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Associations Between Conceptual Reasoning, Problem Solving, and Adaptive Ability in High-functioning Autism

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Abstract

Abstract thinking is generally highly correlated with problem-solving ability which is predictive of better adaptive functioning. Measures of conceptual reasoning, an ecologically-valid laboratory measure of problem-solving, and a report measure of adaptive functioning in the natural environment, were administered to children and adults with and without autism. The individuals with autism had weaker conceptual reasoning ability than individuals with typical development of similar age and cognitive ability. For the autism group, their flexible thinking scores were significantly correlated with laboratory measures of strategy formation and rule shifting and with reported overall adaptive behavior but not socialization scores. Therefore, in autism, flexibility of thought is potentially more important for adaptive functioning in the natural environment than conceptual reasoning or problem-solving.

Keywords

Autism; Conceptual reasoning; Problem solving; Adaptive behavior; Cognitive

Introduction

An important goal of treatment in autism is to help the individual successfully function as independently as possible. This notion is captured by the construct of "adaptive behavior ability," which is an index of how one is able to function in the natural social environment

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across a multidimensional set of skills (Oswald and DiSalvo 2003). Individuals with autism spectrum disorders (ASDs) have extremely high variability in adaptive behavior (Klin et al. 2007; MacLean et al. 1999; Mazefsky et al. 2008). For example, Mazefsky et al. (2008) found that a sample of individuals with autism without intellectual developmental disorder had standard scores ranging from 19 (Impaired Range) to 162 (Very Superior) on the Vineland Adaptive Behavior Scales (VABS; Sparrow et al. 1984), a commonly used measure of adaptive behavior. Whereas the variability in adaptive behavior in ASD is well-documented, the source of this variability is less clear. Understanding factors that influence this variability in adaptive behavior would inform the design of interventions that might improve the outcome for individuals with autism.

Most of the research conducted to understand adaptive behavior in ASD has focused on its relationship to age and intelligence quotient (IQ). This research has been fairly consistent in finding that adaptive behavior skills in autism tend to be much lower than would be expected based on IQ (e.g. Boltë and Poustka 2002; Fenton et al. 2001; Kanne et al. 2011; Mazefsky et al. 2008). It is also clear that the IQ-adaptive behavior discrepancy becomes even more apparent with increasing age, and that the gap between IQ and adaptive behavior ability is often quite significant in samples with higher IQs (Boltë and Poustka 2002; Kanne et al. 2011; Klin et al. 2007; Liss et al. 2001; Mazefsky et al. 2008). Even a recent study with children with ASD (ages 4–17 years) that reported that IQ was a strong predictor of adaptive behavior, noted that having a higher IQ did not indicate that the children would perform well socially (Kanne et al. 2011). The unclear nature of the relationship between IQ and adaptive behavior would suggest that the failure of verbal individuals with IQ scores in the normal range to achieve age and ability appropriate adaptive behavior is related to some other aspect of the disorder than general intellectual ability.

We have conceptualized the pattern of abilities in verbal individuals with autism as a deficit in information processing with the major tenet being that autism is characterized by impairment in complex cognitive processing in multiple domains while simpler abilities in those same domains are intact or sometimes better than normal (Minshew et al. 1997). This general principle has been demonstrated in several individual cognitive domains including attention (Goldstein et al. 2001), memory (Minshew and Goldstein 2001; Williams et al. 2005, 2006b), language (Minshew et al. 1995; Peppeé et al. 2007), and perceptual and motor skills (Minshew et al. 1999, 2004). The results from this body of research has suggested that conceptual development, and more specifically, conceptual reasoning, may function somewhat differently in individuals with autism than typically developing individuals with similar cognitive ability. Indeed, we have previously reported that individuals with autism perform well on tasks requiring concept identification or the ability to learn already established rules and have more difficulty with concept formation or the ability to develop new concepts based upon experience (Minshew et al. 2002).

In individuals with typical development, the ability to think abstractly, particularly with regard to forming new concepts is thought to be highly related to the ability to solve problems. In turn, the ability to solve problems is generally thought to be predictive of better adaptive functioning (Goldstein 1996). Individuals with autism, despite the presence of average or above general intelligence often have prominent deficits in the areas of conceptual reasoning and problem solving (Adams and Sheslow 1983; Rutter 1983; Hill and Bird 2006; Pennington and Ozonoff 1996; Bogte et al. 2007). However, this finding is not universal across the autism spectrum, as there are some reports, particularly of individuals with Asperger Syndrome (AS), of intact or superior abstract reasoning or fluid thinking skills (Hayashi et al. 2008; Soulières et al. 2011). In addition, significant numbers of children and adults on the autism spectrum, including those with AS, have challenges in negotiating social situations in the real world that have to be addressed with explicit training and intervention (Krasny et al. 2003). Furthermore, even those individuals with autism who develop adequate conceptual reasoning abilities and the ability to problem solve in contrived situations may have difficulty in applying these abilities to situations that they encounter in daily life.

The relationship between conceptual reasoning, problem solving, and adaptive functioning may differ in individuals with autism. This would occur if they were depending on the application of rules to determine what the solution to the problem is but had difficulty with creating new concepts based upon environmental experience. Consistent with this hypothesis, social cognitive deficits in autism have been reported to be related to a decreased ability to implicitly encode and integrate contextual information with improved performance when social information is made explicit or rule-based (Baez et al. 2012). Alternately, other research indicates that implicit learning is relatively intact in autism with the important factor being a deficit in the flexibility of response to novel contexts (Kourkoulou et al. 2012).

The relationship between conceptual reasoning and adaptive functioning may also vary by age in individuals with autism. For example, a study of abstract reasoning and social functioning found impairments in both concept identification and concept formation in verbal children ages 8–12 years with ASD and normal intelligence (Solomon et al. 2011). These results suggest that developmental differences may occur with respect to these two components of abstract reasoning; therefore, developmental differences should be considered when investigating the nature of the relationship between conceptual reasoning, problem solving, and adaptive functioning in autism.

The purpose of this study was to examine the relationship between performance on measures of conceptual reasoning, ecologically valid measures of problem solving, and measures of adaptive behavior in verbal children and adults with autism with IQs in the normal range. The hypothesis was that, unlike individuals with typical development, for individuals with autism, conceptual reasoning and problem solving abilities would be correlated with each other but would not be correlated with adaptive function. That is, while aspects of conceptual reasoning might be intact in autism, particularly in concept identification, the ability to adapt to various aspects of the environment will not be related to the overall level of conceptual reasoning ability. Rather, consistent with recent work on learning in autism, adaptive function will be related to the level of flexible thinking or the ability to respond to contextual change.

Methods

Participants

Participants for this study were a group of 65 verbal children and adults with autism with IQ scores in the normal range and an age- and IQ-matched group of 65 children and adults with typical development. Participants ranged in age from 8 to 46 years. Demographic data for the sample are presented in Table 1. For purposes of making age group comparisons, the participants were divided into three groups: 8–12, 13–20 years, and 21+ years, representing children, adolescents, and adults. The study is retrospective in nature, and these data were collected over a number of years; therefore, many of the participants in the present study were the same individuals as those used in previous studies, notably Minshew et al. (1997, 2002), and Williams et al. (2006a).

The diagnosis of autism was made by a detailed evaluation using expert clinical judgment, the *Autism Diagnostic Interview-Revised* (ADI-R; LeCouteur et al. 1989; Lord et al. 1994), and the *Autism Diagnostic Observation Schedule-Generic* (ADOS; Lord et al. 1989, 2000). All participants were required to have evidence of delayed and disordered language development, thus excluding individuals with Asperger's Disorder as defined at that time in the DSM system (DSM-IV-R; American Psychiatric Association 2000). Participants with autism were excluded if they had associated neurologic, genetic, infectious, or metabolic disorders, such as tuberous sclerosis, fragile-X syndrome, or fetal cytomegalovirus infection.

The control participants were community volunteers recruited to match the autism participants on age, Verbal IQ, Full Scale IQ, gender, race, and years of education, and socioeconomic status of family of origin (Hollingshead 1957). Potential control participants were recruited through advertisement and contacts with community organizations and were screened by questionnaire, telephone, personal interview, and observation during screening tests. Potential control participants 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 history of autism, developmental cognitive disorder, or learning disability; mood or anxiety disorder; or other neuropsychiatric disorder thought to have a genetic etiological component.

Measures

Conceptual Reasoning Tests—Tests were neuropsychological measures that were selected to target different aspects of conceptual reasoning or problem solving such as forming and changing hypotheses or plans, concept formation or deductive reasoning, concept identification or abstract reasoning based on rules or general knowledge, planning and organization to accomplish a goal, and formation of mental representations. The tests used in this analysis varied in modality of presentation, some involving language, others visual perceptual analysis, and others purposeful movements associated with problem solving. Tests included the: the *Verbal Absurdities* and *Picture Absurdities* subtests from the *Stanford-Binet* scales (Thorndike et al. 1986), *Tower of Hanoi* (TOH) (Simon 1975), the *Wisconsin Card Sorting Test* (WCST) (Heaton et al. 1993), the *Halstead Category Test* (HCT) (Halstead and Settlage 1943), *the Hooper Visual Organization Test* (Hooper 1983), the *Tactual Performance Test* (Reitan and Wolfson 1993), the *20 Questions Task* (Laine and Butters 1982), and the *Trail Making Test, Part B* (Reitan and Wolfson 1993).

Ecologically Valid Measures of Problem-Solving—*Behavioural Assessment of the Dysexecutive Syndrome* (BADS; Wilson et al. 1996). The BADS is an assessment procedure that is individually administered in a laboratory setting. It provides a micro level of analysis of the skills needed for carrying out specific types of adaptive challenge by characterizing the ability to shift rules, develop a plan of action to solve a problem, develop a plan for a course of action, make temporal judgments, create a plan when structure is minimal as contrasted to use of an externally imposed strategy, and plan and organize multiple tasks. The BADS has been reported to have a higher ecological validity than similar tests of executive function and to be useful when evaluating skills for vocational planning (Chamberlain 2003). Consistent with these prior characterizations of the usefulness of the BADS, for purposes of the present study, we used the instrument as a means of evaluating cognitive function or problem solving ability that underlies adaptive function.

The BADS contains six subtests. Rule Shift requires the subject to initially go through a deck of cards, saying ‘Yes’ for red or ‘No’ for black cards. Then, the rule is shifted by asking the subject to tell whether the card just turned over is the same as or different from the previous card. Scores are time and errors. In Action Sequences the subject attempts to remove a cork from a tube in a beaker filled with water using materials made available. The score is the number of problem solving stages completed independently. Key Search assesses the subject’s ability to plan an effective course of action to find a lost key. The score is the sum of 8 components of the search process, such as entering the field at the bottom. Temporal Judgment asks questions about the duration of events, an ability that contributes to organizing and planning. The Zoo Map Test evaluates planning when constrained by a set of rules. The task is for the subject to plan to visit a series of locations on a map of a zoo while obeying a set of rules (e.g., starting at the entrance and finishing at a designated area). An error score is used. The Modified Six Elements Test requires the subject to perform a dictation, arithmetic, and picture naming task. The test is scored for organizing ability, including the number of sub-tasks completed, rule-breaking on the tasks, and maximum amount of time spent on a subtask. The raw score for each BADS subtest was converted to a profile score ranging from 0 to 4. The profile scores were used in the analyses.

Measures of Adaptive Ability—*Vineland Adaptive Behavior Scales* (VABS; Sparrow et al. 1984). As has been done in prior research examining the relationship between IQ and adaptive behavior, we used the VABS as a measure of functioning in the natural environment. The VABS Survey is a 261 item form that is administered to parents as a measure of how many age-appropriate, socially adaptive behaviors a child or adult exhibits in their natural environment. It is a well-recognized instrument, with demonstrable reliability and validity both for individuals who are typically developing and those with disabilities. It is also the preeminent measure for the assessment of adaptive functioning in children with autism (Newsom and Hovanitz 1997). The VABS assesses three skill domains, each with three subdomains: Communication (receptive, expressive, and written language skills), Daily Living skills (personal self-care, domestic, and community living skills), and Socialization (interpersonal, play or leisure, and coping skills). The VABS provides standard scores (*m* = 100, *SD* = 15) with higher scores indicating better functioning. Domain scores and the Adaptive Behavior composite score were used in the data analysis.

Data Analysis

For purposes of data reduction, the conceptual reasoning tests were factor analyzed in order to assess the latent variables that underlie the series of tests that were used. The principal components method was used with Varimax rotation. Regression based factor scores were computed. Factor scores are composite variables for use in subsequent analyses following performance of a factor analysis. For this study, the factor scores were then correlated with the BADS and VABS scores. Because of narrow distributions of the factor scores in some cases, Spearman's Rho was used as the correlation coefficient rather than Pearson's r. Preliminary inspection of the data indicated that comparable results were obtained between the two coefficients. These correlations were computed separately for each group.

Differences between the autism and control groups and among the three age groups on the eleven conceptual reasoning tests were compared using a 3×2 factorial design analysis of variance for independent samples, with presence or absence of autism constituting one independent variable and age group the other. This form of analysis was also conducted for the BADS and VABS.

Comparisons were made between the autism and control groups on the BADS and VABS using *t*-tests. We also wanted to evaluate the differences in discrepancies on the various abilities measured by these two instruments. While individuals with autism may generally do more poorly than typically developing individuals at adaptive abilities, this discrepancy may not be of the same order of magnitude for all abilities. Specifically, it was hypothesized that adaptive functions requiring relatively high levels of conceptual ability will show a relatively greater level of discrepancy between individuals with autism and groups with typical development. Such differences can be evaluated through obtaining effect sizes and statistical power assessing the magnitude of the statistical significance of group differences. Effect size determination and power analyses were accomplished for all variables; the items were ranked by effect size from largest to smallest. Cohen's d (Cohen 1988) was the statistic used to obtain effect sizes; it is computed by taking the difference between the two obtained means and dividing by the pooled standard deviation. The effect size reflects the magnitude of a difference, whereas power reflects the capacity to reject the null hypothesis given a particular effect size. Thus, some differences may be so robust that acceptance of a false hypothesis is unlikely, whereas minimally significant findings with low power might raise the possibility of having made a Type I error or making false discoveries (Benjamini and Hochberg 1995). Correspondingly, borderline non-significant findings raise the possibility of rejecting a true hypothesis or making a Type II error. The magnitude of the test performance difference between participants with autism and demographically matched normal control participants should provide an index of the extent to which the ability measured by the test characterizes the performance of the individuals with autism. Thus, those tests found to have larger effect sizes reflected by higher d's and relatively greater statistical power to reject the null hypothesis of no difference between autism and normal control groups could be understood as reflecting specific aspects of dysfunction in autism, whereas those tests that do not discriminate measure abilities at which individuals with autism performed relatively similarly to individuals with typical development.

To estimate a more global association between conceptual reasoning and adaptive abilities, entry method and stepwise multiple regression analyses were performed. The three factor scores were the predictor variables and the summary scores (i.e., the Total Standard Score from the BADS and the Adaptive Behavior Composite Score from the VABS) were the dependent variables. The following method was used. Group was coded 1 for autism and 0 for control and multiplied by the factor scores. These new variables, often characterized as "dummy variables", represent interaction between group and factor score. They were entered into the regression equations along with the unweighted diagnostic code itself (Autism or Control) and the factor scores were used as predictor variables with either the BADS or VABS summary score as the dependent variable. The analyses were performed using both the enter all variables and stepwise methods. In addition to the multiple regression coefficients (R), this analysis also provides Beta coefficients for the predictor variables. β represents the independent contributions of each independent variable to the prediction of the dependent variable. *t* tests were performed to determine the significance of the difference in β between groups for the predictor variables. Thus, for example, a significant difference for one of the factors would indicate that the groups differed with regard to their association with the dependent variable.

Results

Factor Analysis of Conceptual Reasoning Tests

As a way of assessing the relationship between conceptual ability, problem solving, and adaptive function, we first performed a principal components factor analysis with Varimax rotation of the scores from the conceptual reasoning tests and then computed correlations between the obtained factor scores and the BADS and VABS. Using Kaiser's Rule requiring stopping extraction of factors when an eigenvalue of below 1 is obtained, a three factor solution was obtained for the conceptual tests. The rotated component matrix is presented in Table 2. The first factor received exceptionally high (>.5) loadings on the Verbal and Picture Absurdities test, the perseverative errors score from the WCST, and the number of constraint seeking questions from the 20 Questions task. These measures assess a high degree of flexibility of thought that underlies concept formation or the ability to spontaneously organize strategies for problem solving. We therefore named it the Flexible Thinking factor. The second factor received high loadings from the Tactual Performance test and the Hooper Visual Organization test, and a moderately high loading from the Picture Absurdities test. It would, therefore, appear to mainly describe reasoning based on perceptual characteristics. We named this the Perceptual Reasoning factor. The third factor received high loadings from the Category and Trail Making Tests and the Tower of Hanoi task. These procedures assess what we have described as concept identification or applying a previously established organizational strategy, and so we called it a Rule Application factor.

Relationship of Conceptual Reasoning Factors to Problem Solving and Adaptive Ability

Spearman Rho correlations between the conceptual reasoning factor scores and the scores from the BADS and VABS are presented Table 3. In general, there were few statistically significant correlations (p <.05), with only four significant correlations in the autism group and three in the control group. Significant correlations in the autism group for the BADS were found between the Flexible Thinking factor and the BADS Key Search (strategy formation) and Rule Shift (changing an established pattern of responding) scores, and between the Perceptual Reasoning Factor and BADS Zoo Map (which involves topographical planning) score. Significant correlations in the autism group for the VABS were obtained between the Flexible Thinking factor and the VABS Adaptive Behavior composite score. In the control group, for the BADS, there were significant correlations between the Perceptual Reasoning factor and the Modified Six Elements (planning and performance monitoring). Significant correlations were found in the control group for the Flexible Thinking factor and the Socialization Domain and Adaptive Composite Behavior Scores on the VABS.

Relationship Between Problem Solving and Adaptive Function

We ranked differences between autism and control groups on the measures from the BADS and VABS with regard to effect sizes and statistical power to evaluate what aspects of problem solving and adaptive behavior distinguish most strongly between the two groups (see Table 4). It was thought that the functions that made the greatest discrimination would have the largest effect size and greatest statistical power to reject the null hypothesis, with less discriminating abilities having lower effect sizes and power. Using Cohen's (1988) conventions indicating that an effect size in the .2 range is small, one in the .5 range is medium, and one in the .8 range is large, then it is clear that there is a wide range of effect sizes. Only one of the BADS subtests, Action Sequences which involves practical problem solving, adequately discriminated between the autism and control groups. On the VABS, the Adaptive Behavior Composite score and Socialization Domain score had highly significant group differences and large effect sizes. The VABS Daily Living Skills and Communication Domains did not distinguish between individuals with autism and controls. Apparently adaptive function as measured by the VABS was more sensitive to differences between the autism and control groups than was the case for most of the tasks on the BADS, even though they are generally considered to have ecological validity (i.e., Chamberlain 2003).

Overall and Age Group Differences

Given previous reports of differences in the relationship between cognitive abilities and adaptive functioning at different ages for individuals with ASD (e.g., Kanne et al. 2011) and the possibility that the components of abstract reasoning, concept identification and concept formation, are influenced by developmental factors in autism (Solomon et al. 2011), we conducted some analyses by age group. As described earlier, the data was separated into three age groupings for children, adolescents, and adults. ANOVA results for comparisons on the conceptual reasoning tests between the participants with and without autism and among the age groups are presented in Tables 5 and 6. Overall, the autism group performed significantly differently from the control group on all tests but the Halstead Category Test.

These results suggest that the autism group as a whole was weaker in conceptual reasoning than the age and IQ-matched controls. As indicated in Table 6, there were also several significant differences among the age groups. However, there were no significant interactions, leading to the conclusion that there are no significant differences in the age related changes in conceptual reasoning test performance between the autism and control groups.

The only significant group difference for the BADS was for Action Sequences which involves practical problem solving, with the autism group performing significantly poorer than the group with typical development. However, no significant age by diagnostic group interaction was obtained.

With regard to the adaptive functioning scale, only the age group main effect was significant for the VABS Daily Living Domain scale. In the autism group the 8–12 year olds group did more poorly than the older groups while in the control group there were very small mean differences among the age groups. Thus, the significant main effect was probably attributable to poor performance by the 8–12 year old autism group. There were two significant age group X diagnostic group interactions one for the VABS Socialization Domain Scale and the other for the VABS Adaptive Behavior Composite Score. Essentially the same patterns appeared in the Socialization Domain and Adaptive Behavior Scale. There were substantially higher mean scores obtained by the controls in the younger age groups, but essentially equal mean scores obtained by adult members of the autism and control groups. These findings would suggest that there were substantial differences in adaptive functioning in individuals with autism and typical development at younger ages, but that this difference was no longer evident in adulthood (Tables 7 and 8).

Multiple Regression Analyses

Results for the BADS Total Standard Score are presented in Table 9. This score shows a high Multiple R ($R = .459$, $p < .001$). Using the stepwise method only the factor scores weighted by group membership were entered. Group membership alone and the three factor scores themselves were not entered. This finding would indicate that the multivariate association between the conceptual reasoning factors and the BADS measure interacts with group membership. If group membership is not considered, as when only the factor scores themselves are used, they are not entered.

For the VABS Adaptive Behavior variable, the enter method also yields a significant multiple R of .428. However, the stepwise method entered group alone (autism vs. control) and Group weighted by Factor Score 1 (Flexible Thinking). It would appear that membership in the control group has little or no influence on the factor scores while membership in the autism group has a substantial influence. However, the analysis of the data presented in Table 3 indicates that the Rho correlation between the VABS Adaptive Behavior Scale and the Flexible Thinking factor is positive (.299) in the autism group while it is negative (−.263) in the control group. This discrepancy would not appear to justify the conclusion that adaptive behavior is negatively correlated with flexible thinking, particularly since the entire set of correlations considered are non-significant. However, this pattern of correlations might affirm the result of the regression analysis indicating that in typically developing individuals, level of adaptive functioning does not appear to be associated with intelligence.

Discussion

In general, individuals with autism have relatively weaker conceptual reasoning abilities than individuals with typical development of similar age and overall cognitive ability. Despite this weakness, individuals with autism appear to be able to apply these conceptual reasoning abilities on most of the laboratory measures of adaptive flexibility, planning, and problem solving, resulting in a lack of differentiation from controls. The level of conceptual reasoning for most of these children and adults with autism allowed them to demonstrate problem solving abilities in a variety of structured or hypothetical situations as measured by the BADS. However, as indicated by the VABS data, individuals with autism may fail to apply these reasoning abilities to real life situations, resulting in dissociation between overall level of cognition and adaptive functioning. This result is consistent with reports of problems with adaptive functioning in children and adults with autism who have average or above IQs (Kanne et al. 2011; Mazefsky et al. 2008). This dissociation between performance on structured tasks and observed daily performance may help explain the rather poor outcome in adult life of verbal individuals with autism despite their academic success in school programs (Farley et al. 2009).

The underlying reason for the disconnect between the ability to apply reasoning in a controlled setting and the ability to demonstrate reasoning in real life situations is not clear, but some understanding may be gained by examining the obtained relationships between the measures of conceptual reasoning and the measures of problem solving and adaptive functioning. For the autism group, the Flexible Thinking factor was significantly correlated with the BADS subtests that assess strategy formation and rule shifting. This relationship suggests that individuals with autism who had more ability to think flexibly were able to form strategies and were more flexible in applying rules. It was not surprising to find that the Flexible Thinking factor was also associated with overall better adaptive functioning in autism. Taken together, these results suggest that the ability to flexibly form concepts is particularly important for better adaptive behavior in individuals with autism.

In a related area of research, it has been proposed that learning difficulties encountered in social situations by individuals with autism are not related to the implicit nature of the information but to a problem with flexibility of response to novel contexts (Kourkoulou et al. 2012). In that study, intact implicit learning was found for contextual cuing tasks; however, deficits occurred in novel contexts, particularly when the paradigm biased learning to local stimuli, suggesting that flexibility of response to novel contexts was the underlying problem not implicit learning per se (Kourkoulou et al. 2012).

The conclusion about the importance of flexible thinking to adaptive functioning in autism is generally supported by the results of the multiple regression analysis. These modest findings may suggest several potential explanations for this reversal of patterns of relationships. First, it may be due to the BADS being a laboratory-based assessment that provides a more micro-level analysis of the conceptual skills needed for carrying out a specific type of adaptive challenge, whereas the VABS scores reflect the integrative use and flexible application of these skills to solve real world problems. It is possible that individuals with autism can demonstrate problem solving and planning when there are reduced temporal demands and the problems are clearer and the solutions more limited. That is, they have adequate cognitive resources to meet these challenges and, therefore, can explain what should be done in a hypothetical situation. However, real world problems are seldom this structured and explicit, beginning with the necessity to identify what the problem to be solved is. Therefore, individuals with autism would have difficulty translating their knowledge into success in real life situations because the complexity of the processing task has increased exponentially. The impact of conceptual reasoning deficits in autism may not be as apparent in highly structured settings that provide rules like schools but is likely to become more evident under open field conditions such as jobs and independent living where there are few established rules that address a particular situation with constantly changing contexts that demand flexibility of thought. Individuals with autism who have a relatively stronger ability to manipulate and form new concepts, to think flexibly, would be at an advantage even as the environmental demands increase.

In addition to Flexible Thinking, another significant relationship was obtained between the Perceptual Reasoning factor and performance on the BADS Zoo Map subtest for the autism group. Abilities associated with the Perceptual Reasoning factor include ideational planning as measured by the TPT and visual imagery and integration assessed with the Hooper Visual Organization Test. Perceptual ability, involving the requirement of the tactual and visual processing demanded by these two measures, may be particularly important for individuals with autism for the aspect of adaptive functioning that involves imaging and planning. Therefore, perceptual reasoning is a type of process that might be capitalized on when helping individuals with autism develop skills to negotiate ever-changing social environments.

The results regarding age differences are of particular interest. It is understood that this was a cross-sectional study and inferences may not be made to the effect that differences noted would be observed in the development of individuals, as could be determined only by a longitudinal study. However, it has been noted for some time that the results of cross-sectional and longitudinal studies are typically the same (Heaton and Drexler 1987). The cross-sectional results obtained here reflect differences among age groups that are not always the same for the autism and control groups, and may reflect differences in developmental course. The pattern for both the measures of conceptual reasoning and problem solving of improved performance from childhood until young adulthood is comparable in individuals with typical development and individuals with autism. Test scores were fairly consistently lower in the autism group, although linear trajectories were noted in both groups. A different pattern emerged for adaptive behavior as measured by the VABS with significant interactions between autism status and age group on the Socialization Doman and Adaptive Behavior Composite scores. We made the remarkable finding that, while the scores of the group with typical development far exceeded those of the autism group in the child and adolescent age groups, they were essentially equal in the adult groups, and, furthermore, were in the average range on these scales. In summary, age differences in cognitive abilities were found to be linear in both groups but at differing performance levels;

however, some adaptive abilities do not have parallel trajectories in the autism and groups with typical development. Rather, the child and adolescent groups showed marked group differences between autism and control groups, while in the adult groups there was essentially no difference. Because this is not longitudinal data, we cannot infer the source for this difference to be developmental in nature. It is, however, important to note that this relatively high functioning group of adults with autism has been able to achieve strong adaptive skills even if they are continuing to be challenged in functioning in the social domain.

The results regarding age differences raise the obviously major question of whether or not individuals with autism undergo a course of development in which they possess certain normal adaptive abilities during adulthood they did not have during childhood, perhaps as a result of lifelong treatment or developmental changes associated with the course of the disorder. Longitudinal data, even retrospective information, might ultimately clarify this matter.

Clinical Implications

The findings from this study have important implications related to the provision of services to verbal individuals with autism who are relatively higher functioning. First, we provide further support for the argument that adults with autism should not be denied social support services because they have an IQ in the average range if they are demonstrating difficulties with real world functioning. Unlike individuals with typical development, the ability to perform well on formal measures such as the BADS may not necessarily reflect actual functioning for individuals with autism.

In particular, better adaptive functioning in autism appears to be related to the development of concept formation, flexible thinking and perceptual reasoning. Given that successful independent living is a goal for individuals with autism, cognitive remediation therapies explicitly targeting these skills seem warranted. However, the way in which this intervention is delivered would appear to be of particular importance for successful skill acquisition in individuals with autism.

Even when individuals with autism can explain what should be done in a hypothetical situation, they may not be able to translate this knowledge into success in real life situations. Based on the results of this study, we would predict that interventions that are limited to answering questions about hypothetical situations and artificial problem solving would have little to no impact on adaptive functioning in individuals with autism. Knowing how to solve a problem does not appear to be enough. Similarly, approaches that emphasize the acquisition of social skills through explicitly teaching social rules or engaging through role playing of social interactions (e.g. MacAfee 2002) may also result in a failure to translate this knowledge into a change in adaptive behavior unless these skills are practiced in the contexts in which they are to be applied.

Although time-consuming and resource intensive, practice of skills in the real world, appears to be essential for individuals with autism (Rao et al. 2008). In fact, this recommendation is consistent with the conclusions of a recent review of research on behavioral interventions for adaptive skills in verbal young adults with autism with normal IQ scores (Palmen et al. 2012). To further facilitate the transfer of reasoning abilities to everyday problem solving, the primary interaction partners of the individuals with autism should be trained to recognize opportunities for learning and to assist the individual with autism in the application of problem solving when faced with real world challenges.

Alternative intervention approaches such as those that incorporated virtual reality techniques may serve as cost efficient alternatives to training in the real world. Virtual reality has reportedly been used to successfully develop the social interaction and theory-of-mind skills in young adults who were on the autism spectrum (Kandalaft et al. 2013). A similar approach could present individuals with autism with more realistic challenges, requiring them to develop solutions to common problems in a contextually-rich environment that might facilitate flexible thinking and generalization to real world settings.

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References

AdamsWV, , SheslowBV. A developmental perspective of adolescence. In: SchoplerE, , MesibovGB, editorsAutism in adolescents and adultsNew York, NY: Plenum Press; 19831136

American Psychiatric AssociationDiagnostic and statistical manual of mental disorders4. Washington, D.C: Author; 2000rev. ed.

Baez S, Rattazzi A, Gonzalez-Gadea ML, Torralva T, Vigliecca NS, Decety J, et al. Integrating intention and context: Assessing social cognition in adults with Asperger syndrome. Frontiers in Human Neuroscience. 2012; 6(302):1–21. [PubMed: 22279433]

Benjamini Y, Hochberg Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. Journal of the Royal Statistical Society Series B (Methodological). 1995; 57:289–300.

Bogte H, Flamma B, van der Meere J, van Engeland H. Cognitive flexibility in adults with high functioning autism. Journal of Clinical and Experimental Neuropsychology. 2007; 11:1–9.

Boltë S, Poustka F. The relation between general cognitive level and adaptive behavior domains in individuals with autism with and without co-morbid mental retardation. Child Psychiatric and Human Development. 2002; 33:165–172.

Chamberlain E. Behavioural assessment of the dysexecutive syndrome (BADS): Test review. Journal of Occupational Psychology, Employment and Disability. 2003; 5:33–37.

CohenJ. Statistical power analysis for the behavioral sciences2. Hillside, NJ: Lawrence Erlbaum Associates; 1988

Farley MA, McMahon WM, Fombonne E, Jenson WR, Miller J, Gardner M, et al. Twenty-year outcome for individuals with autism and average or near-average cognitive abilities. Autism Research. 2009; 2:109–118. [PubMed: 19455645]

Fenton G, D'Ardia C, Valente D, Del Vecchio I, Fabrizi A, Bernabei P. Vineland adaptive behavior profiles in children with autism and moderate to severe developmental delay. Autism. 2001; 7:269–287.

GoldsteinG. Functional considerations in neuropsychology. In: ShordoneRJ, , LongCJ, editorsEcological validity of neuropsychological testingDelray Beach, FL: Gr Press/St Lucie Press; 19967589

Goldstein G, Johnson CR, Minshew NJ. Attentional processes in autism. Journal of Autism and Developmental Disorders. 2001; 31:433–440. [PubMed: 11569589]

Halstead WC, Settlage PH. Grouping behavior of normal persons and persons with lesions of the brain. Archives of Neurology and Psychiatry. 1943; 49:489–506.

Hayashi M, Kato M, Igarashi K, Kashima H. Superior fluid intelligence in children with Asperger's disorder. Brain and Cognition. 2008; 66(3):306–310. [PubMed: 17980944]

HeatonRK, , CheluneCJ, , TalleyJL, , KayGG, , CurtissG. Wisconsin card sorting test manual, revised and expandedOdessa, FL: Psychological Assessment Resources; 1993

HeatonRK, , DrexlerM. Clinical and neuropsychological findings in schizophrenia and aging. In: MillerNE, , CohenGD, editorsSchizophrenia and agingNew York, NY: Guilford Press; 1987145161

Hill EL, Bird CM. Executive processes in Asperger syndrome: Patterns of performance in a multiple case series. Neuropsychologia. 2006; 44:2822–2835. [PubMed: 16930637]

HollingsheadAB. Two-factor index of social positionNew Haven, CT: Yale University, Department of Sociology; 1957

HooperHE. Hooper visual organization test (VOT)Los Angeles: Western Psychological Services; 1983

Kandalaft MR, Didehbani N, Krawczyk DC, Allen TT, Chapman SB. Virtual reality social cognition training for young adults with high-functioning autism. Journal of Autism and Developmental Disorders. 2013; 43(1):34–44. [PubMed: 22570145]

Kanne SM, Gerber AJ, Quirmbach LM, Sparrow SS, Cicchetti DV, Saulnier CA. The role of adaptive behavior in autism spectrum disorders: Implications for functional outcome. Journal of Autism and Developmental Disorders. 2011; 41:1007–1018. [PubMed: 21042872]

Klin A, Saulnier CA, Sparrow SS, Cicchetti DV, Volkmar FR, Lord C. Social and communication abilities and disabilities in higher-functioning individuals with autism spectrum disorders: The Vineland and ADOS. Journal of Autism and Developmental Disorders. 2007; 37:748–759. [PubMed: 17146708]

Kourkoulou A, Leekam SR, Findlay JM. Implicit learning of local context in autism spectrum disorder. Journal of Autism and Developmental Disorders. 2012; 42(2):244–256. [PubMed: 21461602]

Krasny L, Williams BJ, Provencal S, Ozonoff S. Social skills interventions for the autism spectrum: Essential ingredients and a model curriculum. Child and Adolescent Psychiatric Clinics in North America. 2003; 12(1):107–122.

Laine M, Butters N. A preliminary study of the problem solving strategies of detoxified long-tern alcoholics. Drug and Alcohol Dependence. 1982; 10:235–242. [PubMed: 7166135]

LeCouteur A, Rutter M, Lord C, Rios P, Robertson S, Holdgrafer M, et al. Autism diagnostic interview: A standardized investigator-based instrument. Journal of Autism and Developmental Disorders. 1989; 19:363–387. [PubMed: 2793783]

Liss M, Harel B, Fein D, Allen D, Dunn M, Feinstein C, et al. Predictors and correlates of adaptive functioning in children with developmental disorders. Journal of Autism and Developmental Disorders. 2001; 31:219–230. [PubMed: 11450820]

Lord C, Risi S, Lambrecht L, Cook EH Jr, Leventhal BL, DiLavore PC, et al. The autism diagnostic observation schedule—generic: A standard measure of social and communication deficits associated with the spectrum of autism. Journal of Autism and Developmental Disorders. 2000; 30:205–223. [PubMed: 11055457]

Lord C, Rutter M, Goode S. Autism diagnostic observation schedule: A standardized investigator-based instrument. Journal of Autism and Developmental Disorders. 1989; 19:185–212. [PubMed: 2745388]

Lord C, Rutter M, LeCouteur AL. Autism diagnostic interview revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. Journal of Autism and Developmental Disorders. 1994; 24:659–685. [PubMed: 7814313]

MacAfeeJ. Navigating the social world: A curriculum for individuals with Asperger's syndrome, high functioning autism and related disordersArlington, TX: Future Horizons Inc; 2002

MacLean JE, Szatmari P, Jones MB, Bryson SE, Mahoney WJ, Bartolucci G, et al. Familial factors influence level of functioning in pervasive developmental disorder. Journal of the American Academy of Child and Adolescent Psychiatry. 1999; 38:746–753. [PubMed: 10361794]

Mazefsky CA, Williams DL, Minshew NJ. Variability in adaptive behavior in Autism: Evidence for the importance of family history. Journal of Abnormal Child Psychology. 2008; 36:591–599. [PubMed: 18188537]

Minshew NJ, Goldstein G. The pattern of intact and impaired memory functions in autism. Journal of Child Psychology and Psychiatry. 2001; 42:1095–1101. [PubMed: 11806691]

Minshew NJ, Goldstein G, Siegel DJ. Speech and language in high-functioning autistic individuals. Neuropsychology. 1995; 9:255–261.

Minshew NJ, Goldstein G, Siegel DJ. Neuropsychologic functioning in autism: Profile of a complex information processing disorder. Journal of the International Neuropsychological Society. 1997; 3:303–316. [PubMed: 9260440]

Minshew N, Luna B, Sweeney J. Oculomotor evidence for neocortical systems but not cerebellar dysfunctions in autism. Neurology. 1999; 52:917–922. [PubMed: 10102406]

Minshew NJ, Meyer J, Goldstein G. Abstract reasoning in autism: A dissociation between concept formation and concept identification. Neuropsychology. 2002; 16:327–334. [PubMed: 12146680]

Minshew NJ, Sung K, Jones B, Furman J. Underdevelopment of the postural control system in autism. Neurology. 2004; 63:2056–2061. [PubMed: 15596750]

NewsomC, , HovanitzCA. Autistic disorder. In: MashEJ, , TerdalLG, editorsAssessment of childhood disorders3. New York, NY: Guilford; 1997408452

OswaldDP, , DiSalvoCA. Adaptive behavior assessment. In: OllendickTH, , SchroederCS, editorsThe encyclopedia of pediatric and clinical child psychologyNew York: Kluwer Academic/Plenum Publishers; 2003

Palmen A, Didden R, Lang R. A systematic review of behavioral intervention research on adaptive skill building in high-functioning young adults with autism spectrum disorder. Research in Autism Spectrum Disorders. 2012; 6:602–617.

Pennington BF, Ozonoff S. Executive functions and developmental psychopathology. Journal of Child Psychology and Psychiatry. 1996; 37:51–87. [PubMed: 8655658]

Peppeé S, McCann J, Gibbon F, O'Hare A, Rutherford M. Receptive and expressive prosodic ability in children with high-functioning autism. Journal of Speech, Language and Hearing Research. 2007; 50:1015–1028.

Rao PA, Beidel DC, Murray MJ. Social skills interventions for children with Asperger's syndrome or high-functioning autism: A review and recommendations. Journal of Autism and Developmental Disorders. 2008; 38(2):353–361. [PubMed: 17641962]

ReitanRM, , WolfsonD. The Halstead-retain neuro-psychological test battery: Theory and clinical interpretation2. Tucson, AZ: Neuropsychology Press; 1993

Rutter M. Cognitive deficits in the pathogenesis of autism. Journal of Child Psychology and Psychiatry and Allied Disciplines. 1983; 24:513–531.

Simon H. The functional equivalence of problem solving skills. Cognitive Psychology. 1975; 7:268–288.

Solomon M, Buaminger N, Rogers SJ. Abstract reasoning and friendship in high functioning preadolescents with autism spectrum disorders. Journal of Autism and Developmental Disorders. 2011; 41(1):32–43. [PubMed: 20467797]

Soulieères I, Dawson M, Gernsbacher MA, Mottron L. The level and nature of autistic intelligence II: What about Asperger syndrome? PLoS ONE. 2011; 6:e25372. [PubMed: 21991394]

SparrowSS, , BallaDA, , CicchettiDV. Vineland adaptive behavior scalesCircle Pines, MN: American Guidance Service; 1984

ThorndikeRL, , HagenEP, , SattlerJM. The stanford-binet intelligence scale4. Chicago: Riverside Publishing; 1986

Williams DL, Goldstein G, Minshew NJ. Impaired memory for faces and social scenes in autism: Clinical implications of the memory disorder. Archives of Clinical Neuropsychology. 2005; 20:1–15. [PubMed: 15620811]

Williams DL, Goldstein G, Minshew NJ. Neuropsychologic functioning in children with autism: Further evidence of disordered complex information processing. Child Neuropsychology. 2006a; 12:279–298. [PubMed: 16911973]

Williams DL, Goldstein G, Minshew NJ. Profile of memory function in children with autism. Neuropsychology. 2006b; 20:21–29. [PubMed: 16460219]

WilsonBA, , AldermanN, , BurgessPW, , EmslieH, , EvansJJ. Behavioural assessment dysexecutive syndromeBury St. Edmunds, Suffolk, England: Thames Valley Test Company; 1996

Table 1

Demographic data

	Autism group N = 65		Control group N = 65		*t*	p^a
	Mean	**SD**	**Mean**	**SD**		
Age in years (Range 8–46)	18.83	9.68	19.17	10.11	0.20	.85
Years of education	8.77	4.40	9.95	4.42	1.44	.15
Socioeconomic status[b]	3.61	1.63	3.88	1.11	1.03	.31
Verbal IQ	102.00	15.60	102.57	8.90	0.26	.80
Full scale IQ	98.82	14.13	102.08	8.75	1.58	.12

[a]None of these differences are statistically significant ($p < .05$)

[b]This average reflects middle-class status (e.g., administrative personnel, small business owners)

Table 2

Rotated factor loadings for the conceptual reasoning tests

	Factor 1: flexible thinking	Factor 2: perceptual reasoning	Factor 3: rule application
Verbal absurdities	**.847**	−.032	−.116
Picture absurdities	**.598**	−.585	−.009
WCST perseverative errors	**−.580**	.044	.444
20Q constraint seeking	**.570**	−.436	−.193
TPT-time	.138	**.809**	.353
Hooper T score	−.328	**.773**	−.135
Category test errors	−.076	.135	**.748**
Trail making B–time	−.103	−.054	**.695**
Tower of hanoi moves	−.385	.189	**.525**
% Explained variance	22.521	20.491	18.990

Table 3

Rho correlations between factor scores, BADS, and VABS

	Autism			Control		
	Flexible thinking	**Perceptual reasoning**	**Rule application**	**Flexible thinking**	**Perceptual reasoning**	**Rule application**
BADS						
Rule shift	**.311** *	−.151	−.053	.190	−.085	−.063
Action sequences	.041	−.078	−.112	.186	.005	−.078
Key search	**.290** *	−.114	−.209	.030	.073	−.100
Temporal judgment	.065	−.037	−.155	−.033	.075	.158
Zoo map	.104	**−.315** *	−.134	−.075	−.026	−.033
Six elements	.243	−.145	.030	.156	**−.296** *	−.053
VABS						
Communication	.241	−.111	−.095	.067	−.008	.118
Daily living skills	.004	−.115	−.034	−.182	.050	−.037
Socialization	.119	.047	.158	**−.293** *	.201	−.099
Adaptive behavior	**.299** *	.018	.013	**−.263** *	.201	−.098

* Correlation is significant at the 0.05 level (2-tailed)

Table 4

Differences between autism and control groups on adaptive functioning ranked by effect size (d)

Test	Autism		Control		*t*	*p*	d	Power
	M	SD	M	SD				
Behavioral assessment of the dysexecutive syndrome (BADS)								
Action sequences (Practical problem solving)	3.41	.57	3.63	.25	**−2.90**	.004	.50	.81
Key search (Strategy formation)	2.17	.74	2.35	.77	−1.40	.17	.24	.27
Modified six elements (Planning and performance monitoring)	3.01	.81	3.14	.54	−1.08	.28	.19	.19
Rule shift (Ability to change an established pattern of responding)	3.48	.72	3.57	.28	−0.91	.37	.16	.15
Temporal judgment (Ability to estimate how long various tasks take)	1.13	.46	1.10	.28	.50	.62	.08	.07
Zoo map (Planning and following rules)	2.56	.78	2.54	.63	.14	.89	.03	.04
Vineland adaptive behavior scales (VABS)								
Adaptive behavior composite	83.18	12.36	91.37	8.50	**−4.40**	<.001	.77	.99
Socialization domain	83.62	15.16	93.05	9.48	**−4.25**	<.001	.75	.99
Daily living skills domain	93.14	18.32	95.21	6.87	−0.86	.39	.15	.13
Communication domain	99.52	16.00	98.23	7.84	0.59	.56	.10	.08

Table 5

Means and SDs of the three age groups in the autism and control groups on the cognitive tests

M + SD	Autism group				Control group			
Age group	**8–12**	**13–20**	**21+**	**Total**	**8–12**	**13–20**	**21+**	**Total**
Verbal absurdities	8.16 ± 7.7	10.21 ± 4.3	10.85 ± 4.1	9.68 ± 5.7	11.11 ± 2.3	14.16 ± 1.0	13.45 ± 2.9	13.03 ± 2.5
Tower of hanoi	161.31 ±44.5	178.16 ± 73.7	169.0 ± 60.4	169.06 ± 59.4	143.0 ± 51.9	110.12 ± 33.9	106.55 ±44.1	118.8 ±45.2
WCST PE	16.93 ± 12.8	14.84 ± 10.9	16.39 ± 10.4	16.10 ± 11.3	11.84 ± 7.2	7.43 ± 4.9	7.98 ± 5.6	8.91 ± 6.1
Category errors	41.66 ± 22.6	39.53 ± 21.2	40.64 ± 18.7	40.66 ± 20.6	41.61 ± 13.2	28.82 ± 14.6	41.83 ± 29.0	36.69 ± 20.6
HVOT	54.14 ± 6.6	49.26 ± 5.2	51.5 ± 8.3	51.72 ± 7.0	52.58 ± 4.7	47.76 ± 2.9	46.6 ± 3.5	48.83 ± 4.4
Picture absurdities	23.73 ± 2.7	27.42 ± 3.4	26.8 ± 3.2	25.89 ± 3.5	24.79 ± 2.2	28.72 ± 2.0	30.0 ± 2.3	27.94 ± 3.0
TPT	945.78 ± 314.7	790.88 ± 366.2	885.31 ± 543.3	877.71 ± 415.3	916.41 ± 312.0	585.76 ± 177.6	723.34 ± 283.3	726.91 ± 287.7
20 Q	14.14 ± 12	18.89 ± 8.9	16.74 ± 9.9	16.51 ± 10.4	19.47 ± 8.5	23.72 ± 7.3	22.35 ± 7.9	22.03 ± 7.3
Trails B	43.68 ± 27.4	50.89 ± 28.0	77.10 ± 26.3	56.89 ± 30.5	38.37 ± 14.3	39.12 ± 17.6	55.7 ± 14.3	44.08 ± 17.3

Table 6

F-ratios for main effects and interaction for conceptual reasoning tests

	$F_{Autism(AUT)}$	$F_{AgeI(AGE)}$	$F_{AGEXAUT}$
Verbal absurdities	17.05***	4.83**	.28
Tower of Hanoi	28.15***	.78	2.83
WCST perseverative	18.36***	1.40	.36
Category errors	.75	1.78	1.08
HVOT	7.29**	9.65***	1.29
Picture absurdities	14.85***	30.61***	1.88
TPT	4.55*	5.20**	.73
20 Q	10.6***	2.67	.02
Trails B	10.44**	15.45***	1.36

* $p < .05$;

** $p < .01$;

*** $p < .001$

Table 7

Means and SDs for adaptive function variables of the three age groups in the autism and control groups

M + SD	Autism group				Control group			
Age group	**8–12**	**13–20**	**21 +**	**Total**	**8–12**	**13–20**	**21 +**	**Total**
BADS								
Rule shift	3.31 ± .76	3.59 ± .48	3.53 ± .91	3.47 ± .74	3.54 ± .2	3.53 ± .34	3.64 ± .27	3.57 ± .28
Action sequences	3.57 ± .18	3.26 ± .71	3.33 ± .69	3.39 ± .58	3.58 ± .19	3.68 ± .26	3.62 ± .28	3.63 ± .26
Key search	2.2 ± .28	1.89 ± .87	2.32 ± .96	2.15 ± .76	2.35 ± .24	2.2 ± .98	2.54 ± .8	2.35 ± .78
Temporal	1.01 ± .33	1.22 ± .68	1.18 ± .36	1.13 ± .47	1.15 ± .21	1.07 ± .3	1.08 ± .33	1.1 ± .28
Zoo map	2.34 ± .76	2.66 ± .66	2.69 ± .95	2.55 ± .8	2.41 ± .61	2.71 ± .64	2.46 ± .64	2.54 ± .63
6 Elements	2.83 ± .64	3.09 ± .62	3.07 ± 1.15	2.99 ± .83	3.06 ± .03	3.04 ± .77	3.35 ± .44	3.14 ± .55
Total profile	15.3 ± 2.05	15.84 ± 1.97	16.12 ± 3.65	15.74 ± 2.64	16.13 ± .52	16.25 ± 1.63	16.71 ± .95	16.36 ± 1.19
Total standard	86.45 ± 9.6	89.0 ± 9.3	90.23 ± 17.58	88.48 ± 12.6	90.35 ± 2.61	91.06 ± 7.93	92.56 ± 4.1	91.32 ± 5.64
VABS communication	93.64 ± 15.67	100.32 ± 10.85	99.50 ± 2.24	97.64 ± 11.49	97.63 ± 11.35	98.04 ± 8.14	99.0 ± .0	98.22 ± 7.90
VABS daily living	86.55 ± 17.86	96.79 ± 17.41	94.21 ± 5.84	91.94 ± 15.18	94.02 ± 6.1	98.06 ± 9.15	92.90 ± .0	95.25 ± 6.92
VABS socialization	80.04 ± 17.91	78.68 ± 16.63	88.77 ± 5.23	82.77 ± 14.92	97.01 ± 12.02	94.62 ± 9.51	87.60 ± .0	93.13 ±9.53
VABS adaptation	80.18 ± 13.19	80.26 ± 15.42	88.5 ± 6.71	82.93 ± 12.72	93.32 ± 10.40	93.56 ± 9.31	87.0 ± .0	91.44 ± 8.55

Table 8

F-ratios for main effects and interaction for BADS and VABS

	$F_{Autism(AUT)}$	$F_{Agel(AGE)}$	$F_{AGEXAUT}$
BADS rule shift	.88	.94	.72
BADS action sequences	9.4**	.72	2.35
BADS key search	2.69	2.70	.13
BADS temporal	.30	.28	1.71
BADS zoo map	.08	1.98	.56
BADS 6 elements	1.45	1.41	.67
BADS total profile	2.74	1.18	.11
VABS communication	.05	1.85	1.14
VABS daily living	1.88	3.56*	1.51
VABS socialization	23.03***	.40	7.03***
VABS adaptation	19.84***	.11	6.81**

* $p < .005$;

** $p < .01$;

*** $p < .001$

Table 9

Multiple regression analyses using conceptual reasoning factor scores as predictor variables and BADS total standard or VABS adaptive behavior composite summary scores as dependent measures

BADS total standard score	R	R^2	Adj R^2	F	P	B Group	t
Enter method model	.459	.210	.195	4.604	.00	1.785	1.005
Stepwise method model							
AUT1 (Group 9 Factor 1 Score)	.319	.101	.094	14.340	.000	4.040	4.379
AUT2 (Group 9 Factor 2 Score)	.395	.156	.142	11.621	.000	−2.950	−3.152
AUT3 (Group 9 Factor 3 Score)	.444	.197	.178	10.254	.000	−2.278	−2.55
VABS adaptive behavior composite score							
Enter method model	.428	.183	.136	3.878	.001		
Stepwise method							
AUT (Group)	.354	.125	.116	18.188	.000	−7.900	−4.265
AUT1 (Group 9 Factor 1 Score)	.412	.170	.157	12.894	.000	3.043	2.602