched pair t tests: for the autistic group $t = -1.58$, NS; for the normal-control group, $t = -0.83$, NS). Note that ranges of scores overlap substantially for the two groups on both tasks. In a further analysis, performance on human, animate (e.g., dogs) and inanimate sound and word stimuli was examined. Subjects with an autistic disorder performed significantly less well than matched normals on each of the three sound categories (human: $t = 2.17$; animate: $t = 3.50$; inanimate: $t = 3.24$). Autistics made more errors on each of the three word categories, also, but the result was significant only for human stimuli ($t = 3.01$; animate: $t = 2.03$, NS; inanimate: $t = 1.59$, NS).

Scores on the word task are plotted against scores on the sound task for individual subjects in Figure 2. Normal listeners fall into a single group with a few outliers in this plot, but listeners with an autistic disorder fall into two distinct groups. The configuration of high (>70) versus low (<70) Merrill-Palmer scores within the autistic subgroup (shown in Figure 2B) is of particular interest. Subjects with high Merrill-Palmer scores scored significantly higher on the sound identification task than did those with low Merrill-Palmer scores (F (1,23) = 20.80). Thus, those children with demonstrated superior performance on a test that primarily assesses visual nonverbal and pattern recognition abilities also had higher scores on an auditory pattern task.

TABLE 1. *Mean Scores and Ranges of Scores on Sound and Word Tasks, for Autistic and Age- and Sex-matched Normal Control Subjects*

	Autistic Subjects	Normal Subjects
Sounds task		
Mean score	73.34% (26.78)	89.62% (12.00)
Range	25.0–100%	50.0–100%
Words task		
Mean score	78.52% (20.86)	91.65% (12.88)
Range	29.49–100%	42.0–100%

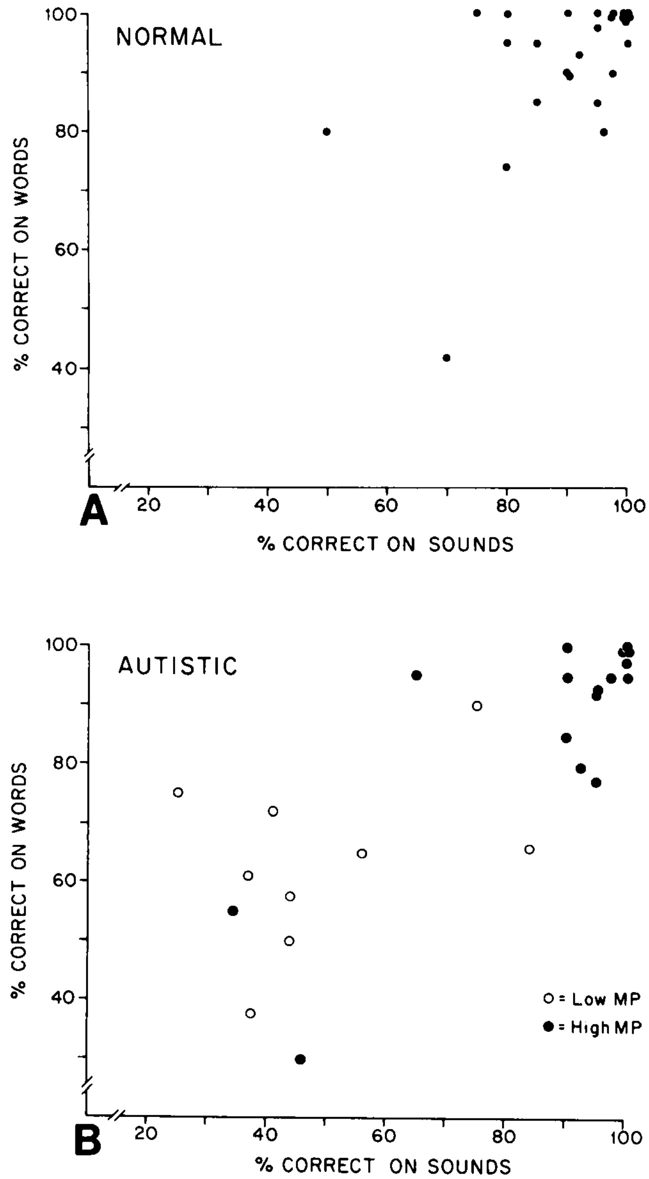

FIG. 2. Percentage of correct recognition on the sound identification task vs. percentage correct on the word recognition task. *A*, Normal subjects. *B*, Autistic subjects. *Filled circles* represent autistic subjects with scores above 70 on the Merrill-Palmer Test, while *open circles* represent subjects with scores below 70.

Fifteen of the 25 subjects in this study were assessed by the handedness measure devised by Satz and colleagues (1985). Of the 15, six are right-handed (mean CA 9.6 years, mean MA 7.7 years), four are left-handed (mean CA 10.2 years, mean MA 5.1 years), and five are in the ambiguous group (mean CA 7.7 years, mean MA 3.7 years). The left- and right-handed groups did not differ in performance on sounds and words. However, scores for the ambiguous group were significantly lower than those for the other two groups, on both sounds ($t = -3.07$, $df = 13$) and words ($t = -4.33$, $df = 13$). This finding agrees with the observation by Dawson et al. (1982) that *any* laterality effect is correlated with better linguistic performance.

Discussion

The purpose of this research was to establish whether children with an autistic disorder show auditory pattern abilities analogous to reported visual pattern recognition abilities. Further, if the view that autism is primarily a left-hemisphere disorder is correct, then children with an autistic disorder would be expected to perform better on sound-picture matching (previously associated with right hemisphere specialization) than on word-picture matching (generally held to be a left-hemisphere function). Contrary to this hypothesis, no overall difference in performance on sound and word recognition tasks was observed. However, the subjects with an autistic disorder did fall into two groups: those with high scores on both sounds and words, and those with low scores. The autistic children having high scores on sounds also had high scores on a visual pattern matching test. The majority of subjects with good visual task abilities (often associated with right hemisphere processing) scored slightly higher on the sounds task than on words.

In this study, laterality in either direction corresponded to higher scores on both words (93 to 95% correct) and sounds (92 to 93% correct) in both right- and left-handed groups. Thus, these results do not contribute to a picture of left-hemisphere impairment with relative sparing of the right hemisphere in autism; rather, they are in accord with more recent views (Damasio, 1984; Fein et al., 1984) that claim a lack of relationship between autistic disorders and isolated "hemispheric" abilities. Our results are also consistent with IQ measures on a larger population ($N = 30$) of clinical research center subjects by Soper et al. (1986) in which both right- and left-handed groups have full scale IQs significantly higher than the ambiguous group. Note, however, that the age difference between the lateralized and the ambiguous group suggests a possible delay in lateralization in some of these subjects.

Despite the clinical observation that many children with an autistic disorder are preoccupied with inanimate objects, no difference in the distribution of wrong answers between animate and inanimate foils was observed in the autistic population. The autistic subjects were as likely to pick drawings of animate objects as drawings of inanimate objects when making a wrong choice. This negative result can perhaps be attributed to the use of pictured rather than actual objects in the testing situation and need not be taken as contradicting the common view that many children with an autistic disorder are preoccupied with and respond to inanimate objects.

It is notable that in an analysis of errors on word-picture matching, children with an autistic disorder *were* found to make significantly more errors on words denoting humans, the single significant effect in the error analysis. Although the number of observations is too small to make a conclusive interpretation, this finding is provocative given the relative deficits in social relating often observed in autistic children (Foldi et al., 1983; Myers, 1979; Weintraub and Mesulam, 1983). If replicated, this finding has implications for clinical evaluation procedures. Standard psychological procedures for the assessment of cognitive and emotional functioning require a significant amount of responding and interactions on the part of the examinee. Psychological testing should be conducted in a nonaversive manner involving many breaks for reinforcement. Such conditions would most likely provide testing results suggestive of the child's highest level of performance.

Typically, for assessment clinicians have used a combination of assessment devices such as the Stanford-Binet, the appropriate Wechsler scales given the child's chronological age, and the Merrill-Palmer to determine IQ and performance abilities. The results of the present study suggest that tests that examine visual and auditory pattern-matching abilities would provide more specific information regarding the nonverbal skills of autistic children. Two suggestions of useful tests in determining visual pattern-matching abilities are the Leiter International Performance Scale and Raven's Progressive Matrices. Furthermore, the development of a test focusing on the auditory modality might yield higher useful information. Such evaluation procedures would have important implications for the education and treatment of individuals in these populations.

This study adds the auditory dimension to the clinical picture differentiating high- from low-functioning autistic groups. The higher functioning child can be expected to perform relatively better on auditory nonverbal as well as visual nonverbal material. This preserved ability might be profitably detected and nurtured in the education of these children.

Finally, the present investigation also recalls another important observation about autistic persons; namely, that they are often unable to "recognize affect" when it is expressed by facial features, voice tone, or situational context (Hobson, 1986a, b). Is this because autistic persons cannot distinguish differences in physical characteristics between differing emotional signals, or is it that they fail to understand the interpersonal meaning or implication of the signal in question? To the extent that autistic subjects in this study were able to correctly differentiate and semantically identify various sounds, the present findings suggest that the latter explanation may be more likely. A study of the degree to which autistic persons can in fact identify the physical differences between various verbal affectual signals is required to settle this issue; the authors are presently engaged in such a study.

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