

Divergent Development in Dyspraxic Children

Part II

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Abstract

This paper reports additional results from a large online survey sent to the parents of children with Dyspraxia. Results analyzed in this paper are divided into six domains: Detailed Medical History, Sensory Processing, Social Life, Autistic Behaviors, and School Life. These domains of analysis allow us to explore the psychosocial aspects of Dyspraxia, such as how affected children interact with peers, what accommodations they receive in school, and what non-motor challenges they often face. For example, in Social Life we discover that many children with Dyspraxia have been bullied. The Sensory Processing section reveals that the majority of participants have some form of sensory sensitivity or sensory processing disorder. This finding leads into our subsequent exploration of autistic behaviors in children with Dyspraxia, for Autism Spectrum Disorder (ASD) has been found to have high rates of comorbidity with Dyspraxia and Developmental Coordination Disorder (DCD). By dividing our participants into three age groups, we were able to see how symptoms change over time. We found that motor challenges remain a daily issue even into teenage years. Implications and limitations of our results are discussed.

Keywords: Dyspraxia, Developmental Coordination Disorder, DCD, neurodevelopment

Introduction

In Part 1 of this report, we investigated Developmental Coordination Disorder (DCD) with regard to five domains: Basic Medical History, Clinical Measures, Progression of Motor Symptoms, Early Signs, and Possible Risk Factors. Using clinical measures embedded with the Questionnaire, we found that 72% of our participants with DCD also classified as having Inattentive, Hyperactive, or Combined Subtype of Attention Deficit/Hyperactivity Disorder (ADHD). This corroborated previous reports in the literature of a high overlap between DCD and ADHD (e.g., Brossard-Racine, Shevell, Snider, Bélanger, & Majnemer, 2012; Waternberg, Waiserberg, Zuk, & Lerman-Sagie, 2007; Barkley, 2014).

In this report, we look more closely at the overlap between DCD and other neurodevelopmental challenges, particularly sensory processing disorder (SPD) and Autism Spectrum Disorder (ASD). SPD shares many of the same risk factors as other neurodevelopmental disorders, including genetic predisposition and pre-, peri-, and post-natal factors such as maternal stress, allergies, and jaundice (May-Benson, Koomar, & Teasdale, 2009). It is characterized by hypersensitivity (i.e., over-responsivity) or hyposensitivity (i.e., under-responsivity) and is commonly seen in children with ADHD (Ghanizadeh, 2011), ASD (Tomchek & Dunn, 2007), and DCD (Wilson & McKenzie, 1998).

Such commonalities between DCD and other neurodevelopmental disorders are found in the use of medications. Interestingly, children with comorbid DCD and ADHD show improvements in fine motor skills when taking a methylphenidate, which is traditionally used to treat ADHD (Flapper, Houwen, & Schoemaker, 2006). Motor challenges that co-occur with ADHD are at least partially ameliorated by the treatment of ADHD (see also Flapper & Schoemaker, 2008; Bart, Podoly, Bar-Haim, 2010). Another example is the use of fatty acid supplementation; fatty acids are being explored as a possible treatment for DCD (Richardson & Montgomery, 2005), ADHD (Richardson & Puri, 2002), and ASD (Amminger, Berger, Schafer, Klier, Friedrich, & Feucht, 2007). A meta-analysis of DCD interventions concludes that there exists no medication for DCD other than methylphenidates, the efficacy of which as a treatment for DCD has not been sufficiently verified. Given these findings, we examine the most common prescription and over-the-counter medications taken by our participants in order to understand how DCD is managed in the real-world medical context.

Our previous report explored the progression of motor symptoms within the domains of fine motor, motor control, and general coordination. Specifically, we explored topics like handwriting, swimming, and balance. We did not, however, analyze motor symptoms in the domains of vision and speech. A large body of research shows that children with DCD frequently present with speech disorders (Dewey, Cantell, Crawford, 2007; Hill, 2001) and oculomotor issues (Robert, Ingster-Moati, Albuisson, Cabrol, Golse, & Vaivre-Douret, 2014; Sumner, Hutton, Kuhn, & Hill, 2016). Thus, the current report also investigates how challenges in motor coordination may affect less-obvious motor functions (e.g., eye movements and speech). If these challenges are commonly observed and emerge early enough, they could offer us another potential early sign to be explored.

This report provides additional analyses of our Dyspraxia Questionnaire survey data in the hopes of gaining a more holistic understanding of DCD. We provide an account of Detailed Medical History, Social Life, Sensory Processing, Autistic Behaviors, and School Life. In each domain of analysis, we expect to find patterns in the data that reflect how DCD impacts the life of the child in domains ranging from emotional wellness to social relationships. In this report we hope to offer some insight into which aspects of DCD show commonalities with other neurodevelopmental disorders such as ADHD and ASD. Lastly, we investigate how DCD is accommodated in the school setting, because ultimately, we want to learn more about DCD so that we can contribute to the development of earlier diagnosis and better, more accessible interventions.

The Detailed Medical History section will focus on psychological and emotional wellbeing in children with DCD. Previous reports found that having DCD presents psychosocial challenges that affect the emotional health of the child (Poulsen & Ziviani, 2004; Cairney, Rigoli, & Piek, 2013). We also observed that roughly one third of our participants classified as having anxiety based on measures from the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS), (see Part 1 of the report). Exploring the emotional health of our participants will help inform the prevalence and type of psychosocial challenges a Dyspraxic child faces. Based on previous reports cited above, we expect to find that self-esteem, sleep quality, and mood are disrupted in our participants.

The following section on Social Life will explore how children with DCD interact with their peers. Most existing studies on the social traits of children with DCD focus on social participation – studies will ask research questions such as, “Do Dyspraxic children, partake in social activities as much as their peers, and do they enjoy taking part? (e.g., Sylvestre, Nadeau, Charron, Larose, & Lepage, 2013; Bart, Jarus, Erez, & Rosenberg, 2003). Researchers have found that the motor challenges associated with DCD often make it difficult for children to participate in group activities, which in turn makes it hard for Dyspraxic children to be accepted by their peers (Mandich, Polatajko, & Rodger, 2003). We will explore extraversion, empathy, friend-making, and bullying. Clumsiness is associated with peer victimization (Bejerot & Humble, 2013), and bullying is also a common experience in children with many other neurodevelopmental disorders (Jawaid, Riby, White, Tarar, & Schulz, 2011). It is possible that our participants are not very extraverted and interact with their peers differently than do other children their same age. Given the symptoms of DCD, there may also be a high prevalence of bullying.

The Sensory Processing section looks into the prevalence and kind of sensory processing issues faced by our participants. As previously mentioned, neurodevelopmental disorders such as ADHD, ASD, and DCD, have frequently been associated with sensory processing challenges (Ghanizadeh, 2011; Tomchek et al., 2007; Wilson et al., 1998). In addition to general sensory sensitivity, we also examine specific sensory domains in order to check which domains are most commonly affected. A high prevalence of sensory processing difficulties may provide evidence that DCD is, in part, a deficit in processing sensory input, rather than purely a motor output deficit. We will explore how sensory processing challenges manifest and how they impact a child’s life. We expect to find a high prevalence of deficits in all sensory domains, but a particularly high prevalence of visual-spatial processing challenges. We expect this based on the reported DCD symptoms of clumsiness and writing difficulties.

Sensory processing challenges, social deficits, and coordination difficulties are closely associated with Autism Spectrum Disorder. Motor deficits are frequently observed in ASD individuals (Kopp, Beckung, & Gillberg, 2010). However, it is unclear whether ASD-related motor challenges and ASD-independent motor challenges have a similar etiology. Another goal of this report is to explore the relationship between DCD and ASD. In the Autistic Behaviors section, we analyze the results from four questions from our survey that best probe the criteria

for ASD outlined in the *Diagnostic and Statistical Manual for Mental Disorders, Fifth Edition (DSM-5)* (American Psychiatric Association, 2013). This section does not represent a validated clinical measure, but rather our best estimate as to the presence or absence of the autistic traits outlined by the *DSM-5*. The patterns of behavior we do or do not find in this section will help illustrate the overlap – or lack thereof – between DCD and ASD. We expect to find a high prevalence of ASD-like behaviors.

The last goal of this paper is to look at the Dyspraxic child's experiences in school. Motor challenges, sensory processing deficits, and other DCD-related difficulties explored in this report can interfere with a child's ability to perform in school (Caçola, 2014). Handwriting difficulties, for instance, actually affects the quality of a child's writing composition (Prunty, Barnett, Wilmut, & Plumb, 2016). The final section of this report will first address the academic strengths and challenges of children with DCD. Because DCD is associated with fine motor challenges and spatial reasoning difficulties, we expect to find that our participants struggle with writing and math.

Lastly, we will look at the accommodations children receive through programs like Individualized Education Plans (IEPs) or 504 plans, which aim to help a child whose needs are not being met in a traditional classroom setting (Stanberry, 2017). An IEP outlines steps that will be taken by the school, student, and healthcare providers to ensure that the student is able to participate in the classroom. Children may receive different or modified homework assignments, additional time on tests, or one-on-one tutoring to help with academic struggles (Stanberry, 2017). Task-oriented interventions such as physical therapy (PT) and occupational therapy (OT) prove the most effective treatments for DCD (Smits-Engelsman et al., 2013). We want to see how many children receive this kind of service through their school. Learning about the status quo of school accommodations for DCD is particularly important in the United States right now because the Department of Education, under its recent change in leadership, may change how the Individuals with Disabilities Education Act (IDEA) is enforced. We need to be aware of what can be done and what is being done in schools to help children with DCD, so that we can ensure these accommodations remain available in the future.

Methods

Creating the questionnaire

The “Princeton University | Dyspraxia Questionnaire” was created on Qualtrics, an online survey platform, over the course of several months. The formation of the survey involved consulting with health care professionals, including a physical therapist and a neuropsychologist, to gain insight into how Dyspraxia presents in a clinical context. We wanted to create a questionnaire that was informative, detailed, ethnographic, and clinically and scientifically relevant. For this reason we included the two clinical measures for neurodevelopmental disorders in our questionnaire: the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS) and the Developmental Coordination Disorder Questionnaire (DCDQ).

The DCDQ is a 15-item questionnaire with 5-point Likert scale questions (Wilson et al., 2009). The questions ask parents to compare their child’s motor skills with those of other children. For example, the first item of the DCDQ asks, “Compared to other children...your child throws a ball in a controlled and accurate fashion.” Total Scores range from 15 to 75, with a reported population average of 61.79 (SD=10.21) (Wilson & Crawford, 2012). For 5- and 7-year-olds, any score below 46 classifies as “Suspect for DCD”; for 8- and 9-year-olds, a score below 55 indicates DCD; and for 10- to 15-year-olds, any score below 57 qualifies as “Suspect for DCD”. Higher DCDQ scores indicate better motor function, which is why the cut off scores for indication of DCD are higher for older children. Almost all of our participants classified as “Suspect for DCD” according to the DCDQ (see Fig 2 under *Participant Demographics*). The DCDQ generates three subscores: Control During Movement, Fine Motor, and General Coordination, which have been validated through factor analysis (Wilson et al., 2012; Cairney, Missiuna, Veldhuizen, & Wilson, 2008; Tseng et al., 2010). These subscores do not include cutoffs to indicate DCD, but are informative as to the child’s specific deficits.

The VADPRS screens for the 18 *DSM-5* criteria for ADHD. The second clinical measure included in the questionnaire was the VADPRS, which screens for ADHD and anxiety. Like the DCDQ’07, the VADPRS utilizes a Likert scale to assess the severity of ADHD or anxiety symptoms. The 4-point scale ranges from “Never” to “Very Often”. The VADPRS screens for inattentive ADHD with statements like “Has difficulty sustaining attention to tasks or activities” and for hyperactive ADHD with statements like “Blurts out answers before questions have been

completed”(Wolraich et al., 2003). When scoring the VADPRS, There are nine questions each subsection, and one point is given for each answer of “Often” or “Very Often”. Accumulating six points in a single subsection indicates someone having that subtype of ADHD. To classify as having ADHD, Combined Subtype, a person must have six or more points in each subsection.

We launched the questionnaire twice – first on December 26, 2015, and then again on January 4, 2016. Participation was by invitation only. We recruited through online support groups, Facebook, and word of mouth. Interested subjects contacted a member of the lab, and after a brief initial screening were given a link to take the survey. The length of the questionnaire varied because there were conditional questions and participants were required to enter information about their child’s siblings, but the maximum length of the questionnaire was around 750 questions. Our pilot subjects reported that the questionnaire took around 2 to 3 hours to complete, but participants did not have to complete the survey in one sitting.

Data Preprocessing

In total, we received 249 responses. Data were downloaded directly from Qualtrics into Microsoft Excel as a CSV. In Excel, some of the question headings were corrected because they did not properly transfer. Next, data from both launches were aligned and concatenated. The questionnaire from the December 26 Launch did not have a question for child’s age, so age was calculated in Excel using the DATEIF function. Four respondents did not provide their child’s age or date of birth. In these circumstances, we estimated age based on the child’s grade in school. These participants included two presumed 9-year-old males, one presumed 7-year-old-female, and a presumed 4-year-old male.

After these minor preprocessing steps, the data was trimmed, and the 48 participants who did not fill out all questions of the DCDQ’07 were excluded. These questions were crucial for standardizing the classification of our subjects into “DCD” and “non-DCD” groups, and later for analyzing the relationship between severity of DCD symptoms and other factors. Thus, we were forced to exclude subjects who did not complete the DCDQ.

Participant Demographics

The questionnaire was directed at parents or guardians of children with DCD. After excluding incomplete responses, we found that 94% of respondents were mothers, 5% were

fathers, and 1% were grandmothers of a Dyspraxic child. Depending on the number of siblings the child had, these dedicated family members answered up to 754 questions about their children.

Demographic information about our participants reveals extensive geographic diversity (Figure 1). Most of our participants were from the United States, but over a quarter came from another country. Unsurprisingly, the majority of our international participants came from Westernized, English-speaking countries such as the United Kingdom, Australia, and Canada, but there was also a large number of individuals from other countries. A plurality of our American participants came from the Northeast, but all geographic regions were represented.

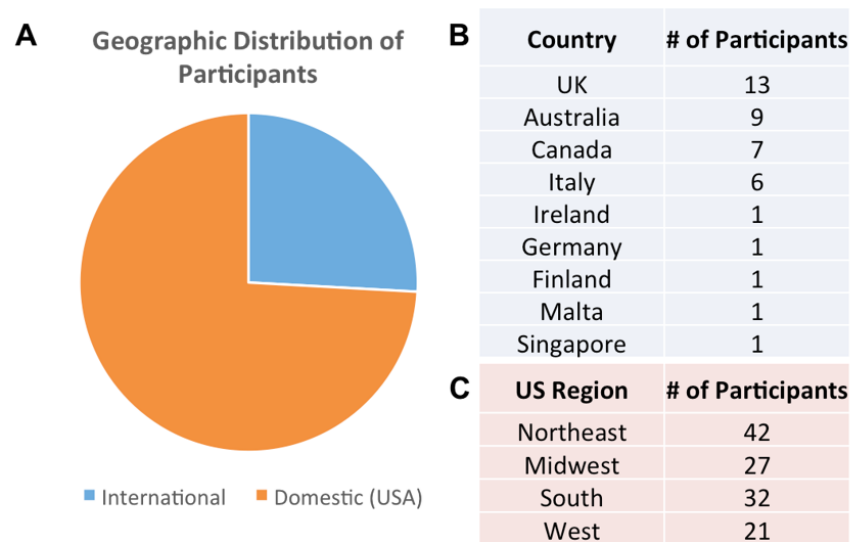


Figure 1. Geographic distribution of participants

(A) Most of our participants are from the United States, and about a quarter are from other countries. (B) Most international participants lived in Western, English-speaking countries such as UK, Australia, and Canada. However, there were still a notable amount of participants from other countries. (C) Geographic divisions based on the current census bureau classifications. Note that 32 of the 42 participants from the Northeast came from the “tristate area” (NJ, NY, and PA)

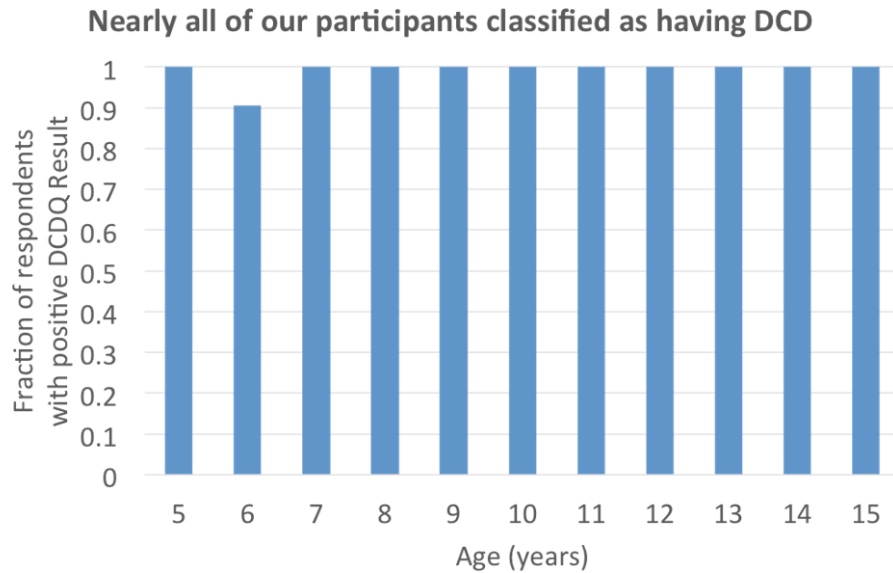


Figure 2. Nearly all of our participants classified as having DCD

We invited parents of children with DCD to participate in our study. Indeed, we found that almost all of our participants showed a clinical indication of DCD, supporting the validity of the DCDQ included in our questionnaire.

According to the results from the DCDQ (see Results, Clinical Measures from Part 1 of the report) almost all of our participants show a clinical “indication of Dyspraxia” (Wilson et al., 2012; Fig 2). This is unsurprising, since we targeted dyspraxia children; however, this result provides an important sanity check, also on the validity of the DCDQ to use for diagnosing DCD. The gender ratio of DCD diagnosis is reported to be ~ 1 girl : 3 boys (McCarthy, 2015). In our sample, we had a ratio of roughly 1 : 2.2 (Figure 3B). The age distribution of participants is shown in Figure 3A, and we see that while the male participants (blue bars) show a roughly normal age distribution, the distribution of female participants has a slightly more pronounced positive skew; we have the lowest proportion of girls in the 10to15 age group. 27% of our participants were either ambidextrous or left-handed (Figure 4), reflecting previous findings that left-handedness is more prevalent in the Dyspraxic population (Goez et al., 2007).

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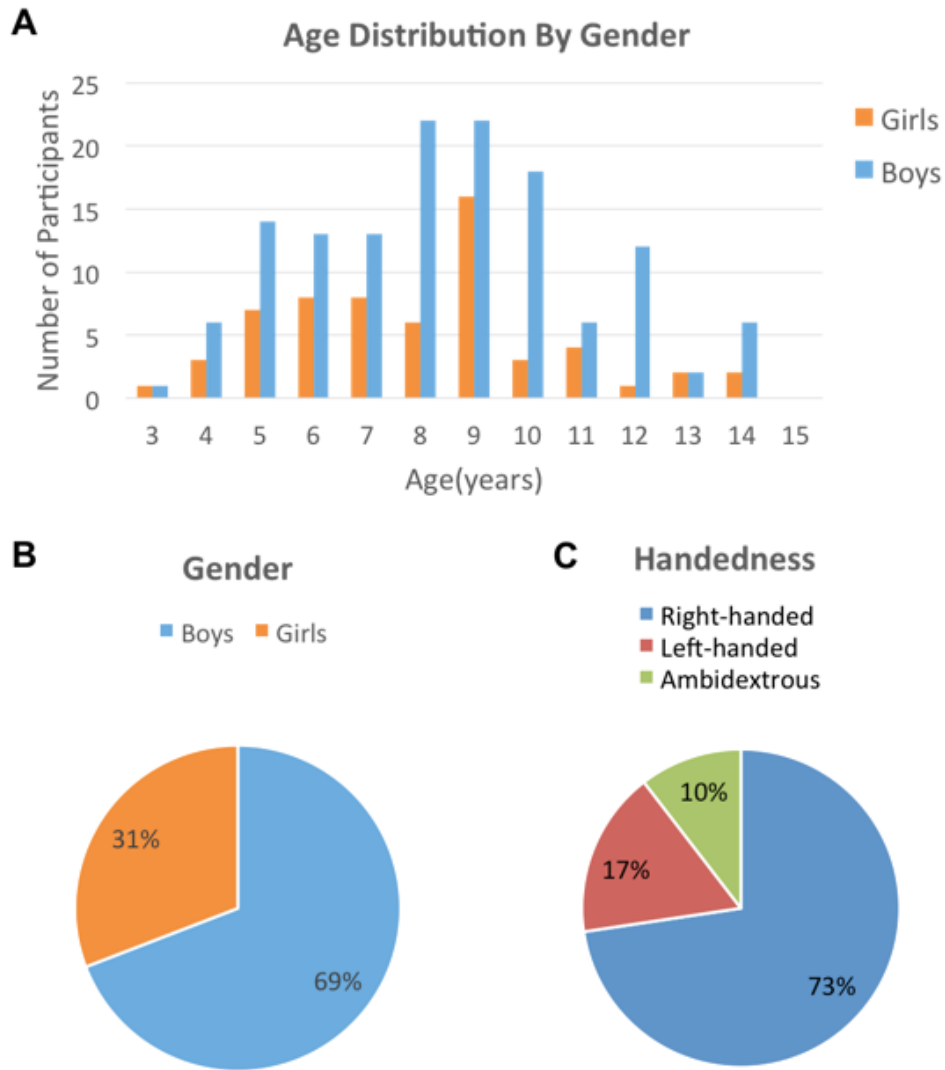


Figure 3. Demographics of cohort: age, gender, and handedness

(A) We have a roughly Gaussian age distribution, with more boys in each age group than girls, except for ages 3 and 13 years. For the subsequent analyses in the paper, we will collapse the subjects into the three age divisions used in the DCDQ: 5-7, 8-9, and 10-15. Each of these groups contains roughly 60 subjects.

(B) Around 30% of our participants were female, reflecting the commonly noted gender bias in Dyspraxia diagnosis.

(C) Estimates for the prevalence of left-handedness and ambidexterity vary, but a sizeable number of our participants reported being ambidextrous or left-handed.

Data Analysis

Analyses were performed in Microsoft Excel, MatLab, and JASP. 49 participants were excluded because they did not complete enough of the questionnaire, leaving us with a total of 200 participants. Analysis domains were formulated after data collection was complete. We did not decide to analyze autistic behaviors until the analysis stage, so we had to come up with a decent measure of autistic behaviors with the questions we had asked. The *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)* served as our template – we found questionnaire questions that adequately screened for four of the seven diagnostic criteria for Autism Spectrum Disorder (American Psychiatric Association, 2013). What results is not a clinically validated questionnaire or a diagnostic tool, but simply an approximation of autistic behaviors. Table 1 below shows the four *DSM-5* diagnostic criteria and the questions we used to screen for each symptom. The third and fourth questions in Table 1 were “yes” or “no” questions, but the first two questions were five-point Likert scale question; in data analysis, scores above 3 out of 5 were considered “yes” responses, and scores below 3 out of 5 were considered “no” responses”. Simplifying the responses in this way helped us analyze the prevalence of these behaviors.

Table 1: Autistic Behaviors Criteria and Questions for Analysis		
<i>DSM-5</i> Criteria	Autistic Behavioral Domain	Questionnaire questions
Deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversation; to reduced sharing of interests, emotions, or affect; to failure to initiate or respond to social interactions.	Social Communication	“Plays cooperatively with other children”
Deficits in developing, maintaining, and understanding relationships, ranging, for example, from difficulties adjusting behavior to suit various social contexts; to difficulties in sharing imaginative play or in making friends; to absence of interest in peers.	Social Interaction	Makes friends easily
Insistence on sameness, inflexible adherence to routines, or ritualized patterns or verbal nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat food every day).	Rigidity	Did your child ever show ritualistic behaviors?
Hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment (e.g., apparent indifference to pain/temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects, visual fascination with lights or movement).	Sensory Processing	Did your child ever get disturbed by things that do not seem to bother others (e.g. sounds, bright lights, being touched, certain texture of food)?

Results

Detailed Medical History

Medications

To gain a better understanding of comorbidities and experimental DCD treatments, we asked about supplements and prescription medications. Figure 4 summarizes the results. The bar graph in Figure 4A reveals that supplement usage is widespread; 76% of participants take a daily multi-vitamin, 63% take Omega-3, 20% take fiber, and 41% take probiotics. Some participants also noted taking other supplements such as melatonin, Vitamin D, magnesium, or Coenzyme-Q10. Figure 4B tells us that 75 participants (37%) are currently taking prescription medications. In Figure 4C, a bar graph we see which medications are most commonly taken. A study by Rick Mayes et al. (2007) reports that 4.5% of all children have been diagnosed with ADHD and are taking a stimulant. With 25 participants using stimulants, the prevalence of stimulant use in our participants was higher, at 12.5%. Stimulants were the class of drug most commonly used in our cohort, and included methylphenidates such as Ritalin, Focalin, and other brand names, as well as amphetamines such as Adderall. Methylphenidates were far more common than amphetamines.

17 participants (8.5%) were taking antidepressants such as Lexapro, Prozac, and Zoloft, which are collectively known as Selective Serotonin Reuptake Inhibitors (SSRIs). For comparison, in 2000, the reported prevalence of antidepressants in youth (ages 0 to 19) was 1.63% (Zito, Tobi, de Jon-van den Berg, Fegert, Safer, Jahnsen, Hansen... & Glaeske, 2006). 16 had been prescribed asthma medications, including daily and emergency inhalers. 12 participants were using dietary or digestive medications, such as prescription-level laxatives and dietary supplements. One participant in this category was taking Vayarin, a new dietary treatment for ADHD. 11 participants reported using $\alpha 2$ Agonists – sedatives used to treat hypertension, anxiety, and ADHD. Allergy medications, melatonin, and benzodiazepines were also reported. The “Other” category in the graph includes drugs such as seizure medications, anti-inflammatories, propranolol, antibiotics, and chemotherapy drugs.

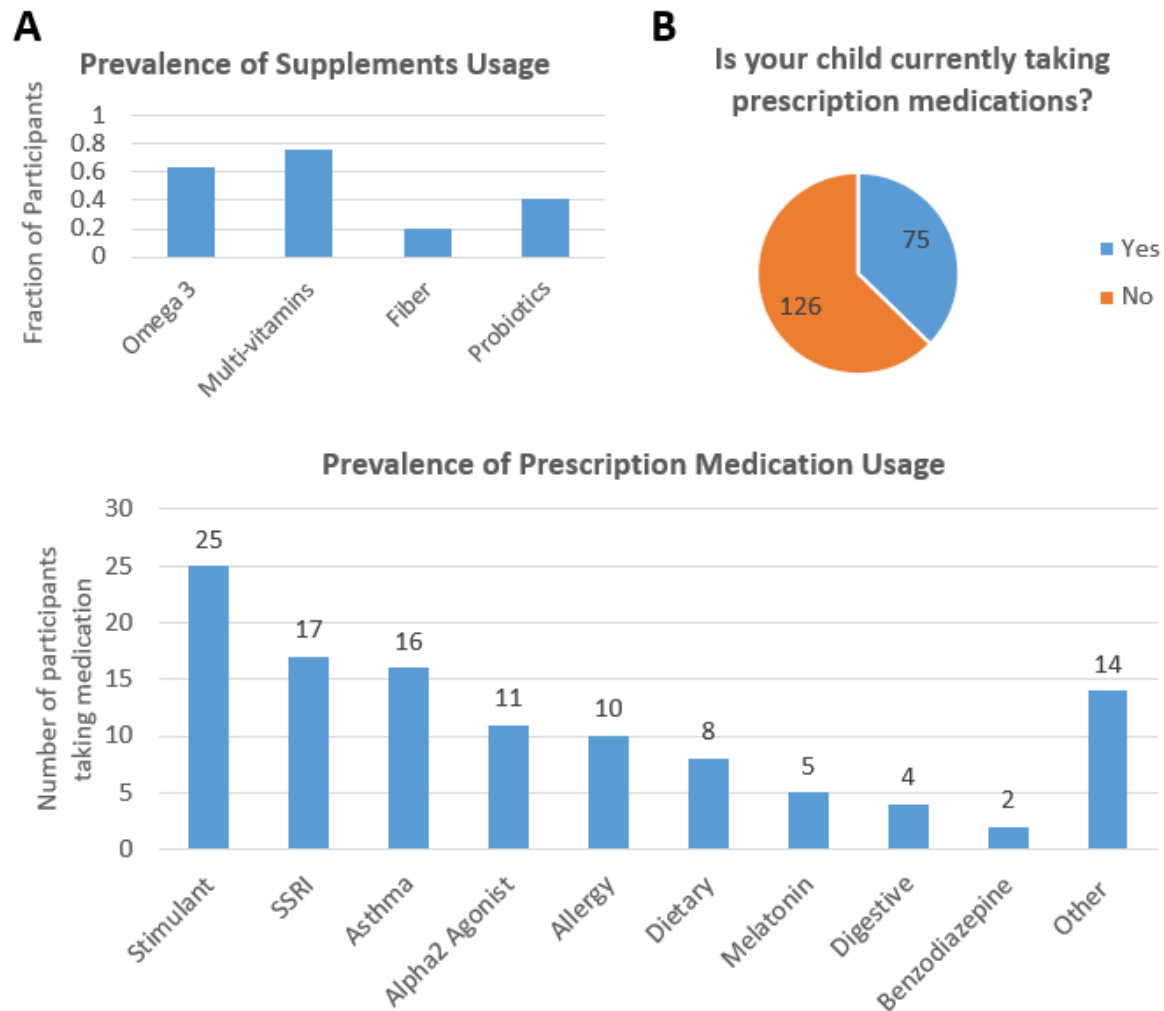


Figure 4. Medication Usage

- (A) The bar graph shows the fraction of participants using various supplements.
- (B) The pie chart shows that 75 children are currently taking prescription medications, and 126 are not.
- (C) The bar graph shows that stimulant medications are the most common prescription medication in use. SSRIs and asthma medications are the second-most common. The “Other” category includes medications such as prescription mitochondria B complex, anti-seizure medications, steroids to treat ear infections, and prescription anti-inflammatory drugs.

Oculomotor Issues

In the questionnaire, we also gathered history about optometry and oculomotor issues. 177 participants reported having been to an optometrist, and 23 reported they had not. Of the 177 who had seen an eye specialist, 165 reported the reason for their visit; these results are reported in Figure 5A. As seen in the bar graph, 78 visits were routine check-ups, and 74 visits were

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scheduled in order to screen for oculomotor issues. 13 participants visited the optometrist for alternative reasons, such as to screen for retinal issues associated with premature birth. As reported in Figure 5B, people who visited the optometrist for alternative reasons typically had their first visit at age 3.3 years. Those who visited for oculomotor issues saw the optometrist at an average age of 4, while routine check-ups occurred at an average age of 5.6 years. In Figure 5C, we see that 23% of participants had received vision therapy to treat oculomotor issues.

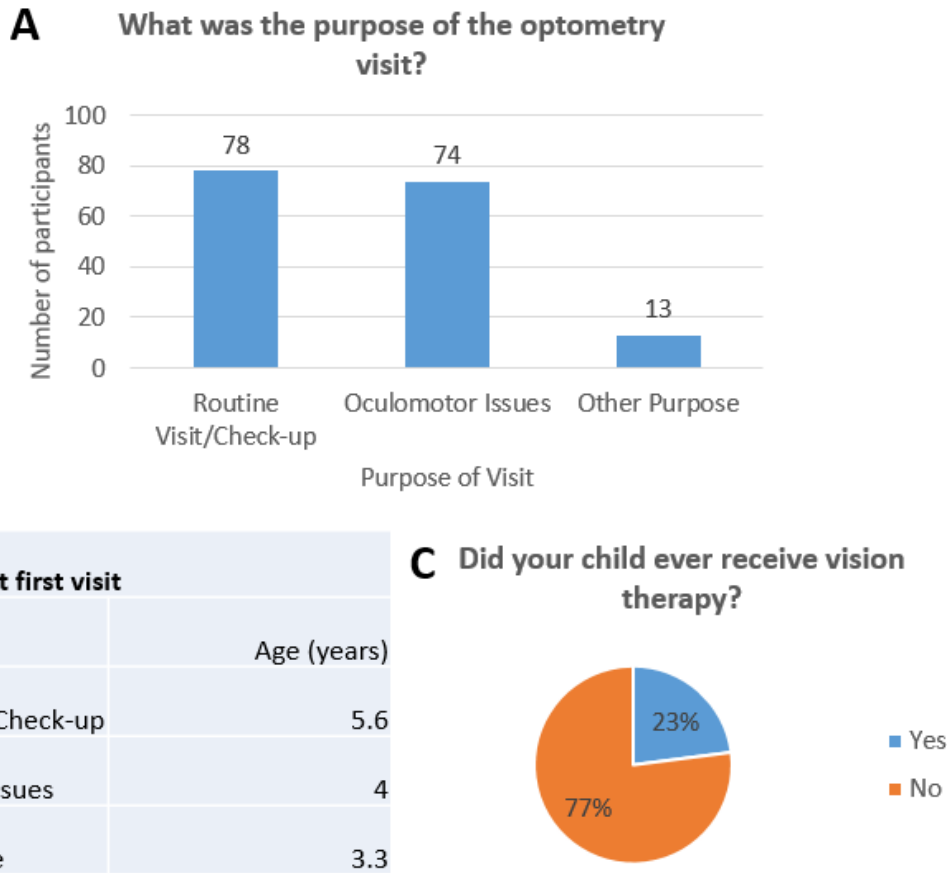


Figure 5. Optometric History

- (A) Bar graph detailing the purpose of optometry visits. (n=165)
- (B) The table shows the average age at first optometry visit.
- (C) Almost a quarter of respondents to this question had received vision therapy. (n=196).

Speech Issues

Information about speech difficulties represents another important aspect of our participants’ medical history. Figure 6 shows the proportion of participants whose speech can be understood by parents (Figure 6A) and strangers (Figure 6B). The x axis of the bar graphs

represents age groups, and the y axis represents the fraction of participants who can be understood (represented by the blue bars) or cannot be understood (represented by the orange bars). For children under the age of five, 36% can be understood by parents and 27% can be understood by strangers. Over time, participants' speech becomes easier to understand, so that by age 10 to 15, 78% can be understood by parents and 86% can be understood by strangers. Still, this means that 22% of 10- to 15-year-olds cannot be understood by their parents, and 14% cannot be understood by strangers. In Figure 6D, we show a pie chart, which reports that 22% of children across all age groups stutter or stammer.

To gather more information about speech difficulties, we asked about specific speech and language diagnoses. Including sub-clinical challenges, 75% of participants reported speech or language difficulties. In Figure 7A, we see that 57% of participants had been diagnosed with a speech or language disorder. To put this number into perspective, a recent study in a population of 10,435 Australian school children found that .33% of children stuttered, .12% classified as having a voice disorder, and 1.06% had a speech-sound disorder (McKinnon, McLeod, & Reilly, 2008). The table in Figure 7B reports the specific diagnoses our participants had received, along with how many children received each diagnosis. Childhood Apraxia of Speech was the most common diagnosis, with 43 children receiving this label. Expressive/Receptive Language Disorder and Global/Verbal Dyspraxia, with 11 and 10 diagnoses, respectively, were the second and third most common labels. 8 children received the diagnosis of articulation disorder. Less-common labels included Motor Speech Impairment, Phonological Processing Disorder, and Dysarthria. The "Other" category included speech and language difficulties such as auditory memory impairment, Speech Disorder, Not Otherwise Specified, Delayed Speech, and Specific Language Impairment.

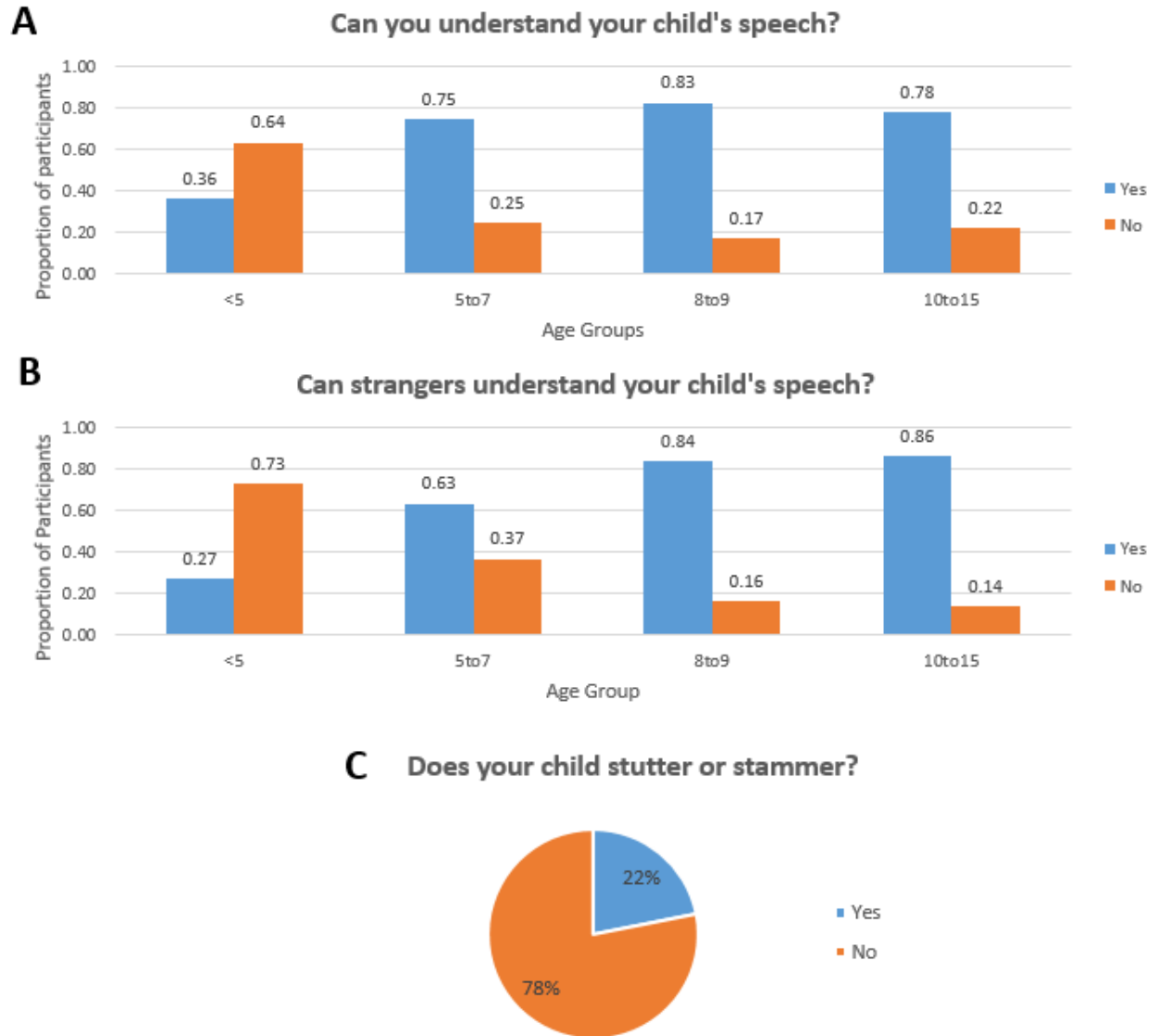


Figure 6. Speech challenges

(A,B) The bar graphs show the proportion of participants within each age group whose speech can be easily understood. (A) shows the proportion of participants who can be understood by the parent filling out the questionnaire. (B) shows the proportion who can be understood by family members, and (C) shows the proportion who can be understood by strangers.

(D) The pie chart shows that 27% of children stutter or stammer.

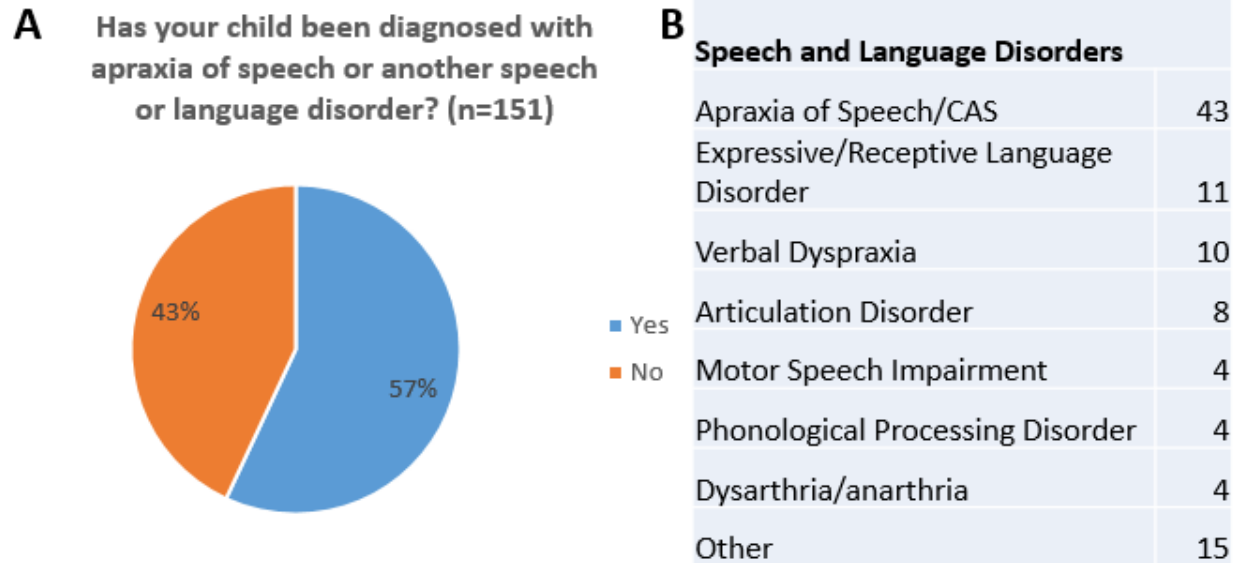


Figure 7. Speech and Language Disorders

- (A) The pie chart shows that 57% of participants have been diagnosed with a speech or language disorder.
- (B) The table shows that Apraxia of Speech is the most common diagnosis. Expressive/Receptive Language Disorder and verbal/global dyspraxia were the next-most common diagnostic labels.

Wellness

The final component of Detailed Medical History consists of wellness measures, which we analyze in order to get a clearer picture of the emotional and psychological health of our participants. Figure 8 is a correlation matrix showing the relationship between six measures of including: “Impact of DCD on Self-esteem”, “Never Loses Temper”, “Has high self-esteem”, “Impact of DCD on emotional health”, “Is a very happy child”, and “Age (years)”. The Pearson’s r statistics in the table represent the strength and direction of the correlation – a small negative r value, for instance, signifies a slight negative correlation between two measures. The p -values in the table represent the statistical significance of each numerical relationship. Smaller p -values signify a more statistically-significant relationship. To account for the 15 individual comparisons we perform in the correlation matrix, we must use a Bonferroni correction to adjust the alpha level – the p -value under which a relationship becomes significant. In our correlation matrix, any p -value under 0.003 is significant. In the table, significant relationships are bolded and starred.

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		Impact of DCD on Self-esteem	Never Loses Temper	Has high Self-Esteem	Impact of DCD on Emotional Health	Is a very happy child	Age (years)
Impact of DCD on Self-esteem	Pearson's r	—	0.012	0.445	0.443	0.284	-0.057
	p-value	—	0.873	< .001*	< .001*	< .001*	0.427
Never Loses Temper	Pearson's r		—	0.224	0.166	0.287	0.075
	p-value		—	0.002*	0.022	< .001*	0.293
Has high Self-Esteem	Pearson's r			—	0.183	0.457	-0.278
	p-value			—	0.012	< .001*	< .001*
Impact of DCD on Emotional Health	Pearson's r				—	0.221	-0.089
	p-value				—	0.002*	0.216
Is a very happy child	Pearson's r					—	-0.2
	p-value					—	0.005
Age (years)	Pearson's r						—
	p-value						—

Figure 8. Correlation Matrix of Wellness Measures

Significant correlations, which have a p value of $<.003$, are bolded with an asterisk. There is a positive and statistically significant relationship between “Impact of DCD on self-esteem” and “Has high self-esteem” ($p<.001$), “Impact of DCD on emotional health” ($p<.001$), and “Is a very happy child” ($p<.001$). “Never Loses Temper” has a significant positive correlation with “Has high self-esteem” ($p=.002$) and “Is a very happy child” ($p<.001$). “Is a very happy child” also has a positive, significant relationship with “Has high self-esteem” ($p<.001$) and “Impact of DCD on emotional health” ($p=.002$). The only significant negative correlation is between “Age (years)” and “Has high self-esteem” ($p<.001$). Additionally, there is negative relationship between “Age (years)” and “Is a very happy child” that is trending toward significance ($p= .005$).

In the correlation matrix we perform 15 individual comparisons. “Impact of DCD on self-esteem” had no significant correlation with “Never Loses Temper” or “Age (years)”, but an extremely significant correlation ($p <.001$) with “Has high self-esteem”, “impact of DCD on Emotional Health”, and “Is a very happy child”. Each of these relationships has a positive Pearson’s r value, meaning there is a positive relationship between all of these measures. A greater impact of DCD on self-esteem is correlated with having high self-esteem and being a very happy child.

Sleep represents another important measure of wellbeing. Figure 7 reports sleep quality and energy levels by showing the results of the 5-point Likert scale questions, “Sleeps well at

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night” and “Has lots of energy”. Children under 5 years of age average a 4 out of 5 for sleep quality; 5- to 7-year-olds average at 3.5 out of 5; 8- to 9-year-olds average 3.7 out of 5; and 10- to 15-year-olds average at 3.1 out of 5. Although sleep quality declines across age groups, the large error bars reveal that this difference is not statistically significant. Energy levels also decline slightly with age. Both of these measures have similar average values that decline slightly across age groups, so it is reasonable to expect that these two measures are related to one another. However, a paired Student’s t test yielded a p value of 0.0413, revealing that these measures are statistically independent. In other words, a child’s sleep quality energy level is not predictive of his or her energy level.

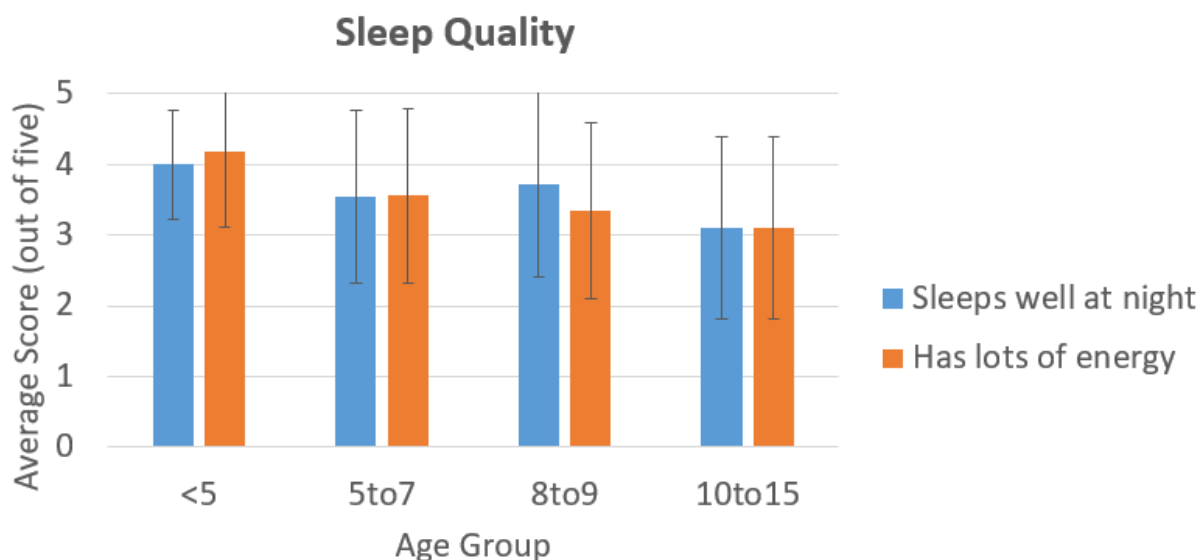


Figure 9. Sleep Quality

This bar graph shows the progression of sleep quality and energy over the four age groups. There is a slight decrease in sleep quality and energy level across the age groups. Children under 5 years of age average a 4/5 on “Sleeps well at night” while children 10 to 15 years old average a 3.1/5. There is also greater variance in the responses of the older children as shown by larger error bars in the older age groups.

Sensory Processing

Given reports of the overlap between DCD and sensory processing challenges (e.g., Piek et al., 2004), we wanted to ask about these difficulties in our questionnaire. In Figure 10A, we see that 80% of children have sensory sensitivity and are bothered by things like sudden sounds, textures, and bright lights. The bar graph in Figure 10B shows that most children enjoy cuddling with loved ones – 70% of children responded “Mostly true” or “Very true” to the question,

“Does your child enjoy cuddling with people close to him or her?” Sometimes physical touch with another person can provide sensory over-stimulation, but this does not appear to be the case for most participants in our cohort. A pie chart in Figure 10C reveals that 57% of children are picky eaters. In the comment section, most parents described their children’s restrictive diets were based on avoiding certain textures. In terms of tactile sensory sensitivity, food is more commonly bothersome than is physical touch through cuddling.

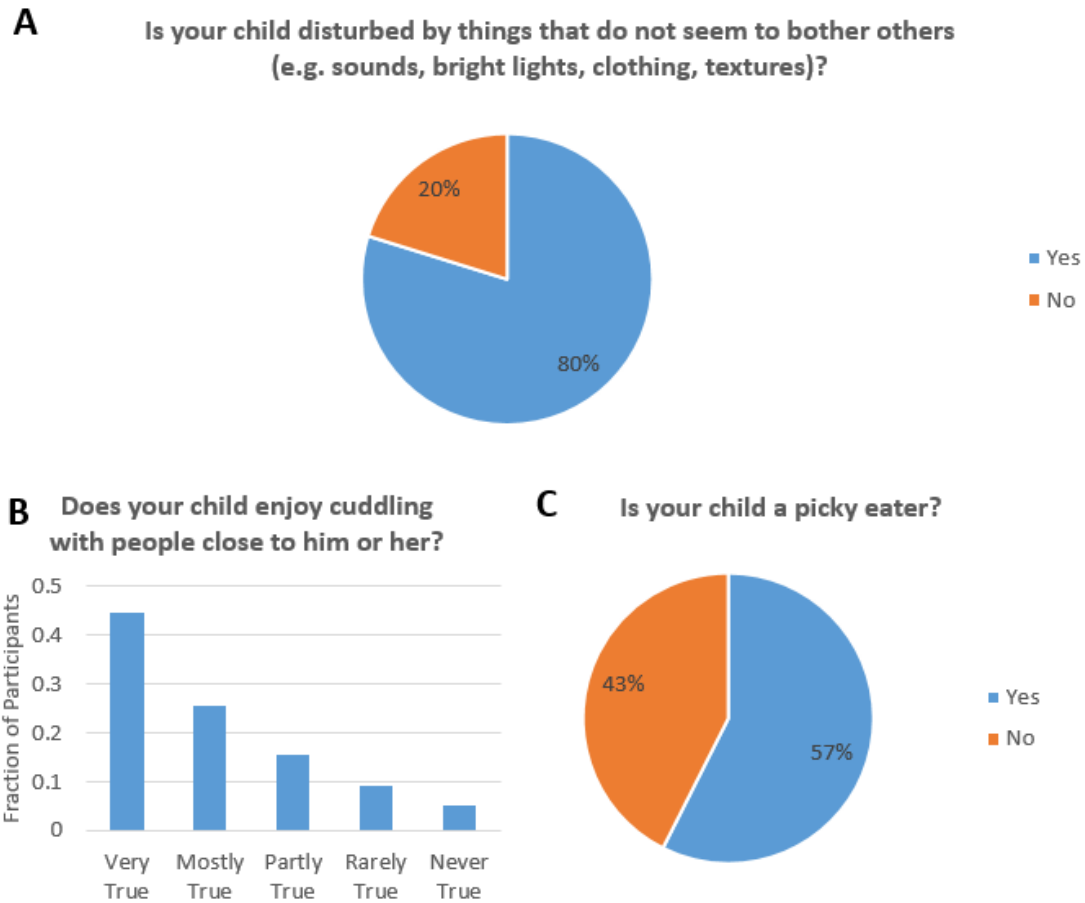


Figure 10. General and Tactile Sensory Processing

(A) The pie graph shows that 80% of children show particular sensitivity to sounds, bright lights, and textures.

(B) The bar graph shows the distribution of responses to the question, “Does your child enjoy cuddling with people close to him or her?”

(C) 57% of children are picky eaters, as seen in the pie chart.

Figure 11 shows results for three questions investigating auditory processing. All three of these questions were scored on the same five-point Likert scale, in which a score of 1 out of 5 represented “Never True” and 5 out of 5 represented “Very True”. The blue, orange, and grey bars in the graph represent average responses for each age group to the statements “Understands

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verbal instructions while writing,” “Would always hear a call for dinner while engaged in a writing task,” and “Has no problem tolerating background music when doing homework.” All three age groups average around 2.5 on the Likert scale for each question. This falls somewhere between Rarely True and Partly True. Auditory processing presents a challenge for the children in our study, and these challenges do not go away with age.

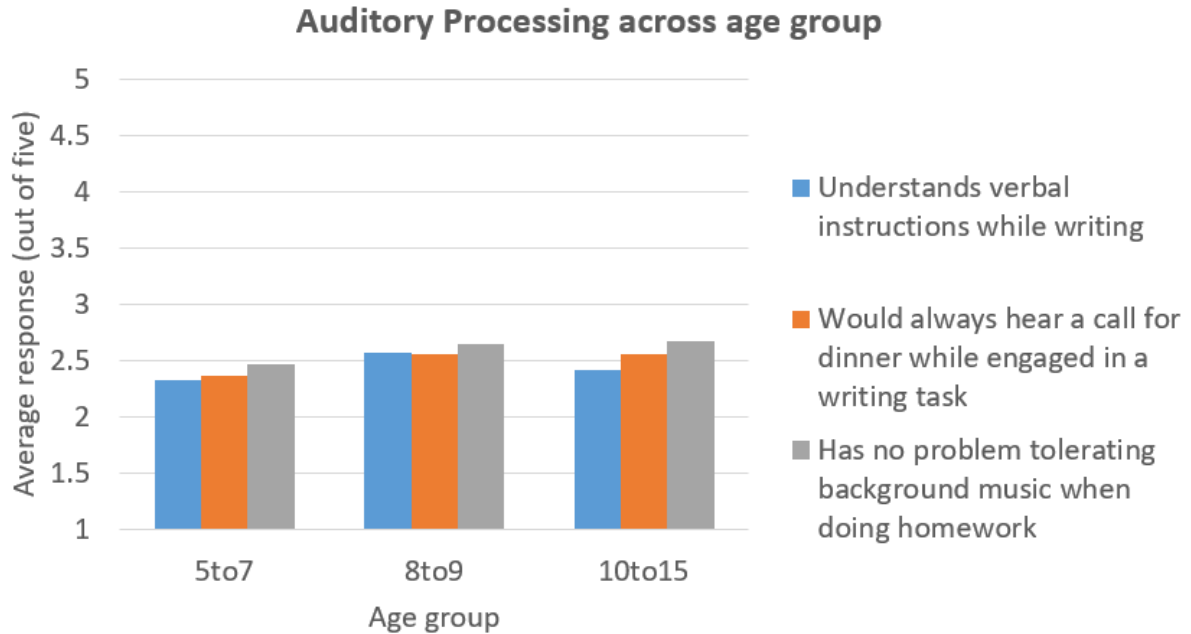


Figure 11. Auditory Processing

The bar chart reveals auditory processing challenges in children of all age groups. Children have trouble understanding verbal instructions while writing, hearing a call to dinner when engaged in a writing task, and tolerating background music while doing homework.

Figure 12 reports the results of two visual-spatial processing questions about children’s handwriting. In Figure 12A, we see that all three age groups average $\sim 2/5$ for the question “Does your child leave appropriate spaces between letters?” On the Likert scale, this corresponds with a response of “Not much like my child.” Figure 12B provides additional evidence that children with DCD struggle with the visual-spatial aspect of writing; 89% of children across age groups have trouble spacing their writing out on the page.

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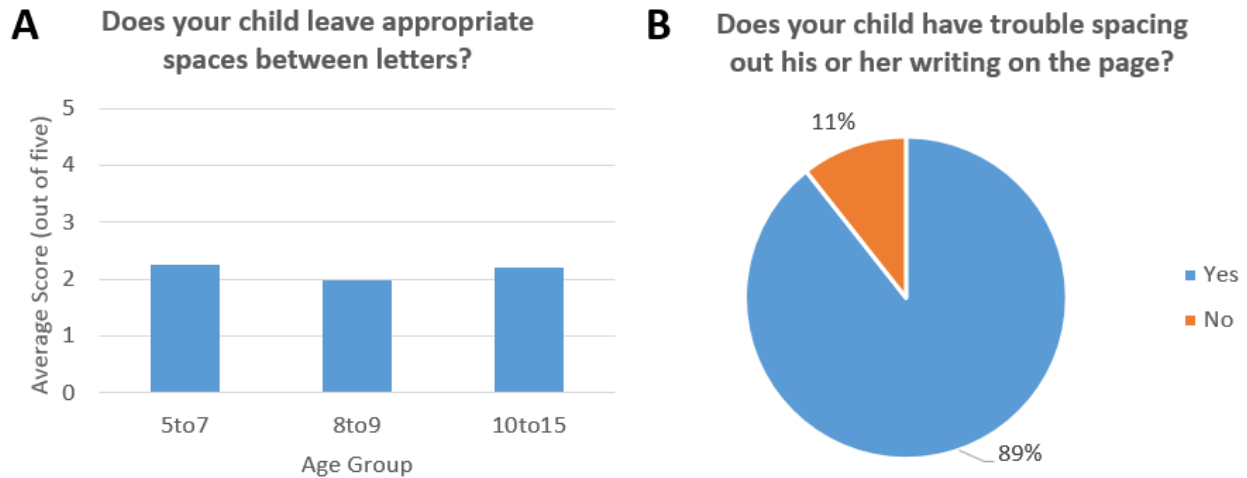


Figure 13. Visual Spatial Processing

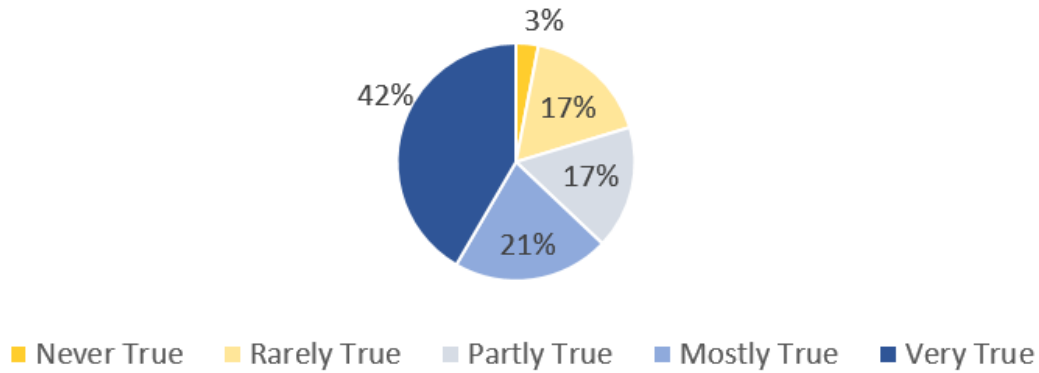
- (A) The bar graph shows that difficulties leaving appropriate spaces between words does not change over time.
- (B) The pie chart shows that 89% of children across age groups have trouble spacing their writing out on the page.

Social Life

Social challenges and differences in peer-interactions are frequently reported in children with neurodevelopmental disorders such as sensory processing disorder (SPD) (Cosbey, Johnston, & Dunn, 2010), autism spectrum disorder (ASD) (White, Keonig, & Scahill, 2007), and attention deficit/hyperactivity disorder (ADHD) (de Boo & Prins, 2007). DCD is also associated with social challenges (e.g. Chen & Cohn, 2009; Mandich, Polatajko, & Rodger, 2003). To look into the specifics of DCD-related social challenges, we gathered information about extraversion, empathy, social interactions, and bullying.

In Figure 13A, we see that extraversion declines with age in three contexts: home, school, and extracurricular activities. The y axis of the graph represents the average score out of five for how extraverted their child was in each situation. A score of five meant that their child was extremely extraverted in that scenario. Children of all ages are most extraverted at home, which we see in the graph as the high blue dots. In the school setting, children 10 to 15 years old have an average extraversion score of 2.9/5, whereas children under 5 years of age have an average score of 3.6/5.

A Is your child unusually empathetic or compassionate?



B Extraversion Declines with Age in All Contexts

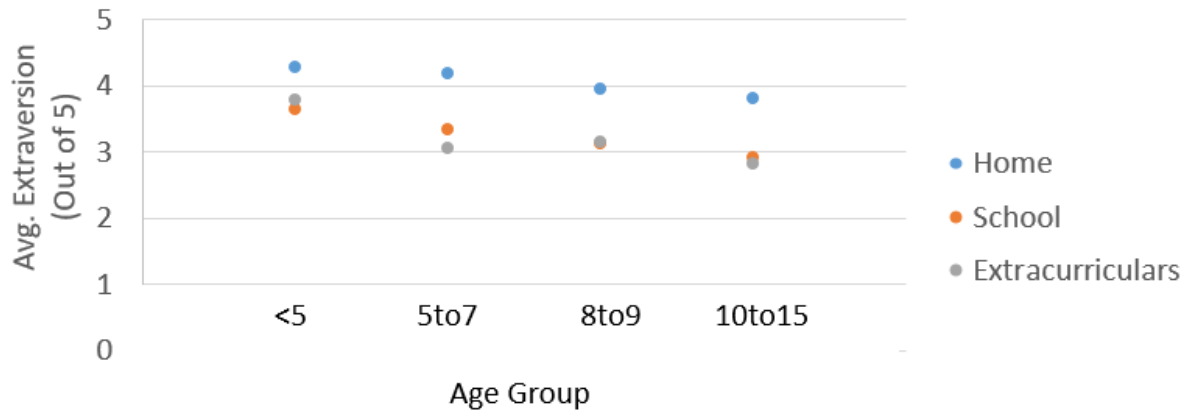
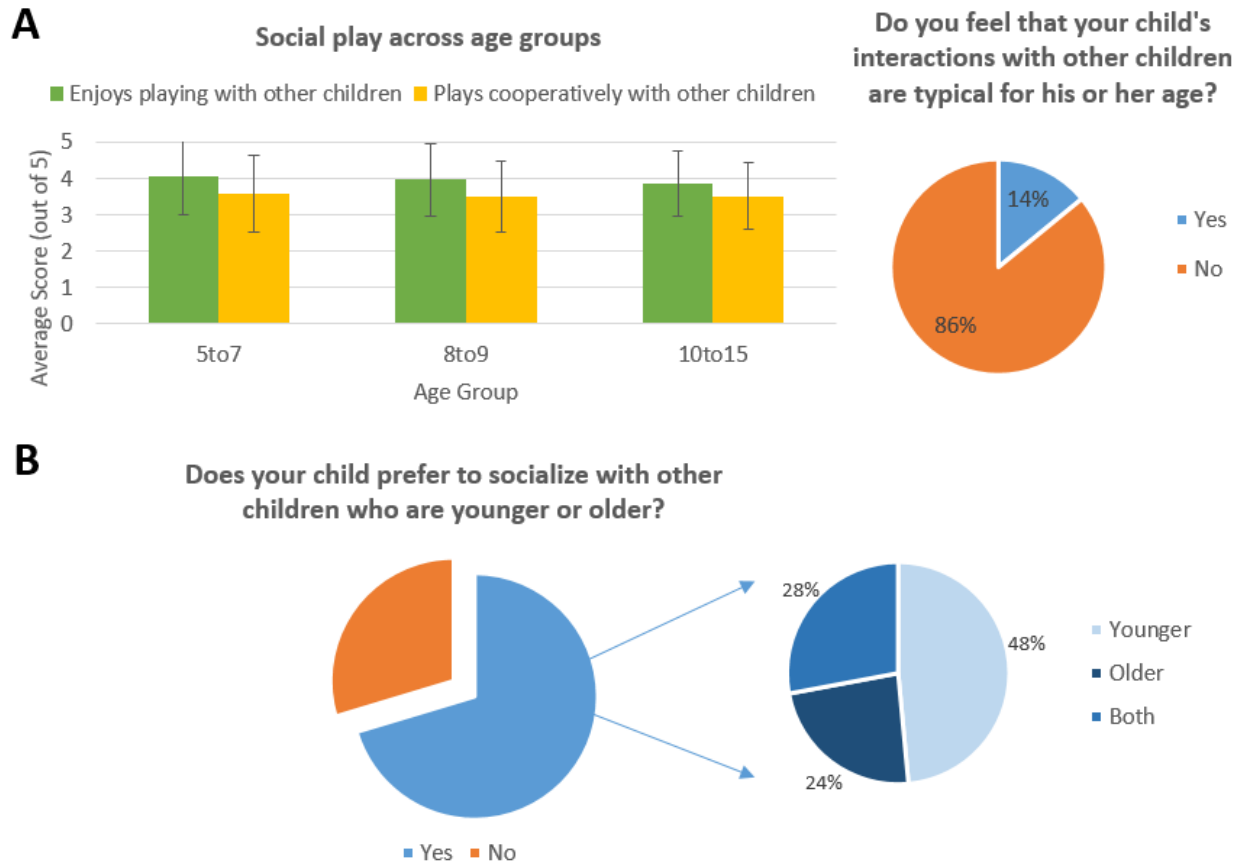


Figure 13. Social Traits

- (A) 63% of parents answered “Mostly True” or “Very True” to the question “Is your child unusually empathetic or compassionate?” Only 3% of parents responded “Never true” to this question.
- (B) The scatter plot shows the progression of extraversion across all age groups. Children of all age groups are most extraverted at home and comparably extraverted at school and in extracurricular activities. Extraversion declines over the course of childhood.

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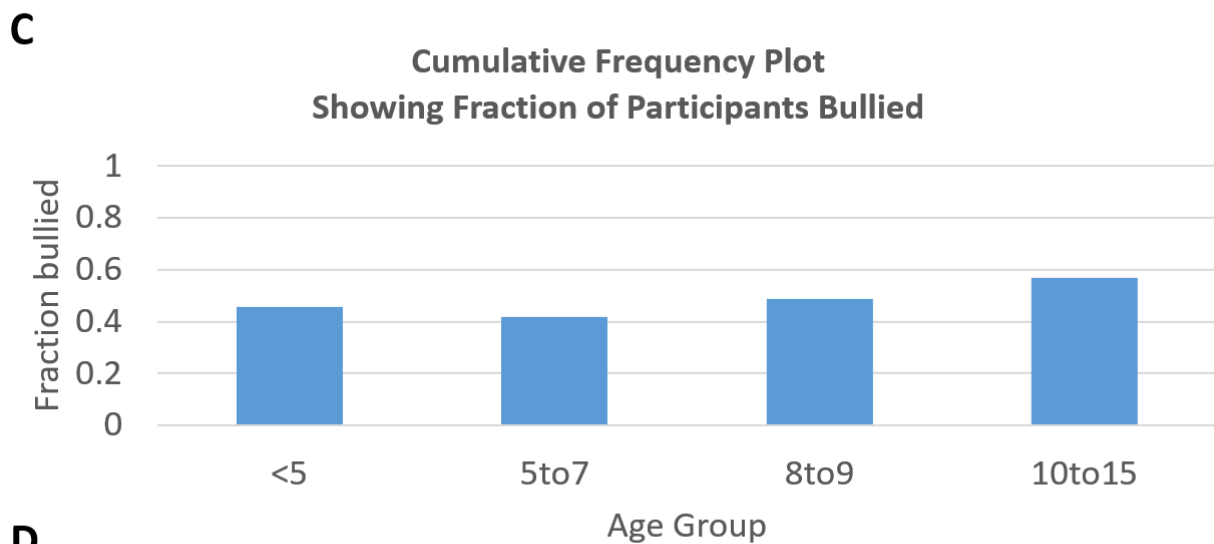
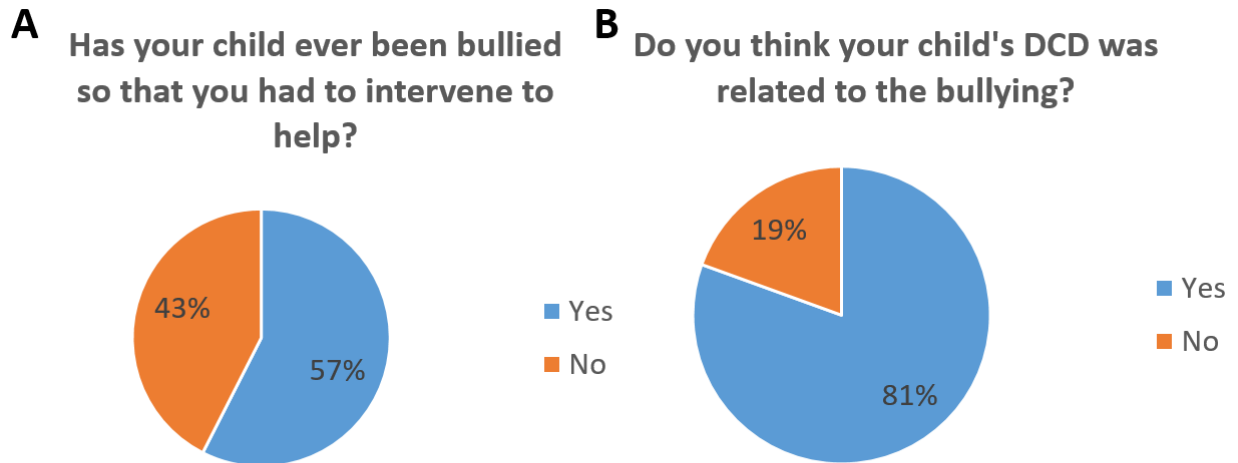
**Figure 14. Social Interactions**

- (A) In the bar graph, we see results from the questions “Enjoys playing with other children” and “Plays cooperatively with other children.” We see that the data change little across age groups.
- (B) The pie chart shows that 86% of parents feel that their child’s interactions are not typical for their age.
- (C) The pie charts show how 2/3 children prefer socializing with other children who are older or younger. The blue pie chart shows that almost half of the children within this group prefer younger playmates; 24% prefer older playmates and 28% prefer spending time with people who are older or younger.

Figure 14A reports results from the questions “Enjoys playing with other children” (green) and “Plays cooperatively with other children” (yellow). There is no significant change in the responses to these questions across age groups. The question was again coded on a five-point Likert scale, and all age groups averaged ~4/5 for “Enjoys playing with other children” and ~3.5/5 for “Plays cooperatively with other children.” Although the average participant enjoys playing with other children and tends to play cooperatively, 86% of parents also say that their child’s interactions are not typical for his or her age, as shown in the pie chart in Figure 14B. Figure 14C further inspects the topic of age appropriate interactions by showing that two thirds of children prefer socializing with children who are older or younger. Within this subset, 48% prefer younger playmates, 24% prefer older playmates (including adults), and 28% prefer to play

with people who were either older or younger. In parents' comments, we learned that children often preferred younger friends because they were at a similar level of maturity, were not as judgmental about DCD-related challenges such as speech impediments, and allowed the child to take control of the social interaction. Many parents noted that their child enjoyed acting as a boss, director, teacher, or mentor to younger children. Older friends were more patient and understanding of DCD-related challenges, took the children under their wing, and were often more interested in non-physical activities such as videogames and board games. Parents frequently commented that their children were more confident when interacting with adults and children outside their own age group.

A few parents also noted that their child sought the company of older or younger children because their child felt ignored by his or her peers. Bullying was common in our participants. As seen in Figure 15A, 57% of children had been bullied so severely that a parent had to intervene to help. Of this group, 81% of parents believed their child's DCD was related to the bullying (Figure 15B). Figure 15C is a cumulative histogram. The x axis represents the four age groups - <5, 5to7, 8to9, and 10to15, and the y axis shows the fraction of participants who had been bullied by the time they reached that age. Usually, a cumulative histogram starts off with small bars and then grows larger, but the shape of this curve is a gentle slope upward. This is because 45% of children in the <5 group have already been bullied. Our results show that for children with DCD, peer rejection often starts at an early age. In Figure 15D, we see that boys and girls have relatively similar experiences in this matter: 61.3% of girls had experienced bullying and 55.4% of boys had been bullied.



D

Gender Distribution of Bullying		
Gender	Fraction Bullied	Percentage Bullied
Male	77/139	55.40%
Female	38/62	61.29%

Figure 15. Bullying

A) (n=200) This pie chart shows that over half of participants have been bullied.

B) (n=113) In most cases of bullying, parents suspected that Dyspraxia played a role.

C) Cumulative frequency plot showing the fraction of children who have been bullied.

Bullying begins at an early age and by age 10 to 15, over half of participants have been bullied.

D) Boys and girls are affected by bullying. The difference in prevalence here is not significant.

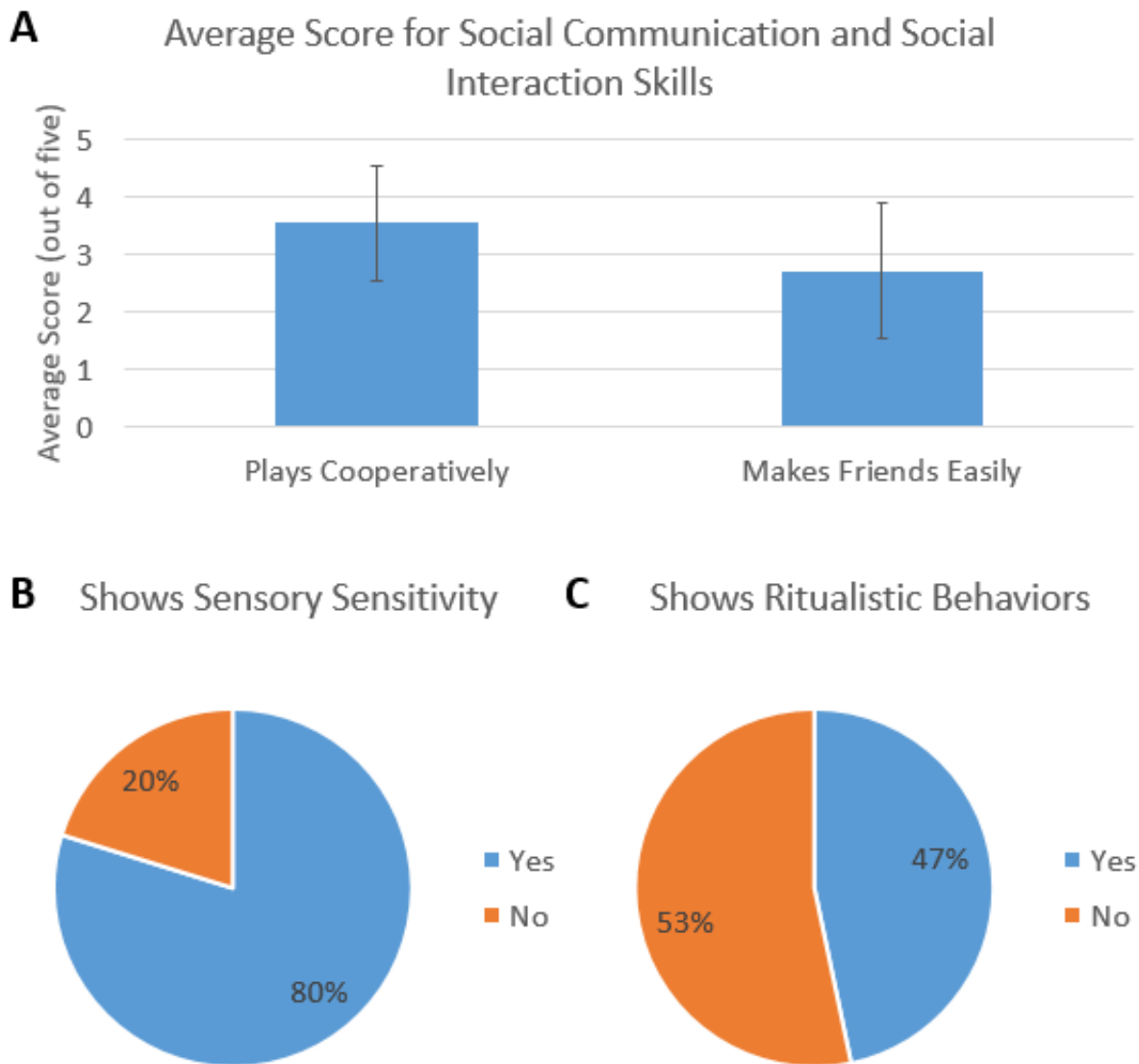


Figure 16. Autistic Behaviors

(A) Average score for two autistic behaviors – “Plays Cooperatively” and “Makes Friends Easily”. The y axis represent a five-point Likert scale ranging from “Never True” to “Very True”. Out participants fall between “Mostly True” and “Partly True” for “Plays Cooperatively” and between “Rarely True” and “Partly True” for “Makes friends easily.”

(B) According to the pie chart, 80% of participants show some kind of sensory sensitivity. This chart appeared in the Sensory Processing section, but is reproduced here because in the present context it represents a behavior associated with ASD.

(C) The pie chart shows that less than half of participants show ritualistic behaviors, such as an inflexible daily routine. 47% of parents reported ritualistic behaviors in their children.

Autistic Behaviors

Autism Spectrum Disorder (ASD) often co-occurs with motor challenges (Kopp et al., 2010), so although this report already probes many symptoms and behaviors associated with ASD – such as cooperativity and sensory sensitivity – we wanted to address the overlap between ASD and DCD in a clear, discrete way. As explained in the Methods section, our questionnaire did not contain a clinical measure for ASD. Therefore, using the *DSM-5* as a template, we isolated four questions within our questionnaire that adequately screened for ASD diagnostic criteria. Figure 16A shows average responses across all age groups for the questions, “Plays Cooperatively” and “Makes Friends Easily”. The bar graph shows qualitatively that our participants are better at playing cooperatively than making friends easily. They fall between “Mostly True” and “Partly True” (3.5/5) for “Plays Cooperatively”, and between “Rarely True” and “Partly True” (2.5/5) for “Makes friends easily.”

The other two traits characteristic of ASD which we asked about were sensory sensitivity and ritualistic behaviors. In Figure 16B, we see a pie chart reproduced from the sensory processing section which shows that 80% of children experience sensory sensitivity, and are bothered by things that do not bother others, like clothing and food textures, vehicle noises, and bright lights. Figure 16C shows that 47% of participants show ritualistic behaviors, such as an inflexible daily routine or an insistence on the arrangement of objects in his or her room.

In Figure 17, we find additional reports about autistic behaviors. In Figure 17A, the bar graph shows that older children find it more difficult to make friends than do their younger counterparts. Figure 17B is a histogram showing the number of participants who classified as having 0, 1, 2, 3, or all 4 autistic traits. The mode number was 2. If DCD were inextricably linked with ASD, we would have expected most participants to display all or almost all of the autistic traits we screened for. Figure 17C is a scatter plot correlating DCDQ score with the number of reported Autistic traits. There is no clear correlation.

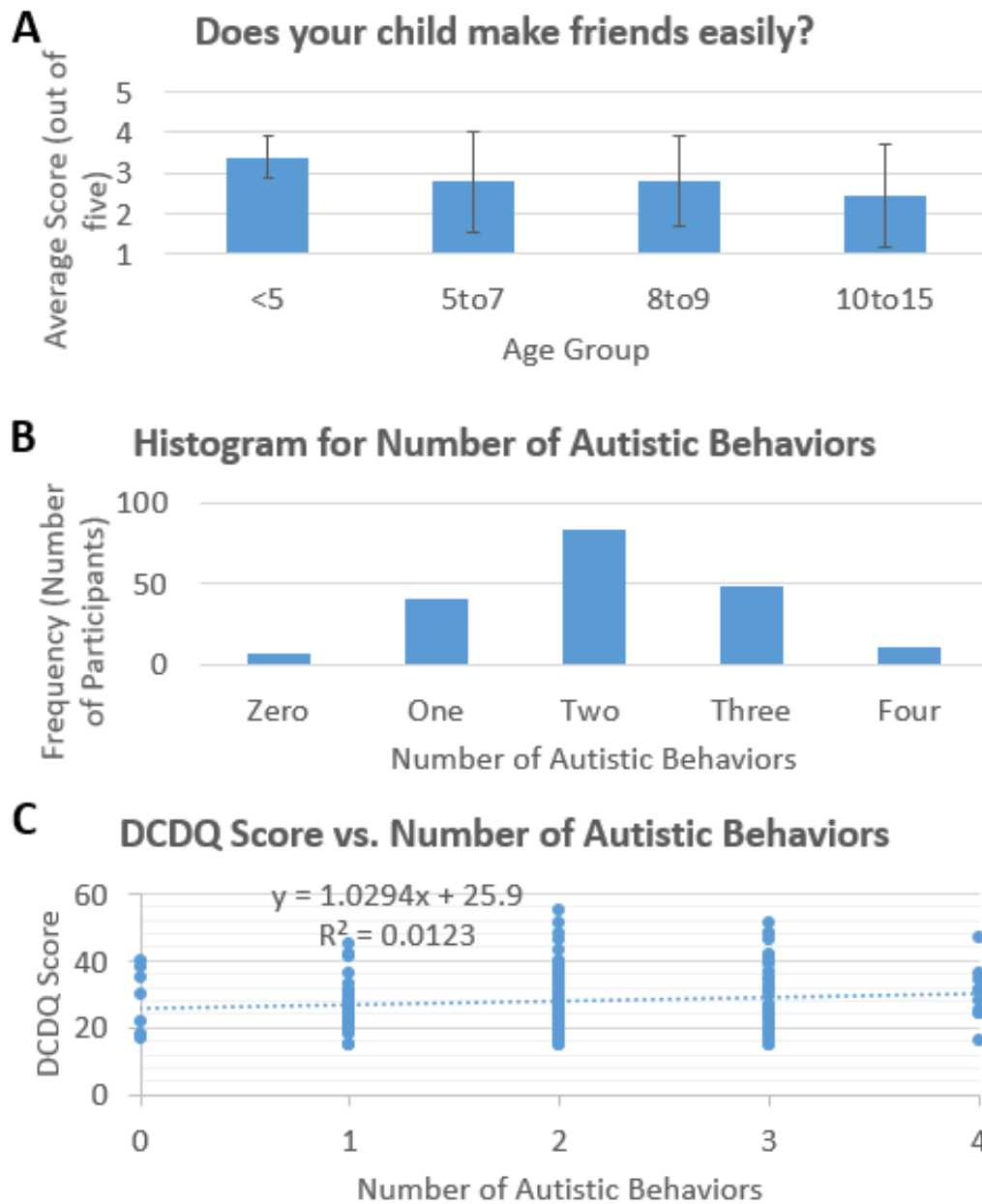


Figure 17. Autistic Behaviors and DCD

- (A) The bar graph shows a slight but not significant decrease in the ability to make friends easily.
- (B) The histogram shows how many participants display zero, one, two, three, or all four of the behaviors associated with ASD.
- (C) According to the pie chart, 80% of participants show some kind of sensory sensitivity. This chart appeared in the Sensory Processing section, but is reproduced here because in the present context it represents a behavior associated with ASD.

School Life

Many findings have suggested that DCD comes with its own set of learning differences, including impaired memory function and math troubles (Alloway & Archibald, 2008). In Figure 18, we look at the pattern of academic strengths and challenges in our participants. Figure 18A is a bar graph showing how many participants rated each academic subject as their hardest and easiest subjects, shown in orange and blue, respectively. Writing, math, reading, and gym were the four most popular answers for “Most difficult subject.” 78 participants found writing the most difficult, 43 struggled with math, 25 had challenges with reading, and 21 had trouble with gym class. The most common responses for “Easiest subject” were reading, science, math, and “none”. Although many participants struggled with math and reading, 29 participants found math their easiest subject, and 47 excel at reading. 32 participants identified science as their easiest class. 18 participants chose “none”. In Figure 18B, we see that ~70% of participants struggle with math facts and spelling compared to their peers. Roughly 65% of children struggle with reading. Even though reading was the most popular response to “Easiest subject”, the majority of participants are still not reading at the level of their peers.

In Figure 18C, we find a bar graph showing the proportion of children who receive subject-specific support in school for reading, writing, spelling, and math. Half of participants receive reading support and over 60% receive writing support. 45% of children have received math support and 35% have received spelling support. Another section of the questionnaire showed corresponding results when 80% of parents reported that they or another family member had helped their child improve his or her writing skills.

Academic support is usually offered in the form of an Individualized Education Program (IEP) or a 504 Plan. Figure 19A shows that around 75% of our participants within each age group have this kind of program, which helps a child meet his or her own specific needs in the classroom. The adjacent bar graph shows that 57% of children with an IEP/504 were classified in Kindergarten. 14% were classified in first grade, and 20% were classified in second or third grade. Very few participants received an IEP/504 classification after third grade.

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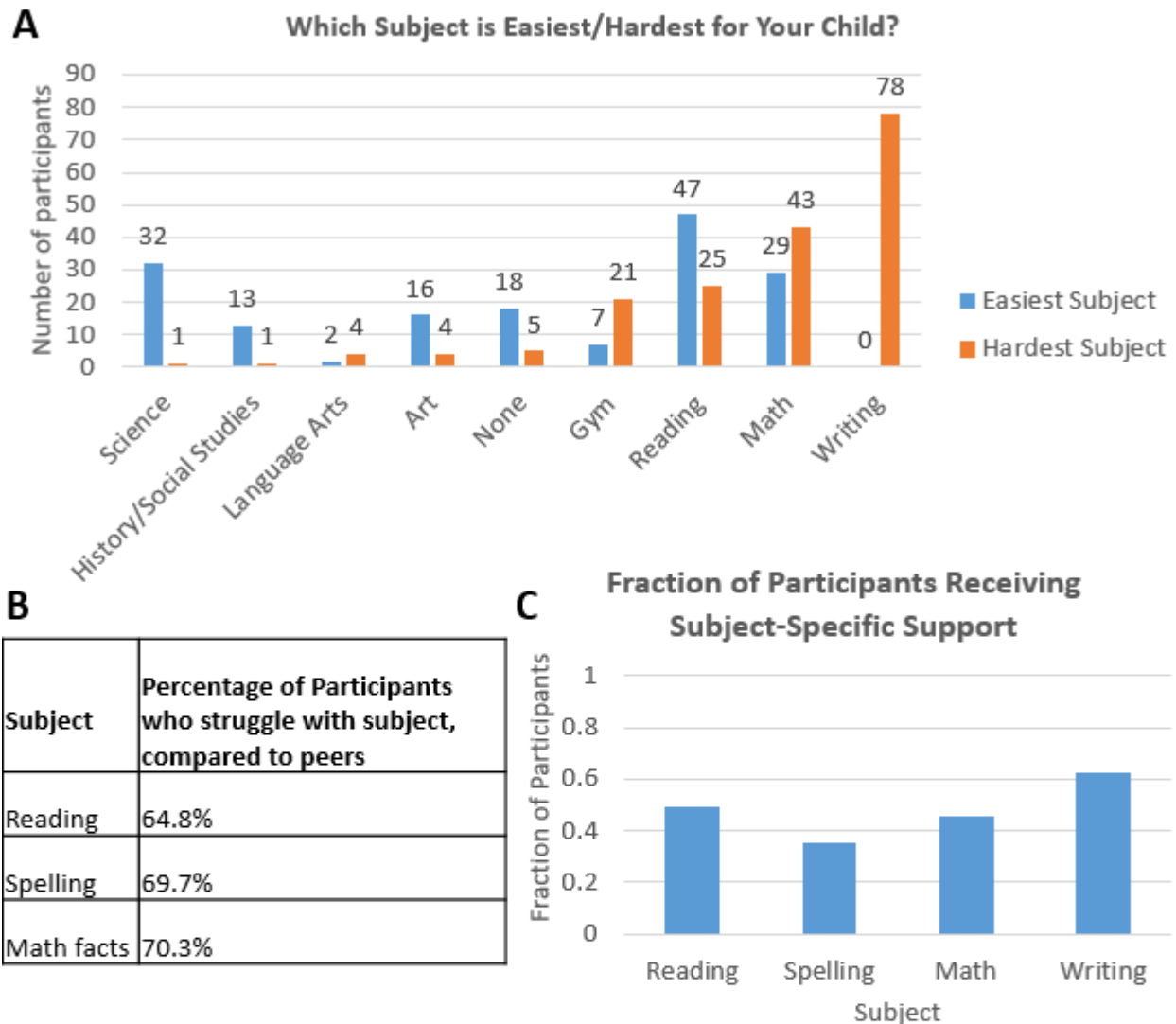


Figure 18. Academic Strengths and Challenges

- (A) The bar graph shows the number of participants who rated each subject as the hardest and easiest for their child. 78 respondents identified writing as their hardest subject; math and reading were the next-most difficult. However, 47 people also identified reading as their easiest subject.
- (B) The table shows the percentage of participants who struggle with reading, spelling, and math facts compared to their peers. The majority of participants struggle with these academic subjects.
- (C) The x axis of this bar graph represents academic subjects and the y axis represents the fraction of participants who receive subject-specific assistance in school

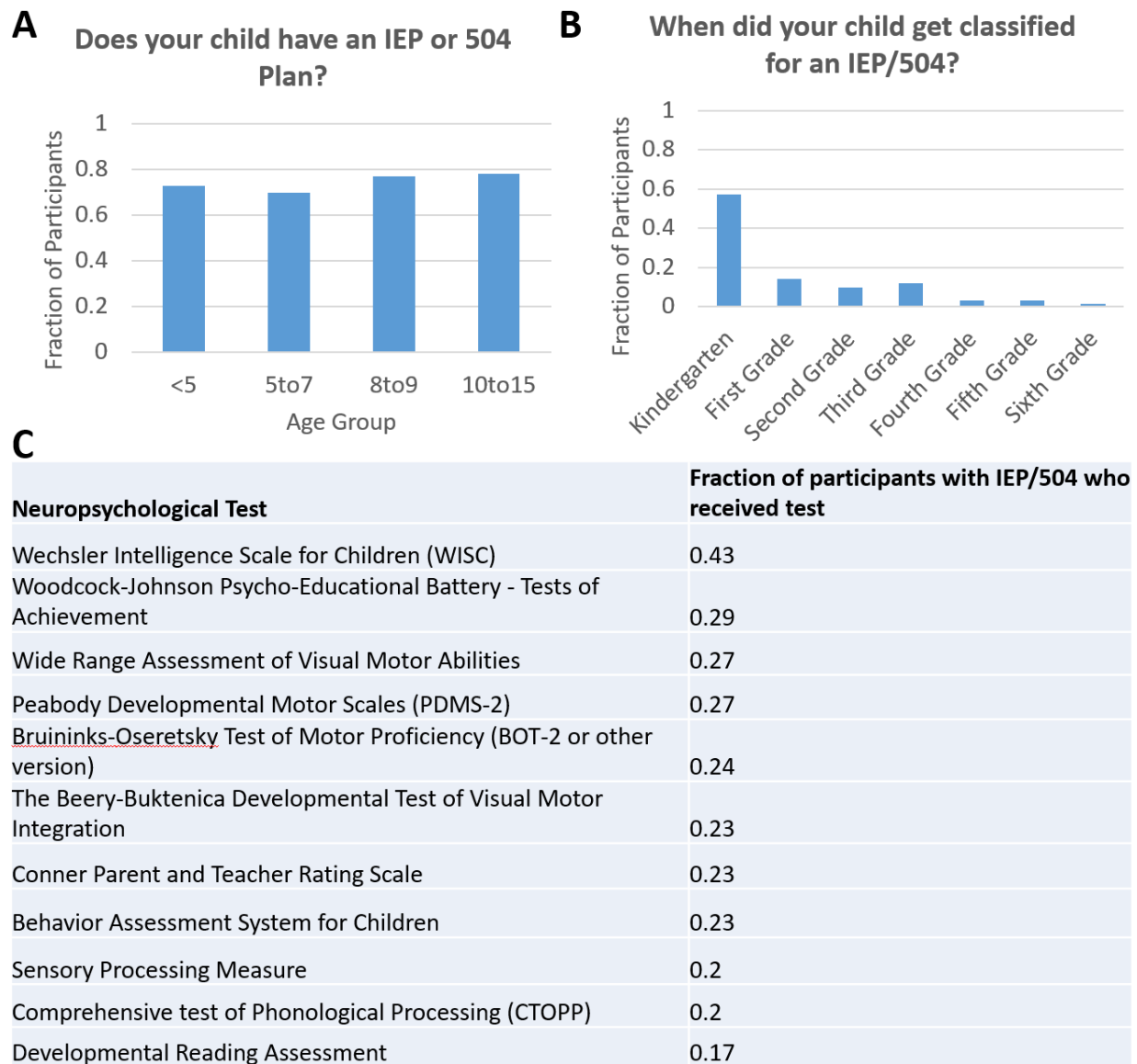
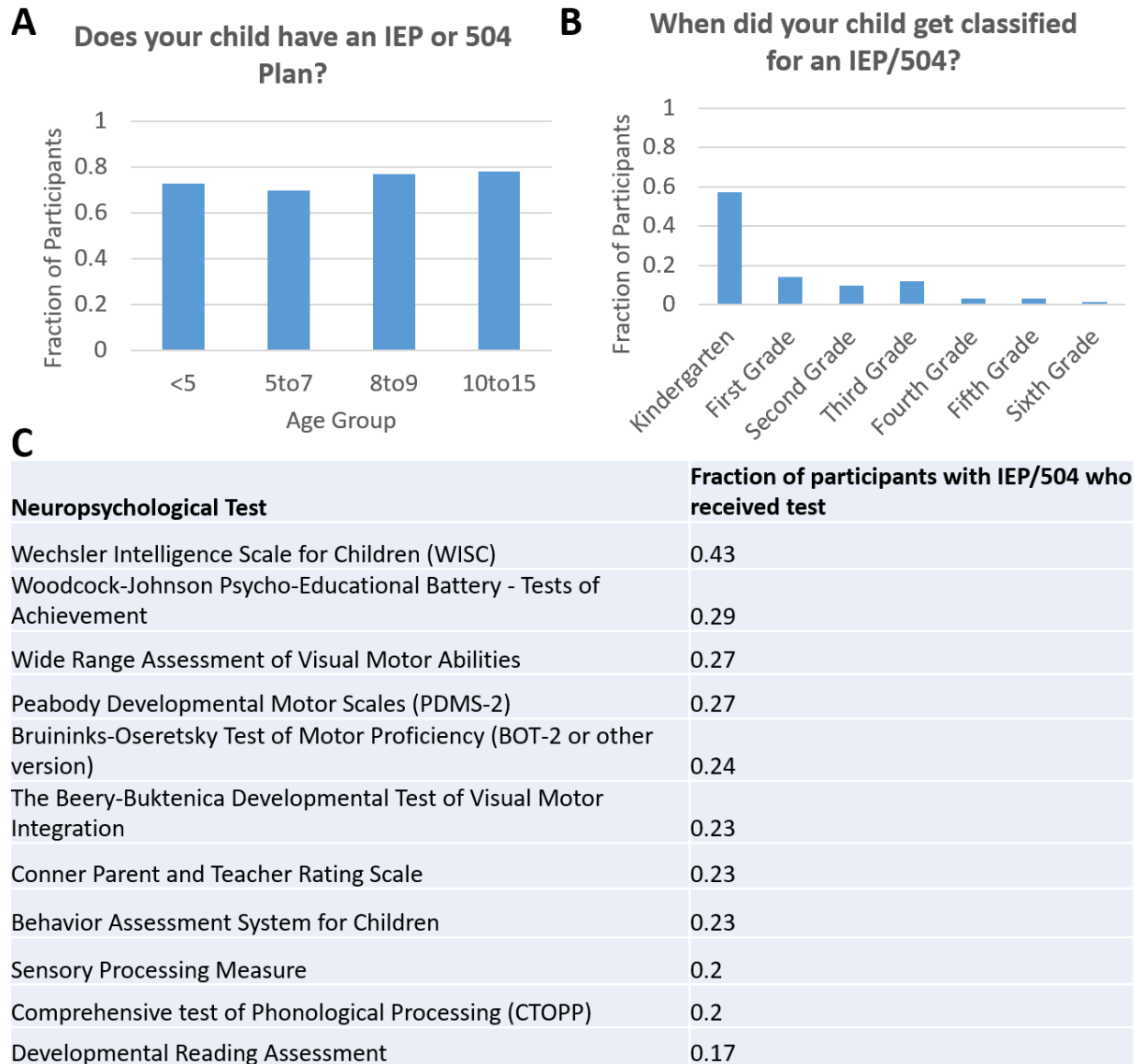


Figure 19. Statistics on IEP/504 Programs

- (A) The pie chart illustrates that at the time of the survey, 75% of participants had an Individualized Education Program or 504 Plan.
- (B) A bar graph shows at what age children were classified for their IEP/504. Most participants of our study were classified in Kindergarten.
- (C) To be classified for an IEP/504, most states require children to go through neuropsychological testing. The table presents the most common tests the children were asked to take.

DIVERGENT DEVELOPMENT FOR DYSPRAXIC CHILDREN

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The process of receiving an IEP/504 Plan classification involves neuropsychological testing, which serves to confirm that support is necessary and identifies specific interventions that will be most helpful (Stanberry, 2017). Figure 19C shows the most common neuropsychological tests our participants received when qualifying for an IEP/504. 43% of

participants received the Weschler Intelligence Scale for Children (WISC), the standard pediatric IQ test. The Woodcock-Johnson Psycho-Educational Battery was the second-most popular; 29% of children had received this test. As seen in the large table, there is great heterogeneity in the specific tests given. Additionally, many parents also described how their children had to undergo multiple rounds of testing, or were required to complete an extensive battery of tests.

Part of academic accommodations includes assistive technology. Only 22% of our participants reported having received an assistive technology evaluation. However, Figure 20A shows that in the school setting, many participants use a scribe or type on a computer or iPad instead of writing. In Figure 20B, a series of pie charts shows how the proportion of children who write, use a scribe, and type in the classroom setting changes over time. The percentage of school aged children (i.e. 5 years or older) who use a scribe stays relatively constant at 14-15%. No children under five years of age use a scribe in school. The percentage of school aged children who type in the classroom grows across the three age groups: 11% of 5- to 7-year-olds, 26% of 8- to 9-year-olds, and 41% of 10- to 15-year-olds type on a computer or iPad in school. Correspondingly, the percentage of children who write in the school setting drops: in the two youngest age groups, <5 and 5to7, 75% of children write in the classroom. This falls to 60% in the 8to9 age group and 44% in the 10to15 group.

The other common type of accommodation reported was physical and occupational therapy. As seen in Figure 21, 58% of children had received physical therapy, and 96% had received occupational therapy. 68 children went to a school PT, and 81 went to a private PT. On the other hand, 115 children had seen a school OT, and 141 had been to a Private OT.

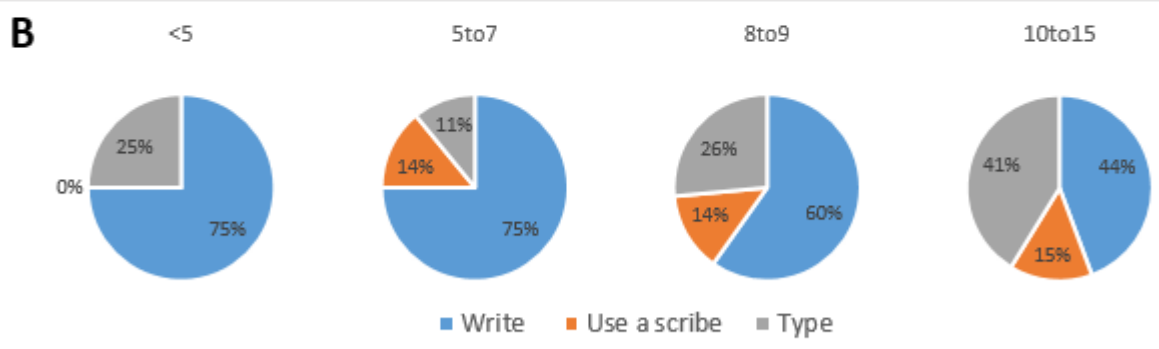
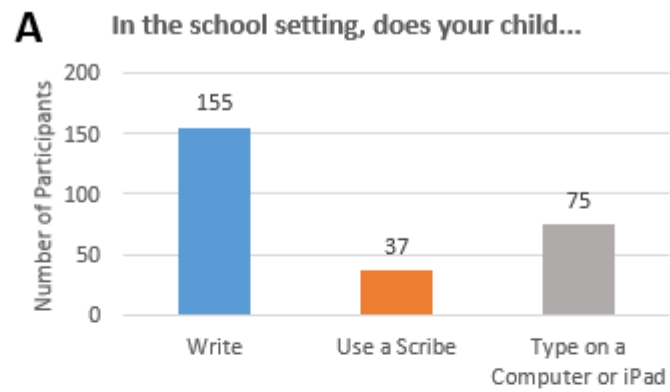
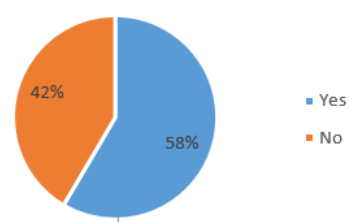


Figure 20. Writing Accommodations at School

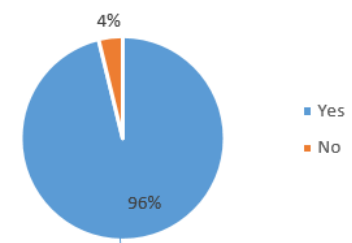
- (A) The bar graph shows the number of participants across all age groups who write, use a scribe, or type in school. 155 participants write, 37 use a scribe, and 75 type.
- (B) The series of pie charts represent the percentage of children within each age group who write, type, or use a scribe. By age 10 to 15, only 44% of children write in the classroom.

Has your child ever gone to Physical Therapy?



School PT	68
Private PT	81

Has your child ever received Occupational Therapy?



School OT	115
Private OT	141

Figure 21. Occupational and Physical Therapy

- (A) The pie charts show the proportion of kids who have received OT or PT, and the tables below detail whether the specialist was affiliated with the school or a private practice.

Discussion

Detailed Medical History

Looking into the medications participants were taking provided a clearer picture of medical, psychiatric, and neurodevelopmental comorbidities of DCD. The prevalence of stimulant and SSRI usage confirms our previous finding in Part 1 of the report that ADHD and anxiety are common in children with DCD. Pharmacological intervention proves to be a common therapeutic measure. The high rate of methylphenidate use invites a discussion of the potential use of ADHD medications to treat DCD motor symptoms. Preliminary findings (e.g. Flapper et al., 2006) suggest that the commonly observed behavioral overlap between ADHD and DCD may correspond with an overlap in effective pharmacological treatments. Clinical trials could help explore the use of methylphenidates in children with DCD or DCD/ADHD to investigate whether methylphenidates are also effective on DCD children who have no attention deficit. The outcome of this clinical trial would provide us with another clue as to the etiology of DCD and could introduce a viable treatment option for children with severe DCD.

In gathering a more detailed medical history, we looked at optometry data and history of speech difficulties. Oculomotor issues in children with DCD are not as widely recognized as speech issues – literature on DCD and oculomotor issues is far scarcer. This lesser recognition is reflected in the fact that only 23% of children ever received vision therapy (Figure 7), even though a large portion of children attended an optometrist because of suspected oculomotor issues. 23% is certainly a higher number than one would find in a population of typically developing children, but compared to the proportion of children who reported oculomotor issues, the number is still relatively small. This could be because oculomotor issues do not pose as big of a daily challenge as speech issues, or because vision therapy may not be as widely recognized as speech therapy.

One fifth of children in our study stutter or stammer (Figure 8C), and the majority of our youngest participants cannot be understood even by their parents. 57% of participants have been officially diagnosed with a speech or language disorder (Figure 9A). We did not ask when children received these diagnoses, but speech challenges may offer another early sign that could be used to promote earlier diagnosis of DCD. A follow-up questionnaire should explore the possibility of speech and language difficulties as an early sign of DCD. Children with DCD may

present with different kinds of early language challenges than children who later develop other neurodevelopmental disorders such as ASD. Understanding the interconnectedness of many neurodevelopmental disorders and being familiar with how they present early on could help a parent or teacher identify a child at risk of later challenges.

The last aspect of Detailed Medical History was wellness. Our exploration of the psychosocial aspects of DCD yielded results both surprising and expected. Unexpectedly, the responses for “Impact of DCD on self-esteem” had a significant, positive correlation with the statements “Has high self-esteem” and “Is a very happy child”. Given reports in the literature of DCD’s negative impact on self-esteem in children, we expected to find the opposite result. It could be that parents who perceived a high impact of DCD on self-esteem were simply more aware of DCD’s effects. Children who grow up with an awareness of their DCD may also end up developing a stronger sense of self-esteem and resiliency.

Another interesting relationship to glean from the correlation matrix in Figure 4 is the significant and negative correlation between age and “has high self-esteem”. According to one study on self-esteem in adolescents, self-esteem has four common trajectories as children enter their teens: 35% stay “consistently high”, 13% are “chronically low”, 21% are “steeply declining”, and 31% experience a “small increase” (Hirsch & DuBois, 1991). In future studies, it would be interesting to see which specific trajectory is most common in children with DCD.

Sensory Processing

In the previous report, we found that 11% of our participants had been diagnosed with Sensory and/or Auditory Processing Disorder. Even though only 11% of participants had received a formal diagnosis, 80% of participants show particular sensory sensitivities (Figure 10A). In fact, the results of the sensory processing section show that children with DCD have processing challenges across many different sensory domains. Touch is usually one of the more obvious sensory sensitivities – a child may refuse to wear certain clothes or require only certain kinds of foods. Most of our participants enjoy cuddling with loved ones (Figure 10B), but 57% are picky eaters, which is often a sign of hypersensitivity to textures.

Auditory processing presents a challenge and does not seem to improve over time, as shown in the bar graph in Figure 11. This domain requires further exploration, however. Our questions asked about auditory processing in conjunction with a motor task. Therefore, we do not

isolate pure auditory processing. It is possible that we would obtain a very different set of results if we asked about simple auditory processing and removed the motor component from these questions. If a child does not hear a call for dinner when engaged in a writing task, would he still have trouble hearing it if he were not writing? The interaction between motor deficits, cognitive load, and sensory processing invites further investigation.

Visual-spatial processing is another area of challenge for children with DCD. This becomes clear when looking at a DCD child's writing – it is often smooshed to one side of the page, has irregular spaces within and between words, and is illegible (Rosenblum, & Engel-Yeger, 2013). Handwriting offers a useful gauge for visual-spatial processing because it is necessary to make implicit spatial calculations when putting down words onto a page.

The Sensory Challenge Protocol is a 15-minute laboratory protocol that measures sensory sensitivity and reactivity. It gathers a baseline measure then gauges reactivity to a set of eight sequential stimuli that span all five sensory domains (Miller, Reisman, McIntosh, & Simon, 2001). A recent study measured the electrodermal activity of children with and without ASD, and found reliable differences in response patterns between the two groups (Schupak, Parasher, & Zipp, 2016). Behavioral tests administered to children with DCD could help us understand the relationship between coordination and sensory processing. Additionally, it may offer a differentiating measure between DCD and ASD.

Social Life

It is clear from this report and previous studies (e.g., Sylvestre et al., 2013) that many children with DCD have trouble fitting in with their peer groups. 86% of parents in our study feel their child's interactions with other children are not typical for the child's age (Figure 14B). In Figure 14C, we show a pie chart which reveals that 2/3 children prefer interacting with children who are older or younger. We can infer from this preference that children with DCD develop social skills at a more variable rate than typically developing peers; alternatively, interacting with older or younger kids may offer specific social advantages

Looking at the parents' comments as to why their child preferred younger or older playmates gives us insight into the skills and types of interactions at which children with DCD excel. Many enjoy orchestrating others' activity, and seek out younger friends whom they can mentor and influence. Many others enjoy the process of being mentored. These types of

relationships, in which there is a clear leader and follower, may offer a more structured setting for social interaction than typical peer-peer relationships. A sociological study of friendship dynamics could provide further insight.

Autistic Behaviors

Given the lack of a clinically validated questionnaire, the results of the Autistic Behaviors section are difficult to assess. We used the *DSM-5* diagnostic criteria to identify questionnaire questions that might roughly screen for autistic behaviors, but we were unable to find questions for three of the seven diagnostic criteria. Our questionnaire did not contain questions that adequately screened for “Deficits in nonverbal communicative behaviors”, “Stereotyped or repetitive motor movements”, or “Highly restricted, fixated interests”.

Despite these limitations, which we will discuss further in the Limitations section, we can still glean some interesting findings from the results that shed light on the overlap between ASD and DCD. Figure 16 reports results from the four autistic behaviors we were able to screen for: Plays Cooperatively, Makes Friends Easily, Sensory Sensitivity, and Ritualistic Behaviors. Our participants showed the most ASD character in the domains Makes Friends Easily and Sensory Sensitivity – similarly to children diagnosed with ASD, many children in our cohort had trouble making friends and 80% had heightened sensory sensitivity. Most participants were relatively adept at playing cooperatively, with an average of 3.6/5 across all age groups. The small error bar in this first column of Figure 16A shows participants cooperate relatively consistently – that is, there is not a large variation in the level of cooperativity that participants display. Further exploration into the social traits of children with ASD and/or DCD may find that cooperativity problems are counter-indicative of DCD.

School Life

In the school life section, we found many interesting results. First, we look at the patterns of academic strengths and challenges. Unsurprisingly, writing was the most challenging school subject for our participants. This reemphasizes the importance of developing early interventions to improve fine motor skills in children with DCD. Math and Reading each had a mixture of participants who rated it as their hardest and easiest subject. In each case, though, the “hardest” answers predominated. In Figure 18C, we find that the most popular types of subject-specific support reflects reports of the most challenging subjects. This is a reassuring finding because it

reveals targeted academic support. Future studies should assess the quality of academic support received.

Another reassuring result of the School Life section was the fact that the majority of children with IEP programs were classified in Kindergarten. This may be the result of our sample – we drew from an online Facebook support group, so our subject pool may be skewed toward more children with more severe DCD symptoms, or toward those with more proactive guardians. 57% percent of children were classified in Kindergarten, and though this is a majority, the number would ideally be higher. With a tactful teacher and proper implementation, an IEP can help a child navigate DCD-related challenges, both academic and social. Earlier intervention will minimize a child's frustration and maximize her potential.

The last noteworthy finding of the School Life section is the abundance of neuropsychological tests given to children in the process of classifying them for an IEP. This process is not standardized which may reflect the heterogeneity of coordination disorders, or else a widespread lack of understanding.

Limitations

As with the previous report, the two biggest limitations of this study are the lack of a control group and a small sample size. In this report, a control group would have strengthened our findings in Sensory Processing, Social Life, and Autistic Behaviors sections – a direct comparison group would show us more clearly whether the patterns are unique to children with DCD. For example, the fact that 57% of participants were picky eaters would be more meaningful if we had an age-matched control group in which only 10% of children were picky eaters.

A larger sample size would also make our study stronger. We started out with ~250 responses, but many of these were incomplete. After excluding incomplete responses, we were left with 200 participants. This number varied for every question; the consent form was the only mandatory portion of the questionnaire, and many respondents skipped questions. In our analyses involving the change or progression of a trait over time, (e.g., Figures 9, 17A, 20C), we were forced to use the age groups defined by the DCDQ (5 to 7, 8 to 9, 10 to 15, and, where appropriate, <5). With more participants, we would be able to analyze each age individually. Analyzing the progression of traits over smaller age ranges would give us more detailed

information about when children undergo certain changes. For instance, we would know more precisely by which age most children have experienced bullying.

The other major limitation of our questionnaire is that it did not contain a clinical measure for Autism Spectrum Disorder (ASD), so to analyze the relationship between DCD and ASD traits, we were forced to create a pseudo-diagnostic ASD measure using questions which were included in our questionnaire. Although we were able to find questions that screened for all seven of the DSM-5's diagnostic criteria, our ASD measure is purely a place-holder and suggestive of ASD traits.

Future Directions

Future survey studies will correct for the major limitations of the present study. Our next Dyspraxia Questionnaire should include a validated clinical measure of ASD symptoms. One option is the Autism Spectrum Quotient: Children's Version (AQ-Child) (Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008). This parent-report questionnaire offers an ASD measure analogous to the Vanderbilt ADHD Parent Rating Scale (VADPRS) (Wolraich, Lambert, Doffing, Bickman, Simmons, & Worley, 2003) and the Developmental Coordination Disorder Questionnaire '07 (Wilson, Crawford, Green, Roberts, Aylott, & Kaplan, 2009), both of which were included in our original survey. The AQ-Child assesses five domains of the autistic phenotype: social skills, attention switching, attention to detail, communication, and imagination (Auyeung et al., 2008). A Dyspraxia Questionnaire which includes this clinical measure will not only be able to assess the overlap between ASD, DCD, and ADHD, but, more specifically, explore which subtypes and phenotypic traits seem to co-occur in these disorders. Gaining a deeper understanding of phenotypic overlap will allow us to ask more targeted research questions in future neurophysiological studies. If we find, for instance, that Theory of Mind is a common deficit in ASD and DCD populations, but not in ADHD populations, we may conduct an fMRI study that focuses on the function and connectivity of the temporal parietal junction in children with and without neurodevelopmental disorders (Saxe & Kanwisher, 2003).

Our survey took upwards of two hours to complete, but future surveys will contain fewer and more streamlined questions. Having shorter questionnaires will allow us to investigate specific research questions in greater depth. In addition, we will likely have an easier time with subject recruitment if our questionnaire is shorter, which will correct for our current limitations

of small sample size and a too-homogeneous sample. Future iterations of the Dyspraxia Questionnaire could also be disseminated through different online platforms such as Mechanical Turk, which may offer a more efficient means of subject recruitment.

We introduced the previous report with a discussion of the National Institute of Mental Health's (NIMH's) recent initiative called Research Domain Criteria, or "RDoC". RDoC is a new research initiative that views psychopathology through the lens of neural circuits. It outlines five domains for mental health research: "Negative Valence Systems", "Positive Valence Systems", "Cognitive Systems", "Social Processes", and "Arousal and Regulatory Systems" ("RDoC Snapshot", NIMH). To provide a framework for research in each of these domains, RDoC defines eight units of analysis, including genes, molecules, cells, circuits, physiology, behaviors, self-reports, and paradigms ("RDoC Snapshot", NIMH). The present study arguably addresses each of the five RDoC domains and uses self-reports and behaviors as the primary units of analysis. Our future, targeted questionnaires will address fewer domains per questionnaire but in greater depth. As we begin to collect physiological data from neuroimaging studies, detailed survey data will help us interpret fMRI results and ask interesting, targeted neurological questions.

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