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Abstract Reasoning in Autism: A Dissociation Between Concept Formation and Concept Identification

Nancy J. Minshew and Jessica Meyer
University of Pittsburgh School of Medicine

Gerald Goldstein
Veterans Affairs Pittsburgh Healthcare System and
University of Pittsburgh

The concept identification and concept formation aspects of abstract reasoning were examined in 90 nonmentally retarded individuals with autism and 107 normal controls. It was hypothesized that pronounced deficits would be found on concept formation tests, whereas performance on concept identification tests would be relatively intact. There was a significant difference between individuals with autism and individuals from a matched control group on all abstract reasoning tasks, but, with the exception of the Wisconsin Card Sorting Test (R. K. Heaton et al., 1993), differences on concept identification tests were not clinically significant. Factor analyses showed that concept formation and concept identification tasks loaded on separate factors in the autism group but not in the control group. Stepwise discriminant function analyses revealed that 2 tests of concept formation correctly classified 78.4% of cases, whereas concept identification tasks did not pass the tolerance test.

A cognitive deficit in abstract reasoning has long been viewed as a fundamental impairment in autism and has been documented across the spectrum of the disorder. Rutter (1978) observed that as general cognitive ability decreased, abstraction abilities dropped precipitously. Adams and Sheslow (1983) characterized the deficit in lower ability individuals with autism as a failure to reach the formal operations stage of intellectual development, which involves the capacity for concept formation and hypothetical thought. Consistent with this formulation, in behavioral intervention programs such as the Lovaas (1987) discrete trial program, young children with autism are taught in massed trials to group objects according to a variety of concepts including color, size, shape, and function. However, generalization of these learned concepts involving application in different contexts often remains a problem. Concrete thinking, or the inability to form concepts based on experience, is commonly ascribed to higher ability individuals with autism (Tsai, 1992). This cognitive deficit has also been described in various other ways, including the application of K. Goldstein's (1939) impairment of the "abstract attitude" (Ozonoff, 1995), the inability to generate novel thoughts and actions (Jarrold, Boucher, & Smith, 1996), the tendency to persist in a once given response rather than select alternates (Hermelin & O'Connor, 1970), and a propensity to strict rule-bound behavior (Boucher, 1977; Frith, 1972). Thus, there is ample evidence of a universally present deficit in abstraction abilities in autism and of a range of severity in its expression (Minshew, Goldstein, Muenz, & Payton, 1992; Prior & Hoffman, 1990; Rumsey, 1985; Schneider & Asarnow, 1987; Szatmari, Tuff, Finlayson, & Bartolucci, 1990).

In an early study of 16 nonmentally retarded adults with autism, Minshew et al. (1992) found normal performance on the Wisconsin Card Sorting Test (WCST; Heaton et al., 1993) accompanied by marked deficits on an object sorting test. It was proposed that a dissociation existed in autism between rule learning, or concept identification abilities, and concept formation abilities. From a behavioral standpoint, this division of abstraction abilities would explain the need to rotely train very young children with autism to recognize and use the rules and the rigid, rule-bound behavior of older, less impaired individuals. This division also provided a cognitive basis for the inability to apply rules in changing circumstances, to generalize, and to form concepts for dealing with novel situations for which rules are not known. Within this framework, the most impaired individuals with autism have neither rule learning nor concept formation abilities, less impaired individuals have rule learning abilities but inflexibility in applying them, and the highest ability individuals can discern and flexibly apply rules but not formulate original concepts.

Concept formation tests involve an open field situation in which the test taker has to initiate proposed solutions through hypothesizing a basis for pertinence or categorization. Sorting tests, such as the Goldstein–Scheerer Object Sorting Test (K. Goldstein & Scheerer, 1941), are the most

Nancy J. Minshew and Jessica Meyer, Department of Psychiatry, University of Pittsburgh School of Medicine; Gerald Goldstein, Research Service, Veterans Affairs Pittsburgh Healthcare System, and Department of Psychiatry, University of Pittsburgh.

Jessica Meyer is now at the Department of Psychology, Louisiana State University.

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Correspondence concerning this article should be addressed to Gerald Goldstein, Veterans Affairs Pittsburgh Healthcare System, 7180 Highland Drive (151R), Pittsburgh, Pennsylvania 15206. E-mail: ggold@nb.net

commonly used procedures of this type. In free sorting, a variety of objects are placed before the test taker, who is asked to group the material with instructions such as “Put those together which you think belong together.” After the first sorting, the participant is asked to put the figures together in another way. These tests assess the capacity to form an abstraction or concept as the basis for the initial sorting, and they also evaluate cognitive flexibility, or the capacity to shift concepts. The concept has to be self-initiated, and the participant makes up the rules that provide the basis for grouping.

Concept identification tests were developed after the free sorting tests and assess abstraction with a different methodology. The basic sorting test strategy was retained, but in these newer tests, notably the Halstead Category Test (Reitan & Wolfson, 1993) and the WCST, the concepts are not formed by the participant but are inherent in the test materials themselves. Bourne (1966) characterized these procedures as concept identification tasks and wrote about the distinction between those tests and concept formation tests. Within the concept identification process, Perrine (1993) has made the additional important distinction between attribute identification and rule learning. The WCST stresses attribute identification. The correct answer is the stimulus attribute of form, color, or number. In the case of the Halstead Category Test, the correct principle is a rule regardless of the attributes of the stimuli. It is interesting to note that Perrine reported only 30% shared variance between the two procedures, suggesting that these are separable abilities within conceptual reasoning.

There are some tests that incorporate aspects of concept formation that do not use a classical sorting procedure. In the 20 Questions task (Mosher & Hornsby, 1966) and the Stanford-Binet Verbal and Picture Absurdities subtests (Thorndike, Hagen, & Sattler, 1986), the participant has to self-initiate problem-solving strategies to arrive at a solution. In the case of 20 Questions, a target object must be named on the basis of questions that can only be answered *yes* or *no*. The strategy for narrowing down the possibilities and arriving at the right answer has to be formed by the player. In the absurdities tests, again the problem is the ruling out of irrelevant materials in the course of arriving at a correct solution. The issue appears to be less of whether or not there is an objective correct answer but more of whether or not the problem solver can develop a strategy that transcends the immediate stimulus properties. In free sorting, the 20 Questions task and the absurdities tests, there is nothing in the stimulus array that provides cues to alternative hypotheses. In the case of the WCST and the Halstead Category Test, the test taker is cued at every trial. Similarly, the WCST is not entirely a concept identification task. Because the relevant attribute changes unbeknownst to the test taker, a requirement is created for spontaneous evaluation and hypothesis formation, perhaps best assessed by the perseverative error score.

Concept identification tests, therefore, require the formation of preliminary hypotheses that are confirmed or disconfirmed by an external source. Concept formation requires the same set of abilities for hypothesis generation, but there is no structured response system that provides feedback about the correctness of a choice. The individual must spontaneously initiate a strategy for eliminating alternatives and pursue it until the problem is solved or a solution is achieved. The strategy needs to be monitored and changed in accordance with experience of success or failure while progressing to the solution. Although concept formation, attribute identification, and rule learning may all require abstract reasoning, they may be separable cognitive abilities within abstract reasoning that may have differing clinical and adaptive implications. The neural processes involved in self-initiating a schema for problem solving may be quite different from those involved in learning to separate relevant from irrelevant aspects of the environment or from learning preexisting rules on the basis of repeated experience. The purpose of the present study was to examine performance among a large sample of nonmentally retarded individuals with autism on a range of abstraction abilities using a set of tests that assessed various aspects of concept formation or identification. The hypothesis was that there would be a dissociation between concept identification and concept formation abilities that accurately characterizes the abstraction deficit in nonmentally retarded individuals with autism.

Method

Participants

The participants for the study were 90 individuals with high-functioning autism and 107 controls. The groups did not differ significantly with regard to age, IQ, social economic status, or gender composition. All participants were 12 years of age or older. Demographic data are presented in Table 1. The diagnosis of autism was made by a detailed evaluation using expert clinical judgment, the Autism Diagnostic Interview—Revised (Lord, Rutter, & LeCouteur, 1994) and the Autism Diagnostic Observation Schedule (Lord et al., 1989). Participants were considered to have autism if they met criteria across all three assessments. All participants were required to have evidence of delayed and disordered language development, thus excluding individuals with Asperger’s disorder.

Potential control participants recruited from the community were excluded if they had a history of birth or developmental abnormalities; brain injury; poor school attendance; current or past history of psychiatric or significant neurological disorder; family

Table 1
Demographic Data

Characteristic	Autism group *M*	Autism group *SD*	Control group *M*	Control group *SD*
Age in years	21.41	9.68	21.23	9.81
Years of education	10.63	3.26	11.13	2.81
Score				
Verbal IQ	100.11	17.99	101.50	13.48
Performance IQ	95.51	14.69	99.95	12.70
Full Scale IQ	97.95	16.01	100.90	13.40

Note. None of these differences are statistically significant ($p < .05$). Verbal IQ, Performance IQ, and Full Scale IQ are all from the Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981).

history of autism in first, second, or third degree relatives; or a family history in first degree relatives of developmental cognitive disorder or learning disability, mood or anxiety disorder, or other neuropsychiatric disorder thought to have a genetic etiological component. The study was approved by the University of Pittsburgh Medical Center Internal Review Board, and informed consent was provided by all participants.

Procedure

All participants received the age appropriate version of the Wechsler intelligence scale for matching purposes. No participants in either group had a Full Scale or Verbal IQ score below 70. The hypotheses were tested through the administration of a series of abstraction tasks described below.

Trail Making Test Part B (Reitan & Wolfson, 1993). The participant must draw lines between consecutively numbered and lettered circles by alternating between the two sequences. Trail Making Test Part A, which only involves connecting numbers, was administered but not used in the data analysis.

Halstead Category Test. Stimuli consisting mainly of geometric forms are presented on a screen, beneath which are four numbered keys. The participant is instructed that the stimuli in each of the seven subtests are united by some principle or idea that can be learned by pressing the keys. A pleasant chime follows the pressing of a correct key and a rasping buzzer follows an error. The participant's task is to identify the relevant concept or rule through the pattern of correct and incorrect responses.

WCST. Four stimulus cards are presented that vary along the dimensions of color, shape, and number. The correct answer is the stimulus attribute of shape, color, or number. Participants are given 128 cards that vary along these dimensions and are instructed to match the cards in the deck with one of the four stimulus cards. The examiner tells the participant whether the card was placed correctly or incorrectly but does not reveal the sorting rule. When 10 consecutive cards have been categorized correctly, the sorting principle changes without warning or comment from the examiner. The participant is expected to use incorrect responses to shift to a new categorization rule. The test continues until six categories have been correctly sorted or until all 128 cards have been exhausted. The perseverative errors and categories achieved scores were used in the data analysis.

Goldstein–Scheerer Object Sorting Test. This test consists of 30 familiar objects that can be grouped according to such principles as function, material, and color. In the first section, the participant is required to find objects that are compatible with one selected by the examiner. Next, the participant is asked to put together those items that he or she thinks belong together and to provide a verbal explanation of the reason. Finally, the participant is required to shift categories or regroup the same objects in another way. The participant must therefore demonstrate full attainment of the abstraction by conceptual shifting. The scores used for this study were the number of sorts rated as abstract and a rating of adequacy of the shift, which was classed as abstract, functional or concrete, or none.

Verbal Absurdities subtest. The Verbal Absurdities subtest of the Stanford–Binet Intelligence Scales requires the participant to point out logical impossibilities in several stories. This task involves verbal reasoning and problem solving in which the participant must evaluate and integrate all aspects of a problem that may not be immediately evident. The problem is one of ruling out irrelevant materials in the course of arriving at a correct solution. To solve the problem, the participant has to develop a strategy that transcends the immediate stimulus properties.

Picture Absurdities subtest. The Picture Absurdities subtest of the Stanford–Binet presents 32 silly or logically impossible situations on pictures of increasing difficulty. The participant responds correctly by identifying the absurd aspect of each situation, again demonstrating the ability to separate relevant from irrelevant aspects of the environment. The score for this task is the number correct out of the 32 possible scenarios. Both absurdities subtests assess logical thinking, comprehension of relationships, and practical judgments.

20 Questions task. The version of the task used was that of Laine and Butters (1982). Participants are presented with an 8×10 in. ($\sim 20 \times \sim 25$ cm) card displaying an array of 42 drawings of objects, representing overlapping categories such as animals, round objects, and paired items. The participant first names all of the items and then is instructed to determine which item the examiner is thinking of by asking as few questions as possible. The participant must form hypotheses regarding the correct response by asking constraint seeking questions that rule out possibilities. Effective constraint seeking questions must be efficient in eliminating alternatives. The score used for this task was the percentage of constraint seeking questions.

All tests were administered by trained technicians under the supervision of a licensed psychologist. This selection of tests was made so as to include measures of concept formation (the Stanford-Binet absurdities subtests, the 20 Questions task, and the Goldstein-Scheerer Object Sorting task) and concept identification (the Halstead Category Test and the Trail Making Test Part B). We viewed the WCST as a test that involves both concept identification and formation. Number of categories achieved is a measure of ability to identify attributes, a form of concept identification. However, the procedure of shifting the relevant attribute unbeknown to the test taker requires formation of alternative hypotheses and would appear to represent an assessment of K. Goldstein and Scheerer's (1941) definition of the abstract attitude relating to reflective shifting from one aspect of a situation to another. Thus, the perseverative errors score can be viewed as reflecting concept formation ability. The Stanford-Binet absurdities subtests do not involve categorization or sorting, but like the 20 Questions task, they present a problem that requires formulation of hypotheses without the use of cuing as the individual proceeds with attempts at solution. We were inclined to view the Trail Making Test Part B as a concept identification task because the problem of alternating between numbers and letters is inherent in the task and does not require spontaneous hypothesis formation. However, the rule to alternate between numbers and letters is provided rather than learned and must be understood, retained in working memory, and accurately and efficiently implemented. The Trail Making Test Part B also uses skilled motor speed as the dependent measure, a function that is often impaired in autism (Smith & Bryson, 1994), thereby providing a potential confound with abstraction ability. Therefore, because of these differences from the other tests administered, we repeated the group comparison data analyses with and without the Trail Making Test's inclusion to evaluate the influence of this test on discriminative accuracy.

Data Analysis

To provide a preliminary evaluation of the construct validity of the proposed distinction between concept formation and identification, we accomplished principal-components factor analyses with Varimax rotations for the autism and control groups. Default options were used (SPSS, 1999). The scores entered into the analysis were time in seconds for the Trail Making Test Part B, errors on the Halstead Category Test, perseverative errors and categories achieved scores from the WCST, number correct for the

Stanford-Binet Verbal Absurdities and Picture Absurdities subtests, and percentage of constraint seeking questions from the 20 Questions task. If the distinction is valid, concept formation and identification tasks should load on different factors in the autism group but not in the normal control group. Correlations were computed between all tests and full scale IQ (FSIQ) scores to determine whether the concept formation tests were more difficult than the concept identification tests.

Discriminant function was used to determine the discriminative accuracy of the tests. A direct method was used initially to assess overall between-groups significance. The scores entered into the equation were the same as those used in the factor analyses. A stepwise discriminant analysis was then performed to determine which variables made the greatest contributions to the discrimination. As mentioned earlier, the analyses were repeated with and without the inclusion of the Trail Making Test Part B. The Goldstein-Scheerer Object Sorting Test data were analyzed with independent group *t* tests comparing the autism and control groups. The metric properties of this object sorting test do not lend themselves to inclusion in a discriminant or factor analysis.

Results

Principal-Components Analyses

Correlations among the test variables included in the factor analyses are presented in Table 2. The Varimax rotated principal-components loadings for the autism and control groups are presented in Table 3. Using Kaiser's rule for extraction of factors, a three factor solution was obtained for the autism group. The first factor received salient loadings from the 20 Questions task constraint seeking questions variable and the Stanford-Binet Picture Absurdities and Verbal Absurdities subtests. The high loadings on the second factor were for the two WCST measures. The third factor received high loadings from the Halstead Category Test and the Trail Making Test Part B. Thus, the tests hypothesized to measure concept formation and concept identification loaded on separate factors. Furthermore, the WCST, a test that involves attribute identification, loaded on a separate factor from the Halstead Category Test and the Trail Making Test Part B, which mainly assess rule learning. A two factor solution was found for the control group. The first factor received high loadings from all of the tests except for the Halstead Category Test and the Trail Making Test Part B, which loaded on the second factor. The Halstead Category Test had salient loadings on both factors.

Correlations With IQ

Correlations between the FSIQ score and the abstraction tests are presented in Table 4. Although all of the abstraction tests were significantly correlated with FSIQ, there was no suggestion in either the autism or the control sample that the concept formation and concept identification tests differed from each other with regard to association with general intelligence. The highest correlations were with the Stanford-Binet Verbal Absurdities subtest, a concept formation test, and the Halstead Category Test, a concept identification procedure.

Discriminant Analyses

The univariate data comparing the two groups are presented in Table 5, which includes the *F* ratios and their levels of statistical significance. All tests discriminated significantly between the two groups at least at the $p < .05$ level. With regard to the discriminant analysis, the direct solution entering all variables simultaneously produced 80.8% correct classifications ($\kappa = .56$; $p < .001$), with

Table 2
Intercorrelations for the Variables Included in the Factor Analyses in the Autism and Control Groups

Variable	1	2	3	4	5	6	7
Autism group							
1. WCST categories	—						
2. WCST perseverative errors	.80	—					
3. Halstead Category Test errors	.32	.39	—				
4. Trail Making Test Part B	.11	.12	.48	—			
5. 20 Questions task	.27	.28	.27	.20	—		
6. Picture Absurdities	.15	.33	.24	.04	.32	—	
7. Verbal Absurdities	.38	.51	.47	.14	.50	.62	—
Control group							
1. WCST categories	—						
2. WCST perseverative errors	.78	—					
3. Halstead Category Test errors	.22	.32	—				
4. Trail Making Test Part B	.17	.26	.41	—			
5. 20 Questions task	.08	.11	.01	.04	—		
6. Picture Absurdities	.22	.39	.50	.19	.12	—	
7. Verbal Absurdities	.30	.40	.46	.23	.00	.64	—

Note. Plus and minus signs are not presented because tests are scored in different directions with regard to relatively good and poor performance. Picture Absurdities and Verbal Absurdities are from the Stanford-Binet Intelligence Scales. WCST = Wisconsin Card Sorting Test.

Table 3
Varimax Rotated Factor Matrices for the Autism and Control Groups

Variable	Factor 1	Factor 2	Factor 3
Autism group			
WCST categories	.10	.94	−.10
WCST perseverative errors	−.27	−.90	.11
Halstead Category Test errors	−.32	−.27	.71
Trail Making Test Part B	.02	−.00	.92
20 Questions task	.64	.12	−.27
Picture Absurdities	.87	.08	.11
Verbal Absurdities	.82	.31	−.19
% of Variance	43.90	17.60	15.90
Control group			
WCST categories	.29	−.84	
WCST perseverative errors	−.45	.80	
Halstead Category Test errors	−.77	.05	
Trail Making Test Part B	−.47	.16	
20 Questions task	.25	.51	
Picture Absurdities	.84	.00	
Verbal Absurdities	.79	−.13	
% of Variance	41.10	18.00	

Note. Picture Absurdities and Verbal Absurdities are from the Stanford-Binet Intelligence Scales. WCST = Wisconsin Card Sorting Test.

10.7% false positives and 34.8% false negatives. The stepwise discriminant function analysis using standard tolerance criteria entered two variables that produced a classification accuracy of 78.4%. Kappa for the matrix is .54 ($p < .001$). The Landis and Koch (1977) criteria classify this level of kappa as representing fair-to-good agreement beyond chance. The variables passing the tolerance test were the scores for the Stanford-Binet Verbal Absurdities subtest and the 20 Questions task percentage constraint seeking questions. Of the normal control participants, 14.8% were classified as autistic, whereas 31.7% of the participants with autism were classified as normal controls. The classification matrices are presented in Table 6.

The direct solution with Trail Making Test Part B excluded to eliminate the potential contribution of psychomotor slowing in the autism group produced 81.5% correct classifications and a kappa of .58 ($p < .001$). When the score for the Trail Making Test Part B was not included in the stepwise discriminant function, the Stanford-Binet Verbal Absurdities subtest and the 20 Questions task percentage constraint seeking questions passed the tolerance test. Of the cases, 78.4% were correctly classified with a kappa of .54 ($p < .001$), which is also within the fair-to-good agreement range. Thus, the inclusion of a measure involving psychomotor speed only had a minor influence on classificatory accuracy. On the Goldstein-Scheerer Object Sorting Test, there was no significant difference between the autism and the control groups on the number of abstract sorts, but there was a significant difference ($p < .01$) on the adequacy of shifts in sorting, with the autism participants making significantly more concrete or functional shifts than the controls or no shift at all.

Discussion

This study has produced factor analytic and discriminant validity data, indicating a dissociation between the concept formation and the concept identification components of abstraction in nonmentally retarded individuals with autism. The factor analyses further subdivided concept identification in the autism group into attribute identification and rule learning, suggesting that they are also separable cognitive abilities. The individuals with autism in this study also had difficulty with cognitive flexibility, an intermediate ability between concept identification and concept formation, indicating incomplete understanding of learned concepts. Significant between-groups differences were found for the concept identification tasks, but the performance of both groups on these tasks was within the normal range, with the exception of the perseverative error score on the WCST. The present study, thus, provides evidence that nonmentally retarded individuals with autism have a limited degree of abstraction ability that is restricted to rule learning and attribute identification. This pattern of deficits and intact abilities in abstraction can be characterized as a dissociation between concept identification and concept formation.

The construct validity of this hypothesized dissociation was supported by factor analyses, with concept formation, attribute identification, and rule learning tasks loading on separate factors in the autism group. This loading pattern did not occur in the control group, in which both concept formation and concept identification tasks loaded on the same factors. The predominance of the deficits in concept formation was also demonstrated by the stepwise discriminant analyses, which showed that two tests of concept

Table 4
Correlations Between Full Scale IQ and Abstraction Test Scores

Group	WCST categories	WCST errors	Category Test	Trail Making B	20 Questions	Verbal Absurdities	Picture Absurdities
Autism	.42	−.43	−.70	−.41	.54	.75	.64
Control	.29	−.45	−.62	−.41	.45	.50	.51
Total	.42	−.43	−.70	−.41	.54	.75	.64

Note. All correlations are statistically significant ($p < .01$). Picture Absurdities and Verbal Absurdities are from the Stanford-Binet Intelligence Scales. WCST = Wisconsin Card Sorting Test; Category Test = Halstead Category Test; Trail Making B = Trail Making Test Part B; 20 Questions = 20 Questions task.

Table 5
Univariate Results for the Abstract Reasoning Tests

Scores	Autism group *M*	Autism group *SD*	Control group *M*	Control group *SD*	$F(1, 195)$	*p*
Abstract reasoning results						
Verbal Absurdities	9.61	3.91	13.45	2.26	50.65	< .001
Picture Absurdities	26.48	3.10	28.60	3.10	13.84	< .01
20 Questions % constraint seeking	35.91	23.79	57.21	14.54	40.12	< .001
WCST perseverative errors	18.72	14.19	10.46	9.61	15.49	< .001
WCST categories	5.00	1.49	5.48	1.29	3.61	< .05
Halstead Category Test errors	49.00	30.75	38.15	23.98	4.96	< .05
Trail Making B (in seconds)	71.26	46.94	49.93	27.01	10.84	< .01
Object sorting results						
Abstract sorts	1.80	1.70	2.00	1.82	−0.60[a]	> .05
Adequacy of shift[b]	1.91	1.00	1.40	0.83	2.80[a]	< .01

Note. Verbal Absurdities and Picture Absurdities are from the Stanford-Binet Intelligence Scales. 20 Questions = 20 Questions task; WCST = Wisconsin Card Sorting Test; Trail Making B = Trail Making Test Part B.
[a] This is a *t* test value, with a *df* of 195. [b] The scores for the object sorting task were rated as 1 = abstract shift; 2 = concrete or functional shift; 3 = no shift at all.

formation alone correctly classified 78.4% of the cases and that none of the concept identification tests passed the tolerance test. This disparate performance was not explained by the greater difficulty of the concept formation tasks, as concept identification tests were not more highly correlated with IQ than with concept formation and cognitive flexibility tests. This dissociation between concept formation and concept identification abilities appears to be unique to autism in that it has not been reported in other clinical groups that have difficulty with abstract reasoning, notably schizophrenia, chronic alcoholism, and dementia (G. Goldstein, 1998).

The full attainment of an abstraction permits conceptual shifting, such that the basis for pertinence may be changed with changes in the task demands or environment. On sorting tasks, this capacity is assessed by asking the participant to sort the materials in a different way from the initial sort. If the principle for the sorting is initially conceptualized in terms of a general solution in which one of many possible attributes of the objects may be used as the basis for the initial sort, then shifting is not a problem. However, if the principle is construed more concretely, primarily in terms of a single attribute, then shifting becomes more difficult because the task is conceptualized at a lower level of abstraction. The adequacy of shift score from the Goldstein-Scheerer Object Sorting Test and the significant increase in the WCST perseverative errors score provided evidence in this autism group of cognitive inflexibility and the incomplete attainment of concepts. Normative data indicate that for the age and education of the autism group, the WCST perseverative error score is in the 27th percentile, whereas the score for the controls was in the 93rd percentile. This difference is clinically as well as statistically significant. These results indicate that nonmentally retarded individuals with autism appear to encode concepts at a lower level of abstraction that limits their generalizability and results in inflexibility.

Table 6
Classification Matrices for the Discriminant Analyses

Actual group	% predicted group membership: Autism	Control
Direct method		
Autism	65.2	34.8
Control	10.7	89.3
Stepwise method		
Autism	68.3	31.7
Control	14.8	85.2

Note. As indicated in the text, exclusion of the Trail Making Test Part B produced minor differences. Total correct classifications for the direct method were 80.8%. Total correct classifications for the stepwise method were 78.4%.

Difficulty with concept formation appears to be expressed in other cognitive domains in individuals with autism. In the memory domain, individuals with autism have been found to be less able to use cognitive organizing strategies necessary for remembering large amounts of information or for detecting and using the organization of material that is inherently complex. Individuals with autism also have difficulty with self-generation of logical thematic sequences and with comprehending the theme or gist of stories, both of which are basically concept formation tasks. Imaginative play is another typical area of impairment in autism and it also requires understanding of the symbolic or conceptual meaning of toys and the self-generation of play themes. Thus, concept formation appears to be a deficit that transcends a number of domains in autism. That is not to say that it is a single primary deficit but rather one that contributes to dysfunction in multiple domains.

Several different theories or constructs have been proposed to explain the impairments in conceptual abilities in autism. These include the executive function theory (Ozonoff, 1995), central coherence theory (Shah & Frith, 1993), and the Minshew, Goldstein, and Siegel (1997) theory proposing selective deficits in complex information processing abilities. All three terms have been used to refer to the abstraction deficits defined by our study. The use of separate terms for the same phenomena adds confusion and fragments the data in the field rather than integrating it into a theory that has a substantial degree of agreement.

The limitation of the executive function term is that it is imprecisely and variably defined, and in autism, this deficit has not proven to be universal. Performance on the WCST, a test commonly used to document executive dysfunction in autism, has been found to be normal in some nonretarded individuals with autism and in preschool children with autism who are in intervention programs (Griffith, Pennington, Welner, & Rogers, 1999; Minshew et al., 1992). Computer administration of the WCST has also been shown to attenuate performance deficits (Ozonoff, 1995). In addition to these considerations, high-functioning individuals with autism have cognitive and neurologic deficits in areas that go beyond even a broad definition of executive function, and thus, this theory does not account for the broad range of deficits seen in autism.

Central coherence is a term introduced to the autism literature and is defined as a drive to make sense of things and to consider the whole entity and not only the parts in isolation (Frith, 1989). This construct evolved on the basis of a pattern of deficits in higher order abilities similar to that delineated in Minshew et al. (1997). From all descriptions, the term central coherence appears to be synonymous with concept identification and concept formation, and when more broadly applied to the cognitive profile in autism, this term appears to also be synonymous with a selective deficiency in complex information processing. The disadvantage of the central coherence term is that it is virtually unknown outside the area of autism and substitutes a new term for well-known cognitive phenomena widely described by more conventional terms.

The complex information processing terminology was introduced to refer collectively to a profile of deficits in higher order abilities across cognitive and perceptual–motor domains. Its advantage is that it provides a single conceptualization under which all cognitive and noncognitive deficits in autism can be embraced, which facilitates translational thinking about the cause of autism. The co-occurrence of these deficits in higher order abilities suggests that there is a class of qualitatively different neural circuitry that develops to support higher order abilities and that this circuitry may have a common developmental neurobiologic mechanism. The alternative to such a unifying conceptualization and integration is to think in terms of a number of separate deficits that occur as a syndrome for no apparent reason and result from separate unrelated abnormalities in the brain. The limitation of this construct is that the appreciation of complex information processing as a shared feature of all the impairments has been minimal. One contributing factor may be the superficial difficulty in applying the theory to lower ability children with autism, who show an overall reduction in information processing ability. This issue can be clarified by considering autism as a disorder of information processing that disproportionately impacts complex information processing. From this perspective, increasing autism severity corresponds to increasing reduction in overall information processing capacity, which ultimately results in mental retardation with a disproportionate impact on complex information processing. Fein et al. (1996) have shown that children with autism who are mildly mentally retarded and have borderline range of intelligence display a selective impairment in the higher order abilities expected at this level of function.

Characterizing the abstract reasoning impairment in terms of concept identification and concept formation provides a reasonable account of the pattern of abstract reasoning deficits that has been reported in autism. Deficits in concept formation and the inflexibility resulting from incomplete understanding of concepts also provide a potential cognitive basis for such diverse phenomena as the need to train basic concepts in very young children through massed trials, as the inability to generalize learned concepts to other situations, as the inability to consider context in applying a concept, and as the difficulty coping with novel situations and problems for which rules are not known. Deficient concept formation may also potentially explain the narrow range of interests and focus on details as the result of an inability to organize information around conceptual themes.

It is understood that the differences found in the autism group on these tests may be based on more complex considerations than on the one distinction among concept formation, concept identification, and rule learning. For example, the tests differed with regard to presence of social content and demands on working memory. However, in other studies of individuals with high-functioning autism, we did not find significant differences between autism and normal control groups on tasks like the information and vocabulary subtests of the Wechsler intelligence tests that have social content (Siegel, Minshew, & Goldstein, 1996) or on tasks that make demands on verbal working memory (Minshew & Goldstein, in press) but do not involve conceptual reasoning.

In summary, the abstraction deficit in nonmentally retarded individuals with autism is characterized by a dissociation between concept formation and concept identification. The deficit in concept formation results in cognitive inflexibility and in the inability to spontaneously form schemata or paradigms that organize information. The latter is expressed in multiple domains, including memory, language, and play. This dissociation provides a potential cognitive basis for a number of common behavioral features of autism. This dissociation also suggests that concept formation, attribute identification, and rule learning are separable cognitive abilities that may develop differentially in autism; appreciation of this could be helpful in guiding cognitive and behavioral interventions. This dissociation also suggests that there may be a separable neural basis for these two aspects of abstract reasoning.

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