Nonverbal and verbal cognitive discrepancy profiles in autism spectrum disorders:

Influence of age and gender
Abstract

Research suggests that discrepant cognitive abilities are more common in children with Autism Spectrum Disorder (ASD) and may indicate an important ASD endophenotype. The current study examined the frequency of IQ discrepancy profiles (NVIQ > VIQ, VIQ > NVIQ, and no split) and the relationship of gender, age, and ASD symptomatology to IQ discrepancy profile in a large sample of children with ASD. The NVIQ > VIQ profile occurred at a higher frequency than expected, had more young males, and showed more autism symptoms than the other groups. Results suggest that the NVIQ > VIQ profile may be less likely to represent a subtype of ASD, but rather a common developmental pathway for children with ASD and other disorders.
Introduction

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder marked by extreme phenotypic variation ranging from severely affected and intellectually disabled individuals to individuals with mild social and neuropsychological symptoms. Recent advances in genetic technology reveal diverse genotypes, with over 100 genetic events contributing to the etiology of this heterogeneous disorder (Betancur, 2010). The identification of phenotypically defined subtypes can inform molecular analysis and provide insight into the etiology of ASD (Abrahams & Geschwind, 2008; Ozonoff, South, & Miller, 2000). A recent linkage analysis identified a quantitative trait locus influencing IQ discrepancy in ASD families suggesting that an uneven cognitive profile, an IQ “discrepancy” or “split,” may serve as a potential autism-related phenotype (Chapman et al., 2010). The cognitive profile is an individual’s pattern of performance in cognitive domains, such as the verbal and nonverbal reasoning (or performance) domains. An IQ discrepancy or split indicates significantly greater nonverbal reasoning skills compared to verbal skills (NVIQ > VIQ) or significantly greater verbal reasoning skills compared to nonverbal reasoning skills (VIQ > NVIQ).

Previous studies examining the cognitive profile of ASD present conflicting findings. Possible reasons for this include small sample sizes, the application of different ASD diagnostic criteria over time, differing age groups and cognitive abilities, and choice of cognitive test among other possible factors (see Table 1 for a description of selected previous studies).

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Insert Table 1 about here
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Many reports of an IQ profile in ASD indicate enhanced visual spatial and nonverbal skills relative to the verbal skills of vocabulary and language comprehension (Allen et al., 1991; Lincoln et al., 1988; Ohta, 1987; Shah & Frith, 1993). This pattern, however, has not been
observed consistently and the opposite profile of higher verbal relative to nonverbal skills has also been found (Mayes & Calhoun, 2003; Minshew, Turner, & Goldstein, 2005; Siegel, Minshew, & Goldstein, 1996; Szatmari et al., 1990).

Cognitive profile analysis has been used to examine differences in diagnostic classification in ASD. Individuals with Asperger’s Disorder have been found to demonstrate enhanced verbal IQ relative to performance IQ when compared to individuals with Autistic Disorder (Ehlers et al., 1997; Klin et al., 1995). Other studies, however, have found that individuals with Autistic Disorder can also demonstrate enhanced verbal skills relative to nonverbal skills (Manjiviona & Prior, 1999; Ghazziudin & Mountain-Kimchi, 2004; Ozonoff et al., 2000; Williams et al., 2008). Thus, research to date indicates great heterogeneity in the cognitive profiles of children with ASD and that IQ discrepancies in either direction are likely best understood independent of diagnostic classification, especially in light of the proposed changes to ASD diagnostic criteria in DSM-V (APA, 2012).

The relationship between gender and cognitive discrepancy profiles in ASD has not been examined to date. Research on gender as it relates to ASD in general is lacking, partly because ASD continues to affect boys much more frequently than girls. However, there is evidence to indicate that females with ASD tend to have more severe symptoms and, thus, are more impaired on measures of both verbal and nonverbal IQ than males (Volkmar et al., 1993). Other studies have indicated that females with ASD perform lower than their male counterparts specifically on measures of nonverbal IQ (Banach, et al., 2009; Baron-Cohen & Hammer, 1997; Lord, et al., 1982).

Several studies have suggested age may play a role in IQ discrepancy in children with ASD. One study of 456 preschool children found that those who had an extreme NVIQ > VIQ
split were significantly younger compared to children without an extreme split (Munson et al., 2008). Other studies of cognitive profiles in children with ASD have found that older children as a group demonstrated a smaller discrepancy between verbal and nonverbal IQ, ostensibly due to resolving delays in language over time (Joseph, Tager-Flusberg, & Lord, 2002; Mayes & Calhoun, 2003). In fact, Joseph and colleagues (2002) found that the NVIQ > VIQ profile was more common in the younger child group compared to the older child group who had an equal distribution of NVIQ > VIQ and VIQ > NVIQ discrepancies. One obvious limitation of the above studies is their cross-sectional design. Howlin and colleagues (2004) used a longitudinal design and found a similar pattern of improving verbal IQ in contrast to relatively stable nonverbal IQ from childhood to adulthood in individuals with ASD. It is important to note that these studies used different cognitive measures to assess NVIQ and VIQ ranging from the Mullen, Stanford-Binet, and Bayley for young children and the DAS and Wechsler tests for older children and adults respectively. In each study, choice of test administered was based on what was most developmentally appropriate for the individual child or adult within the constraints of the study design.

Lastly, there is evidence that IQ discrepancy profiles within ASD may relate to autistic symptomology. Joseph and colleagues (2002) found that IQ discrepancies in either direction occurred more frequently in a sample of children with ASD compared to a representative sample of children. Also, older children with a discrepancy indicating greater nonverbal skills showed increased social skill impairments compared to those with discrepantly high verbal skills and those without an IQ split. This finding was bolstered by a follow-up study which found a significant relationship between nonverbal IQ discrepancy and head size and brain volume respectively (Tager-Flusberg & Joseph, 2003). Thus, it has been suggested that individuals with
discrepantly high nonverbal scores (NVIQ > VIQ) might comprise a subtype of ASD due to the significant association with social impairment and abnormal brain volume. More recently, discrepancies in either direction were reportedly linked to social impairments, but not communication deficits or repetitive behaviors in a sample of high-functioning (as defined by an average IQ of 98.5) children with ASD (Black et al., 2009).

Given the limitations in many of the above studies, and the potential of IQ discrepancy to aid in the identification of genetic risk factors, we aimed to explore IQ discrepancy in ASD using a very large, well-characterized sample with a wide range of cognitive ability. Our aims were to determine if a significant IQ discrepancy was evident with greater frequency than would be expected, and, if so, to explore the relationship of gender, age, and ASD symptomatology to IQ discrepancy. We hypothesized that a distinct cognitive split in both directions (NVIQ > VIQ & VIQ > NVIQ) would be observed in our sample of children with ASD with greater frequency than expected. We also expected that boys would be more likely to exhibit a NVIQ > VIQ discrepancy than girls. We expected to observe a relationship between NVIQ > VIQ discrepancy and age, with younger children more likely to exhibit this cognitive profile. Lastly, we expected to observe a relationship between NVIQ > VIQ discrepancy and greater ASD symptomatology.

**Methods**

**Participants**

Participants included 1954 children (1710 males, 244 females) with ASD between the ages of 4 years and 17 years, 11 months old (mean age = 8.8 years) from the Simons Simplex Collection (SSC). Individuals were selected for this analysis from the total sample in Distribution 13 of 2648 children with autism if they were administered the Differential Ability Scales – Second Edition (DAS-II) as part of their participation in the SSC. The DAS-II was chosen for
analysis as it was administered to the majority of the children in the SSC sample and provides norms for analyzing cognitive discrepancies for children who are administered the same battery (Early Years or School Age) for the verbal and nonverbal domains. Of the 694 excluded children, 44 were administered the Wechsler Intelligence Scale for Children for both domains, 68 were administered the Wechsler Abbreviated Scales of Intelligence for both domains, 202 were administered the Mullen Scales of Early Learning for both domains, 103 were administered a combination of the DAS-II for one domain and another instrument for the second, and 131 were administered two different DAS-II batteries. In addition, 146 participants were excluded due to missing data.

The SSC is a project funded by the Simons Foundation Autism Research Initiative to identify de novo genetic variants related to ASD and includes 12 data collection sites across North America (see sfari.org; Fischbach & Lord, 2010). Data is released in numbered distributions as carefully cleaned and validated data becomes available. Inclusion criteria for the SSC requires that the child meet ASD criteria on the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) and meet the Collaborative Programs for Excellence in Autism (CPEA) ASD criteria on the Autism Diagnostic Interview- Revised (ADI-R; Lord et al., 1994). CPEA criteria require the child to score within 2 points of the cut-off on social or communication domains or within 1 point on both, with no requirement for the repetitive behavior or age of onset domains. The child must also have a nonverbal IQ estimate greater than 35. Exclusion criteria included children with significant hearing, vision or motor problems, significant birth complications (e.g., extended NICU stay), or diagnosis of ASD related disorders, such as Fragile X. Finally, any child with ASD who had a relative (up to 3rd degree) with ASD or who had a
sibling with ASD related symptoms (e.g., social challenges necessitating an Individualized Education Program) were excluded to increase the likelihood of identifying de novo events.

Participation in the SSC included diagnostic evaluation, collection of phenotypic measures, and cognitive assessment. Data collection, data entry, and data validation methods were standardized across sites to ensure reliability of sample collection (Fischbach & Lord, 2010). The core deficits of children with ASD can create challenges for testing. Prior to assessment, information was gathered on each participant’s communication level and behavior. Skilled clinicians with high levels of expertise in the assessment of children with ASD administered the cognitive assessments, and extensive training efforts and protocols ensured reliability in administration and scoring. To ensure appropriate diagnosis and cross-site reliability on the ADOS and ADI-R, SSC consultants, expert in the administration and scoring of these measures, validated videotaped clinician administrations on a quarterly basis. Acceptable protocol and algorithm reliability was 80% or above on the ADOS and 90% or above on the ADI-R. These strict standards ensured highly accurate classification of the ASD sample.

**Measures**

The Differential Ability Scales - Second Edition (DAS-II; Elliott, 2007) is a cognitive assessment that evaluates abilities across a variety of domains in children ranging from 2:6 to 17:11 years. It is a well-validated measure that correlates highly with other measures of cognitive ability frequently used with children including the Bayley-III, WPPSI-III, and WISC-IV (Elliott, 2007). The DAS-II includes two overlapping batteries: the Early Years battery (2:6 to 8:11 years) and the School Age battery (5:0 to 17:11 years). Within the Early Years Battery, there are two sub-levels, the Lower Level (2:6 to 3:5 years) and Upper Level (3:6 to 8:11 years). The Early Years-Lower Level battery is comprised of four subtests that yield an overall cognitive
ability score and two domain scores: the Verbal domain comprised of the Verbal Comprehension and Naming Vocabulary subtests, and the Nonverbal domain comprised of the Picture Similarities and Pattern Construction subtests. The Early Years-Upper Level battery is made up of six subtests, which yield an overall ability score and three domain scores: the Verbal domain (Verbal Comprehension and Naming Vocabulary subtests), Nonverbal domain (Picture Similarities & Matrices subtests), and a Spatial domain (Pattern Construction and Copying subtests). The School Age battery is also comprised of six subtests that yield an overall score and the same three domains as the Early Years-Upper Level. These include Verbal Reasoning (Similarities and Word Definitions), Nonverbal Reasoning (Matrices and Sequential & Quantitative Reasoning), and Spatial (Recall of Designs and Pattern Construction). DAS-II standard scores for overall cognitive ability and subdomains are reported with a mean of 100 and a standard deviation of 15. The specificity of the subtests and the resultant domain scores provides a foundation for profile analysis. The DAS-II normative sample consists of 3480 children aged 2:6 to 17:11 years stratified by age, gender, ethnicity, parent education, and geographic region. One additional strength of the DAS-II norming sample is that it includes a representative proportion of children with documented weaknesses (e.g., intellectual and learning disabilities) and strengths (e.g., giftedness) in order to accurately represent the population. Domain discrepancy cutoff values reported in the manual are based on this normative sample.

Autism symptomatology was measured using the ADOS and ADI-R. The ADOS is a semi-structured assessment consisting of play and conversational activities that elicit social and communication behaviors related to the diagnosis of ASD. The Calibrated Severity Score (CSS, Gotham, Pickles, & Lord, 2009) is an estimate of autism severity based on the ADOS module administered and the achieved ADOS score. It was developed as a means of determining autism
severity with less variance attributable to verbal intelligence than previous measures, and it was used to define autism severity in this study. The CSS ranges from 1 to 10 with scores below 4 representing non-spectrum functioning. The ADI-R is a detailed parent or caregiver interview of developmental history and autism symptoms. Scores are aggregated into three symptom clusters that correspond to DSM-IV criteria for a diagnosis of autism, which include the communication, social, and restricted and repetitive behaviors domains.

**Procedure**

Individuals with DAS-II derived IQ deviation scores for both domains were selected for analysis. Deviation scores for VIQ and NVIQ were compared and a NVIQ-VIQ score was computed to identify IQ discrepancies.

For this study, an "IQ discrepancy" was defined as a difference value between VIQ and NVIQ standard scores exceeding the clinically significant critical cutoff score for which 15% or less of the DAS-II normative sample have a split that size or greater as indicated in the DAS-II manual (Elliott, 2007). It has been suggested that discrepancies that occur in less than 10-15% of the standardization sample are rare (Sattler, 2001). For the DAS-II, the clinically significant cutoff score differs by the three test batteries.

For the Early Years-Upper Level and School Age batteries, the Nonverbal and Spatial clusters are combined to yield a Special Nonverbal Composite. For these two batteries, the Verbal cluster is compared to the Special Nonverbal Composite to identify the existence of a discrepancy. However, clinically significant cutoffs are identified in the DAS-II manual for the Verbal compared to both the Nonverbal and the Spatial composites, but not for the Verbal compared to the Special Nonverbal Composite. Therefore, the clinically significant cutoff value for the Verbal compared to the Special Nonverbal Composite was computed by taking the mean
cutoff score of the Verbal to Nonverbal and Verbal to Spatial cutoffs. The resulting Verbal compared to Special Nonverbal Composite cutoffs were used for the Verbal-Nonverbal IQ discrepancy analyses for the Early Years-Upper Level and School Age batteries. For the Early Years-Lower Level battery, the Verbal cluster is compared to the Nonverbal cluster to calculate the IQ discrepancy; however, due to the available data, the same, stricter, criteria as the Early Years-Upper Level was applied to the Early Years-Lower Level. The cutoffs indicating an IQ discrepancy for each of the three batteries are shown in Table 2.

Insert Table 2 about here

These strict clinically significant cutoff criteria also exceed the criteria listed in the DAS-II manual indicating statistically significant domain discrepancies at the .05 level (Elliott, 2007). The resultant IQ difference scores were recoded according to the above criteria to reveal individuals who had a significant IQ discrepancy. Individuals were placed into three cognitive profile groups: Nonverbal > Verbal IQ Discrepancy (NVIQ > VIQ); Verbal > Nonverbal IQ Discrepancy (VIQ > NVIQ); and no Discrepancy (NVIQ = VIQ).

Results

Cognitive profile group descriptive data is included in Table 3.

Insert Table 3 about here

First, full-scale IQ was examined as a function of cognitive profile group using one-way analysis of variance. None of the cognitive groups differed significantly on full-scale IQ, but the two discrepancy groups showed the expected significant differences on mean NVIQ and VIQ using Tukey post-hoc comparison.
To examine cognitive discrepancy rates in ASD, chi-square analysis was conducted. The rate of cognitive profile group membership in the study sample was compared to the expected rates of 15% of children demonstrating a NVIQ > VIQ discrepancy and 15% demonstrating a VIQ > NVIQ discrepancy utilizing the cutoffs in Table 2, with the remainder demonstrating no significant split as identified in the DAS-II normative sample (Elliott, 2007). Of the 1954 subjects included in the analysis, 1150 (58.85%) showed no cognitive split, 535 (27.38%) showed a cognitive split with NVIQ > VIQ, and the remaining 269 (13.77%) subjects displayed a cognitive split with VIQ > NVIQ. Results indicate a greater rate of a NVIQ > VIQ discrepancy relative to the DAS-II normative sample ($\chi^2 (2) = 236.31, p < .001$); see Table 4.

Gender was also examined as a function of cognitive profile group. First we examined whether there was an association between gender and the presence of a cognitive split in either direction (NVIQ > VIQ or VIQ > NVIQ) using 2 X 2 chi-square analysis. A significant association between gender and the presence of a cognitive split was found with more males and fewer females than expected having a cognitive split in either direction, $\chi^2 (1, N=1954) = 4.29, p < .05$ (with Yates Continuity Correction). Then 2 X 3 chi-square analysis was conducted to assess the relationship between gender and cognitive profile group. A significant association between gender and cognitive profile group membership was found, $\chi^2 (2, N=1954) = 11.42, p < .05$. Specifically, there were fewer females and more males than expected in the NVIQ > VIQ group and more females and fewer males than expected in the NVIQ = VIQ group (see Table 4). Moreover, for those males and females who did have a cognitive split, the split direction rate differed; females had roughly equal numbers of NVIQ > VIQ and VIQ > NVIQ split whereas males had the NVIQ > VIQ profile more often.
Post-hoc exploration of IQ and gender was conducted using a multivariate analysis of variance (MANOVA) with gender as the independent variable, and verbal IQ and nonverbal IQ as dependent variables. One-way between groups MANOVA indicated a significant difference between males and females on the combined dependent variables (VIQ and NVIQ), $F(2, 1951) = 13.01$, $p < .001$, Wilks’ Lambda = 0.987. When the results for the dependent variables were considered separately, the only difference to reach statistical significance, using a Bonferroni adjusted alpha level of .025, was NVIQ, $F(1,1952) = 18.46$, $p < .001$, partial $\eta^2 = .009$. The mean IQ scores by gender are reported in Table 5.

To examine the relationship between cognitive profile group and age, ANOVA was calculated with cognitive profile group as the independent variable and age as the dependent variable. Analysis of variance examining age revealed a significant main effect for cognitive profile group on age, $F(2, 1951) = 17.92$, $p < 0.001$. As can be seen in Table 3, Tukey post-hoc comparisons indicate that the VIQ > NVIQ group ($M = 119.96$) is significantly older than the no split ($M = 103.43$) and the NVIQ > VIQ group ($M = 104.25$), $p < 0.001$.

To more closely examine the association between age group and cognitive profile, for those children with a cognitive profile split ($n=804$), we divided the sample as follows: 4-6 years old ($n=270$), 7-9 years old ($n=253$), 10-12 years old ($n=150$), 13-15 years old ($n=87$), and 16-17:11 years old ($n=44$). These age groups were chosen to examine potential developmental characteristics within approximate three-year time periods based on our sample’s age range of 4-17:11 years. First we examined whether there was an association between age group and the...
presence of a cognitive split in either direction (NVIQ > VIQ or VIQ > NVIQ) using 2 X 5 chi-square analysis and found that there was no significant association. We then conducted another chi-square analysis to examine the association between age group and cognitive profile group and found that there were more younger children (age groups 4-6 and 7-9 years) in the NVIQ > VIQ group than would be expected and more older children (age groups 10-12, 13-15, and 16-18 years) in the VIQ > NVIQ group than would be expected, $X^2 (4, n=804) = 28.18, p < 0.001$ (see Figure 2). For example, in the 4-6 age group, 73% of the children with a cognitive split displayed a NVIQ > VIQ discrepancy ($n=197$), and in the 7-9 age group, 73% ($n=184$) displayed a NVIQ > VIQ discrepancy. In the later age groups, the percentage of children with a split in either direction begins to trend closer to 50%.

To examine the relationship between cognitive profile group and autistic symptomatology, a multivariate analysis of covariance (MANCOVA) was calculated with cognitive profile group as the independent variable and ADOS CSS (Calibrated Severity Score) and ADI-R domain scores as dependent variables. MANCOVA, with age and gender covaried, revealed significant group differences in ASD symptomatology on the ADOS CSS ($F(2, 1845) = 12.62, p < .001$), ADI-R social ($F(2, 1845) = 8.75, p < .001$), and ADI-R communication ($F(2, 1845) = 11.23, p < .001$) domains. No significant group differences were found in the ADI-R restricted and repetitive behavior domain (see Table 3). Post-hoc analyses using pairwise comparison with Bonferroni correction revealed that the NVIQ > VIQ group was significantly more impaired in each of these domains as compared to the VIQ > NVIQ and no split groups respectively (CSS mean difference = 0.57, $p < .001$, 0.40, $p < .001$; ADI-R social mean
difference = 1.43, p < .001, 1.08, p < .001; ADI-R communication mean difference = 1.36, p < .001, 0.92, p < .001).

Discussion

Recent research has raised the possibility that discrepant cognitive abilities are more common in children with ASD and may indicate an important autism endophenotype. To explore this question, we investigated the existence of distinct cognitive profiles based on strict clinical and statistical definitions of verbal and nonverbal IQ discrepancy in ASD and examined the relationship of identified profiles with gender, age, and autistic symptomatology. Our findings indicate that within our large cohort of well characterized children with ASD, significantly more children exhibit the NVIQ > VIQ discrepancy profile than would be expected in a representative sample. This finding supports and extends previous work identifying higher rates of a NVIQ > VIQ discrepancy in smaller samples of children with ASD. Conversely, the number of children in our study with a VIQ > NVIQ discrepancy mirrored roughly what would be expected in a representative sample suggesting that this profile is not unique to ASD.

We found that gender differed as a function of cognitive profile. Fewer females and more males than expected were represented in the NVIQ > VIQ discrepancy group. Furthermore, our analysis indicated that males and females did not differ in terms of verbal IQ, but that males scored significantly higher (> 5 points) in nonverbal IQ. While the clinical significance of this finding is unclear due to its small effect size, it may reflect differential developmental effects related to sex as males with ASD historically have exhibited higher nonverbal IQ compared to females (Lord, et al., 1982; Baron-Cohen & Hammer, 1997). In the general population, minor
gender differences do exist in verbal ability, with females having a slight advantage given a
tendency for them to acquire language at an earlier age and develop larger vocabularies than
males (e.g., Burton, Henninger, & Hafetz, 2005). Females also tend to have fewer reading and
stuttering difficulties than males (Sattler, 2001). Males, however, tend to vary more than females
in mathematical and spatial abilities (Feingold, 1994; Sattler, 2001). Given the relative cognitive
strengths of males and females in the general population, the NVIQ > VIQ profile’s
overrepresentation among the males in our sample may simply reflect a combination of these
general sex differences coupled with the common communication deficits associated with ASD.

We also found that age differed as a function of cognitive profile. The individuals in the
NVIQ > VIQ discrepancy group were significantly younger than the VIQ > NVIQ group. This is
consistent with previous research. Joseph and colleagues (2002) found more young children in
the NVIQ > VIQ group and suggested that decreased NVIQ > VIQ discrepancy rates among
older children were driven by improvements in verbal abilities as children with ASD aged.
Mayes & Calhoun (2003) studied different cognitive abilities across age groups in individuals
with ASD and also found that discrepantly high nonverbal IQ relative to verbal IQ was more
apparent in young children, but not older children. Although the current study utilizes a cross
sectional approach, these findings support the suggestion that age-related improvements in verbal
ability may contribute to the reduced discrepancy rates in older children with ASD.

In terms of ASD symptomatology, we found that the NVIQ > VIQ group showed more
significant impairment compared to the other cognitive groups on the ADOS CSS and ADI-R
social and communication domains. This finding supports the work of Joseph and colleagues
(2002) and Black and colleagues (2009) linking the NVIQ > VIQ profile to greater social
impairment. However, these results must be interpreted in light of several potentially
confounding factors. For one, our NVIQ > VIQ group had significantly lower verbal IQ compared to the other groups. Thus, it is unclear if these results are simply the result of lower verbal IQ or cognitive group membership. Further, while these results reached statistical significance, their clinical significance is unclear as actual differences in the scores were quite modest.

In summary, our findings indicate that a significant proportion of young male children with ASD display a distinct NVIQ > VIQ discrepancy. For this profile to be a unique subtype of ASD, one would expect to observe it with equal frequency in all age groups, which we did not. Mervis (2004) cites the importance of sensitivity and specificity when examining profiles of children with various developmental disabilities for genotype/phenotype research. In our sample, while a significant proportion of children with ASD exhibit the NVIQ > VIQ profile, this profile is not necessarily specific to ASD as children with other disabilities can demonstrate this profile. Both Klin and colleagues (1995) and Williams and colleagues (2008) noted that their samples of children with Asperger’s Disorder and high functioning autism respectively shared common cognitive features with children diagnosed with Nonverbal Learning Disability. Thus, the NVIQ > VIQ profile may lack the specificity required to be a meaningful endophenotype for ASD. Also, while the NVIQ > VIQ profile was associated with increased social and communication impairment relative to the other two cognitive groups, the clinical significance of this association is unclear. It appears that this profile may be less likely to represent a unique ASD subtype, but rather a common developmental pathway for children with ASD and other developmental disabilities (e.g., Specific Language Impairment) who have early language impairments that, in many though certainly not all cases, improve over time resulting in increased verbal ability. Further, given the gender ratio observed in ASD, the higher proportion of young males with
discrepantly high nonverbal skills may simply reflect concentrated sex differences in cognitive ability with males displaying mildly stronger nonverbal skills compared to females.

These findings must be considered in light of the limitations of this study. First, cognitive inclusion criteria of the Simons Simplex Collection (e.g., NVIQ > 35 and no VIQ requirement) ensured careful diagnostic characterization of the sample, but presented a potential bias in favor of greater nonverbal IQ relative to verbal IQ. Despite this, only 14 of the 1954 participants with DAS-II derived deviation scores in both verbal and nonverbal domains had verbal IQ scores below 35. Follow up analysis removing these 14 participants did not impact any of our results. Also, it is important to note that our exclusion of children who were administered the Mullen removed a fair number of lower functioning and younger children from our analysis. However, these were children for whom the DAS-II was not a developmentally suitable measure. So, although we lost some lower functioning children in our analysis, the validity of our sample’s cognitive scores was strengthened by this exclusion. Additionally, the SSC sample consists solely of simplex families, and while the NVIQ > VIQ cognitive profile has been observed in multiplex families (Chapman et al., 2010), it is unknown if our specific findings would be replicated in a sample of multiplex families. Finally, our study was limited by its cross-sectional design and, therefore, our conclusions regarding developmental effects over time must be interpreted with caution. More longitudinal studies are needed to elucidate the significance of cognitive discrepancy profiles in children with ASD, as well as other disabilities, and to determine if, in fact, the NVIQ > VIQ profile is unstable over time as our results suggest.

In this study we investigated verbal and nonverbal IQ discrepancy in ASD. Our findings indicate that more children with ASD exhibit the NVIQ > VIQ discrepancy profile than would be expected. However, the observed shift in discrepancy rates as age increases suggests this profile
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may simply represent a common developmental pathway for children with ASD. Future work needs to clarify this pattern through longitudinal analysis of cognitive profiles in large, well-characterized samples of ASD.
References


Figure Captions

Figure 1. Count of children with cognitive split (NVIQ > VIQ or VIQ > NVIQ) as a function of gender. Error bars represent the 95% confidence interval.

Figure 2. Count of children with cognitive split as a function of age group. Error bars represent the 95% confidence interval.

Figure 3. a. Mean autism severity score as measured by the ADOS Calibrated Severity Score as a function of cognitive profile group. Error bars represent the 95% confidence interval. b. Mean ADI-R domain scores as a function of cognitive profile group. Error bars represent the 95% confidence interval.
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<th>Author, Year</th>
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</table>
| Ohta, M. 1987 | 16 AUT; 8 TD; 8 HKS; (all 9-15 yr., PIQ > 70) | DSM-III and Rutter (1978) | WISC | -AUT group exhibited mean PIQ > VIQ (strength in block design, object assembly; weakness in comprehension)  
-AUT group showed greater mean difference due to overall lower VIQ  
-small sample |
| Lincoln, et al. 1988 | Study I: 33 AUT (8-29 yr.)  
Study II: 13 AUT; 12 DYSPH; 10 ODD; 12 DYSTH; (8-12 yr., IQ range UNK) | Study I & II: DSM-III  
Study I: WISC-R, WAIS-R  
Study II: WISC-R | -AUT group exhibited mean PIQ > VIQ  
Study II  
-AUT, DYSPH, and ODD groups exhibited mean PIQ > VIQ with AUT group showing greatest discrepancy  
-AUT children show uneven cognitive profile with strength in nonverbal skills  
-Small samples  
-AUT group’s mean FSIQ significantly lower than other groups |
| Szatmari, et al., 1990 | 26 ASG (8-18 yr.); 17 HFA (7-32 yr., FSIQ > 70); 36 OPC (7-18 yr.) | Wing’s criteria for ASG; chart review using DSM-III for AUT; dx. confirmed by testing | WISC-R, WAIS-R | -No difference in mean VIQ and PIQ scores for HFA or ASG groups; their performance was similar on all subtests  
-When HFA/ASG groups split into high IQ and low IQ groups, low IQ group shows more of a strength in nonverbal tasks whereas high IQ group is more variable  
-Dx. criteria for ASG not established  
-Small sample |
| Allen, et al. 1991 | 20 AUT (6-12 yr., NVIQ > 70); 20 DRLD (7-12 yr., NVIQ > 85) | DSM-III-R | WISC-R | -Both AUT and DRLD groups exhibited mean PIQ > VIQ but AUT group showed greater mean difference due to overall lower VIQ  
-Small sample |
| Shah & Frith, 1993 | 20 AUT (16-25 yr., High IQ group NVIQ 85-108, Low IQ group NVIQ 57-84); 33 TD (old normal group > 15 yr., young normal group, elementary age); 12 LD (16-25 yr., borderline NVIQ) | DSM-III or DSM-III-R | WISC-R, WAIS | -High IQ AUT group and Low IQ AUT group exhibited mean PIQ > VIQ (block design and object assembly strength); LD children showed no mean difference  
-Lends support to hypothesis of weak central coherence in AUT.  
-Small sample |
| Klin, et al., 1995 | 21 ASG (child to young adult); 19 HFA (child to young adult, FSIQ > 70); groups did not differ on age, | Record review using ICD-10 criteria for ASG and HFA. | Unknown | -ASG group showed mean VIQ > PIQ profile; HFA group showed no mean discrepancy  
-ASG profile differed from HFA profile and appears to align more closely with NLD |
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<td>Siegel, et al., 1996</td>
<td>45 AUT children (6-16 yr., FSIQ, VIQ &gt; 70); 36 AUT adults (16-51 yr., FSIQ, VIQ &gt; 70)</td>
<td>DSM-III criteria and ADI (ASG individuals excluded); WISC-R, WAIS-R</td>
<td>-No significant difference between mean PIQ and VIQ; splits found in both directions in individual cases seems to mirror population base rates; -Individuals with AUT do not conform to a specific Wechsler IQ subtype as cognitive profiles are variable; -Lower FSIQ individuals with AUT excluded</td>
</tr>
<tr>
<td>Ehlers, et al., 1997</td>
<td>40 ASG; 40 AUT; 40 DAMP (all 6-15 yr., FSIQ &gt; 70)</td>
<td>DSM-III-R criteria for AUT and Gillberg &amp; Gillberg (1989) criteria for ASG; WISC</td>
<td>ASG group exhibited mean VIQ &gt; PIQ; no mean difference in AUT group (but block design strength noted); AUT group had significantly lower FSIQ; -No association between ASD and a specific cognitive profile on WISC</td>
</tr>
<tr>
<td>Manjiviona &amp; Prior, 1999</td>
<td>35 ASG (6-17 yr., FSIQ normal); 21 AUT (7-15 y.o., FSIQ normal)</td>
<td>ICD-10 criteria for ASG, DSM-III-R criteria for AUT; WISC-R, WAIS-R</td>
<td>-ASG group had signif. higher FSIQ than AUT group; -No signif. mean (group) differences between PIQ or VIQ in either group; however, there were individuals in both groups who showed a signif. cog. split in <em>both</em> directions; appears to align with population norms; -Small sample; -Normal range IQ not fully representative of ASD</td>
</tr>
<tr>
<td>Ozonoff, et al., 2000</td>
<td>23 HFA; 12 ASG; 27 TD; matched on age, gender, FSIQ (all 6-20 yr., FSIQ &gt; 85)</td>
<td>ADOS, ADI and DSM-IV criteria; WISC-III, WAIS-III</td>
<td>-Both groups showed higher mean VIQ compared to PIQ with ASG group showing a greater split; -ASG and AUT groups showed similar sx. with main difference being level of severity; -Small sample</td>
</tr>
<tr>
<td>Joseph et al., 2002</td>
<td>120 AUT (3:8-13:11 yr., GCA &gt; 55; 74 in the younger group (Preschool DAS) and 47 in the older group (School-Age DAS)</td>
<td>Met ADI-R criteria and diagnosis confirmed by experienced clinicians; DAS</td>
<td>-Both groups exhibited greater rate of discrepancy compared to DAS normative sample; -NVIQ &gt; VIQ more common in younger group; both discrepancy profiles occurred equally in older group; -NVIQ &gt; VIQ children in the older group showed more impairment in social fx. on ADOS; -Did not need to meet on ADOS to qualify; -Cross-sectional design</td>
</tr>
<tr>
<td>Mayes &amp; Calhoun, 2003</td>
<td>164 AUT (3-15 yr.; High IQ group FSIQ 81-143, Low IQ group FSIQ 14-80)</td>
<td>DSM-IV criteria</td>
<td>-VIQ lagged behind NVIQ in preschool years but gap closed by school age in both low and high IQ groups; -IQ discrepancy scores decreased with age in both low and high IQ groups; -Cross-sectional design</td>
</tr>
<tr>
<td>Study</td>
<td>Participants</td>
<td>Measures</td>
<td>Results</td>
</tr>
<tr>
<td>-------</td>
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<td>---------</td>
</tr>
<tr>
<td>Ghazziudin &amp; Mountain-Kimchi, 2004</td>
<td>22 ASG (child to young adult FSIQ &gt; 70); 12 HFA (child to young adult FSIQ &gt; 70); matched on age, sex, FSIQ</td>
<td>DSM-IV criteria and ADI-R for HFA; DSM-IV criteria for ASG, excluded if met on ADI-R</td>
<td>WISC, WAIS-R - ASG group had signif. higher VIQ compared to AUT group - While ASG group showed higher mean VIQ to PIQ, this profile was not consistent at individual level; individuals in both groups showed a cog. split in both directions - Small sample</td>
</tr>
<tr>
<td>Howlin, et al., 2004</td>
<td>68 children with AUT (PIQ &gt; 50) who were seen again as adults</td>
<td>DSM-IV-TR</td>
<td>Study I: PIQ measured by WISC-R, WPPSI, Merrill Palmer, and others; VIQ measured by WISC, WPPSI, PPVT, and others - No signif. differences between mean PIQ and VIQ - PIQ scores remained relatively stable from childhood to adulthood. - VIQ scores less stable over time, especially in those who scored &lt; 70 at childhood. Overall, there was a signif. increase in mean VIQ over time (about 8 points). - wide variety of IQ measures used</td>
</tr>
<tr>
<td>Minshew et al., 2005</td>
<td>113 HFA adults, 102 HFA children (FSIQ &gt; 70); 143 control adults, 122 control children; ages 8-55 yr.</td>
<td>ADI-R and ADOS</td>
<td>WISC-III, WAIS-III, WAIS-R - WISC short form has good predictive accuracy in HFA individuals who have uneven cog. profiles in either direction</td>
</tr>
</tbody>
</table>
| Williams, et al., 2008 | 69 HFA children (6-16 yr., FSIQ and VIQ > 70); 77 HFA adults (17-53 yr., FSIQ and VIQ > 70); 72 child and 107 adult controls matched on age, VIQ, FSIQ | ADI, ADOS, and DSM-IV | WISC-R, WISC-III, WAIS-R, WAIS-III - 18% of HFA sample showed NLD profile of VIQ > PIQ. Thus, this profile not a good discriminator between NLD and HFA - "A single, prototypic IQ profile that characterizes all individuals with autism does not exist."
| Munson, et al., 2008 | 456 preschool children with ASD (24-66 months old; IQ AE ranged from extremely low to average range) | ADOS-G, ADI-R (within 2 points) | Mullen (ratio scores) - Children in the group with the largest NVIQ > VIQ discrepancy were, on average, a year younger than children in the other groups (3 vs. 4 yr.) - Cross-sectional design |
| Black, et al., 2009 | 18 ASD, VIQ > NVIQ; 24 ASD, NVIQ > VIQ; 36 ASD, NVIQ = VIQ; (all 6-17 y.o., NVIQ > 70) | ADI-R and/or ADOS plus expert clinical opinion | WISC-III, WISC-IV, WASI - Discrepancy high NVIQ and VIQ associated with ASD social sx. but not communication sx. or repetitive bx. sx. - High VIQ and NVIQ associated with adaptive communication - Small sample |

**Abbreviations:** AE: age equivalence; AUT: Autistic Disorder; ASG: Asperger’s Disorder; DAMP: Deficits in attention, motor control, and perception; DRLD: Developmental Receptive Language Disorder; DYSPH: Receptive developmental dysphasia; DYSTH: Dysthymic Disorder; HFA: High Functioning Autism; HKS: Hyperkinetic syndrome of childhood; ODD: Oppositional Defiant Disorder; OPC: Outpatient Control; LD: Learning Disabled; TD: typically developing children; UNK: unknown

*Scaled or standard IQ scores used unless otherwise noted*
Table 2: IQ Discrepancy Cutoffs*

<table>
<thead>
<tr>
<th>DAS-II Test Battery</th>
<th>NVIQ &gt; VIQ</th>
<th>VIQ &gt; NVIQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Years: Lower Level</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Early Years: Upper Level</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>School Age</td>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>

*Cutoffs based on DAS-II normative sample (Elliott, 2007)

Table 3: Cognitive Profile Group Descriptive Data

<table>
<thead>
<tr>
<th></th>
<th>Total Sample (N=1954)</th>
<th>NVIQ &gt; VIQ (N=535)</th>
<th>VIQ &gt; NVIQ (N=269)</th>
<th>NVIQ = VIQ (N=1150)</th>
<th>F, p values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>Range</td>
<td>M (SD)</td>
<td>Range</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Age in months</td>
<td>106 (42)</td>
<td>48-216</td>
<td>104.25 (39.52)</td>
<td>48-214</td>
<td>119.96 (44.41)</td>
</tr>
<tr>
<td>FSIQ</td>
<td>90.99 (19.95)</td>
<td>35-167</td>
<td>89.59 (20.43)</td>
<td>40-150</td>
<td>92.85 (20.03)</td>
</tr>
<tr>
<td>NVIQ</td>
<td>93.06 (18.98)</td>
<td>33-161</td>
<td>99.14 (19.21)</td>
<td>45-159</td>
<td>85.20 (18.02)</td>
</tr>
<tr>
<td>VIQ</td>
<td>89.44 (21.74)</td>
<td>30-167</td>
<td>75.49 (19.64)</td>
<td>30-130</td>
<td>107.80 (19.80)</td>
</tr>
<tr>
<td></td>
<td>Total Sample (N=1848)</td>
<td>NVIQ &gt; VIQ (N=506)</td>
<td>VIQ &gt; NVIQ (N=247)</td>
<td>NVIQ = VIQ (N=1095)</td>
<td>F, p values</td>
</tr>
<tr>
<td>------------------</td>
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<td>-------------</td>
</tr>
<tr>
<td></td>
<td>M (SD) Range</td>
<td>M (SD) Range</td>
<td>M (SD) Range</td>
<td>M (SD) Range</td>
<td></td>
</tr>
<tr>
<td>ADOS CSS</td>
<td>7.37 (1.71) 4-10</td>
<td>7.69 (1.69) a 4-10</td>
<td>7.12 (1.59) 4-10</td>
<td>7.28 (1.73) 4-10</td>
<td>12.62, &lt;0.001</td>
</tr>
<tr>
<td>ADI-R Social</td>
<td>19.15 (5.52) 8-30</td>
<td>20.00 (5.57) a 8-30</td>
<td>18.85 (5.18) 8-30</td>
<td>18.83 (5.53) 8-30</td>
<td>8.75, &lt;0.001</td>
</tr>
<tr>
<td>ADI-R Communication</td>
<td>16.14 (4.27) 6-26</td>
<td>16.87 (4.14) a 6-26</td>
<td>15.59 (4.41) 6-26</td>
<td>15.93 (4.26) 6-26</td>
<td>11.23, &lt;0.001</td>
</tr>
<tr>
<td>ADI-R Restricted and Repetitive</td>
<td>6.56 (2.58) 0-12</td>
<td>6.62 (2.53) 0-12</td>
<td>6.34 (2.79) 0-12</td>
<td>6.57 (2.55) 0-12</td>
<td>0.75, n.s.</td>
</tr>
</tbody>
</table>

a NVIQ>VIQ group significantly different from VIQ>NVIQ & NVIQ=VIQ.
b VIQ>NVIQ group significantly different from NVIQ>VIQ & NVIQ=VIQ.
c NVIQ>VIQ group significantly different from VIQ>NVIQ & NVIQ=VIQ.
d Each group significantly different from the other two groups.

Table 4: Chi Square Results

<table>
<thead>
<tr>
<th></th>
<th>NVIQ &gt; VIQ</th>
<th>VIQ &gt; NVIQ</th>
<th>NVIQ = VIQ</th>
<th>Total</th>
<th>X², p values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASD</td>
<td>Expected</td>
<td>ASD</td>
<td>Expected</td>
<td>ASD</td>
</tr>
<tr>
<td>Total Sample* N (%)</td>
<td>535 (27.38%)</td>
<td>293 (15%)</td>
<td>269 (13.77%)</td>
<td>293 (15%)</td>
<td>1150 (58.85%)</td>
</tr>
<tr>
<td>Males** N (%)</td>
<td>490 (28.7%)</td>
<td>468 (27.4%)</td>
<td>229 (13.4%)</td>
<td>235 (13.7%)</td>
<td>991 (58.0%)</td>
</tr>
<tr>
<td>Females** N (%)</td>
<td>45 (18.4%)</td>
<td>67 (27.4 %)</td>
<td>40 (16.4%)</td>
<td>34 (13.9%)</td>
<td>159 (65.2%)</td>
</tr>
</tbody>
</table>

*Expected values based on DAS-II normative sample.
**Expected values based on chi-square with study sample.
Table 5: Mean IQ by Gender

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>F, p values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonverbal IQ</td>
<td>93.75 (18.67)</td>
<td>88.19 (20.43)</td>
<td>18.46, <em>p</em> &lt; .001</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>89.61 (21.50)</td>
<td>88.22 (23.32)</td>
<td>0.87, <em>p</em> = n.s.</td>
</tr>
</tbody>
</table>