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ACCEPTANCE

This dissertation, VISUAL, MOTOR, AND VISUAL-MOTOR INTEGRATION DIFFICULTIES IN STUDENTS WITH AUTISM SPECTRUM DISORDERS, by KIMBERLY B. OLIVER, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education, Georgia State University.

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ABSTRACT

VISUAL, MOTOR, AND VISUAL-MOTOR INTEGRATION DIFFICULTIES IN STUDENTS WITH AUTISM SPECTRUM DISORDERS

by
Kimberly Oliver

Autism spectrum disorders (ASDs) affect 1 in every 88 U.S. children. ASDs have been described as neurological and developmental disorders impacting visual, motor, and visual-motor integration (VMI) abilities that affect academic achievement (CDC, 2010). Forty-five participants (22 ASD and 23 Typically Developing [TD]) 8 to 14 years old completed the Bender-Gestalt Test, Second Edition (BG II), Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition (VMI-V), NEPSY Second Edition (NEPSY-II), Test of Visual Perceptual Skills-3 (TVPS-3), Navon Task, Kaufman Test of Educational Achievement, Second Edition, Kaufman Brief Intelligence Test, Second Edition, Behavior Assessment Scale for Children, Second Edition, and Autism Spectrum Screening Questionnaire. Three hypotheses examined whether students with ASDs were more likely than TD peers to have: (1) a visual processing bias; (2) fine motor difficulties; and (3) VMI difficulties. Additional hypotheses analyzed the relationship between (4) local processing bias and fine motor difficulties on VMI ability and (5) local processing bias, fine motor difficulties, and VMI difficulties on academic achievement. A series of *t*-tests indicated the TVPS-3 ($p=.72$), Navon Task ($p=.78$), BG-II ($p = .39$), and VMI-V ($p = .14$) were not significantly different between groups. Students with ASDs demonstrated increased difficulty compared to TD students on the NEPSY-II ($p = .01$) and slower completion time on the Navon Task ($p = .01$). Regression analyses for VMI indicated the best predictors for the BG-II ($p < .001$) were the TVPS-3 and Navon Completion Time; the best predictor for the VMI-V ($p < .001$) was the TVPS-

3. Regression analyses indicated that VMI-V predicted all domains of academic achievement. In addition to VMI-V, fine motor skills related to writing achievement, and BG-II related to math achievement. Based on the results, the speed of processing plays an important role on VMI skills and academic achievement, more so than the local processing bias. Although this study may have been impacted by homogeneity in the participants, it investigates a relationship between visual processing biases, fine motor difficulties, visual-motor integration and academic achievement that has received little attention in the literature. Findings can inform the development of more effective interventions for academic functioning for students with ASDs.

VISUAL, MOTOR, AND VISUAL-MOTOR INTEGRATION DIFFICULTIES IN
STUDENTS WITH AUTISM SPECTRUM DISORDERS

by
Kimberly Oliver

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ABBREVIATIONS

ASD	Autism Spectrum Disorder
VMI	Visual-Motor Integration
BG-II	Bender-Gestalt Test-Second Edition
VMI-V	Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition
NEPSY-II	NEPSY Second Edition
TVPS-3	Test of Visual Perceptual Skills-3

CHAPTER 1

THE IMPACT OF VISUAL, MOTOR, AND VISUAL-MOTOR INTEGRATION PROCESSES ON THE ACADEMIC ACHIEVEMENT OF STUDENTS WITH AUTISM SPECTRUM DISORDERS

Autism spectrum disorders (ASDs), which include Autistic Disorder, Asperger Syndrome, and Pervasive Developmental Disorder – Not Otherwise Specified, are developmental and neurological disorders that affect an individual's social, communicative, and behavioral functioning (American Psychological Association [APA], 2000; Centers For Disease Control and Prevention [CDC], 2010). ASDs affect 1 in every 110 U.S. children (CDC, 2010). From 1992 to 2006 there was a 1,342% increase in the number of children serviced through the Individuals with Disabilities Education Act (IDEA) Autism eligibility criteria (Sansosti, Powell-Smith, & Cowan, 2010), and it was suggested that at least 300,000 school-aged children have an ASD (CDC, 2010). According to the U.S. Department of Education (2009) the percentage of children with ASDs who spend 80% of their school day in general education classrooms has increased from 4.8% in the 1990-1991 school year to 29.1% in the 2003-2004 school year. The percentage of students served in general education classrooms was expected to increase rather than decrease with the continued implementation of the No Child Left Behind Act (Whitby, Travers, & Harnik, 2009). This suggests that interventions targeting the academic achievement of students with ASDs are of increasing importance for school psychologists, teachers and other school personnel (Hess, Morrier, Heflin, & Ivey, 2008).

Researchers have suggested that the social impairments observed in individuals with ASDs are a key component of the disorder (Heflin & Alaimo, 2007; Johnson, Myers, & and the Council on Children With Disabilities, 2007). Patterns of social

impairments have been identified that may include a lack of engagement, disinterest in joint activities, and a lack of symbolic or imaginative play (Gamliel & Yirmiya, 2009).

The social deficits that may affect individuals with an ASD can lead to distractibility and focusing on small or inappropriate details; which may resulting in difficulty understanding social and environmental cues (Heflin & Alaimo, 2007).

In addition to social impairments, there are communicative deficits associated with ASDs, which may include a lack or delay in spoken language, difficulty sustaining conversations, and stereotyped use of language (APA, 2000). These impairments may impede an individual's ability to understand figurative language, begin and maintain conversations, and utilize pragmatic language skills (Heflin & Alaimo, 2007; Kutscher, 2005). These communication deficits may affect a student's ability to focus on class room instruction; and their ability to formulate appropriate responses in class discussion (Wilczynski, Menousek, Hunter, & Mudgal, 2007).

Stereotyped and restricted patterns of behaviors and interest are the third domain of symptoms third area impacted for individuals with ASDs (APA, 2000). These patterns of behaviors and interests are observed as abnormal preoccupations, inflexibility in routines, and stereotyped and repetitive movements such as hand flapping (APA, 2000; Johnson et al., 2007). These patterns of behaviors and interests may get in the way of learning new information, negatively impact the student's ability to adjust to changes in the day, and cause peer alienation (Johnson et al., 2007).

In addition to the three diagnostic areas, ASDs have been identified by researchers as neurological disorders that also affect many aspects of an individual's sensory perceptions and processes (Akshoomoff, Pierce, & Courchesne, 2002; Brasic &

Gianutsos, 2000). Visual and motor processing (Beversdorf, 2001a), and auditory, tactile, and vestibular perceptions (Heflin & Alaimo, 2007) are among the sensory systems that research has shown to be affected by ASDs. These variations are suspected to cause the differences in sensory input observed in individuals with ASDs (Johnson et al., 2007).

Experienced developmental pediatricians, child neurologists, psychologists, or psychiatrists can make a reliable diagnosis for ASDs at two years of age (Lord et al., 2006). However in the report published by Rice (2007) for the U.S. Department of Health, mean age of diagnosis in the United States ranges between 4.5 and 5.5 years of age (Rice, 2007). The report does note that even in the absence of an early ASD diagnosis, 51% – 91% of the children diagnosed with ASDs had documented concerns about their development by age 8 (Rice, 2007). Students with less severe cases of ASDs are often not identified until they enter school (Brock, Jimerson, & Hansen, 2006; Ysseldyke, 2006). In schools, comprehensive educational evaluations are completed by a multi-disciplinary team that can include: teachers, school psychologists, speech-language pathologists, occupational therapists, and parents to determine the scope of a child's educational needs (IDEA, 2004). Educational evaluations determine whether a child meets the IDEA eligibility criteria; as well as gathering information to assist in academic and social intervention planning and educational placement (IDEA, 2004). Educational evaluations are completed for diagnostic purposes. The completion of a comprehensive educational evaluation for eligibility into special education is intended to produce information that could be used to identify academic, social and emotional areas that can be targeted for intervention (IDEA, 2004). It is important the educational evaluations of

students with ASDs not only include academic, intellectual, social, and emotional functioning, but information about their sensory processing as well (IDEA, 2004).

Visual, Motor, and Visual-Motor Integration for Children with ASDs

Visual, motor, and visual-motor integration (VMI) sensory differences can directly impact the reading, writing, and attending abilities of students in the classroom (Sanghavi & Kelkar, 2005); making it challenging for students to meet academic goals even when they have the cognitive capacity. When sensory processes such as visual-motor integration impact a student's ability to perform academic tasks, teachers may not be able to fully ascertain what a student has learned (McHale & Cermak, 1992; Sanghavi & Kelkar, 2005). According to McHale and Cermak (1992), the completion of many teacher assigned academic tasks is dependent of visual, motor, and visual-motor integration (e.g., reading, writing, and math). According to Kulp (1999), a student's VMI difficulty was positively correlated with teacher perception of academic success on tasks such as reading, writing, spelling and math. This is important because teacher perception of student performance is positively correlated to standardized measures of academic achievement. This suggests that visual-motor integration skills may have a relationship to student academic achievement, independent of intellectual functioning (Kulp, 1999). Although Kulp's study was not causal, the results suggest that improving a student's visual-motor integrations skills may positively influence their academic achievement.

Although academic outcomes have not typically been the focus of ASD research, the presence of students with ASDs in the general education setting has been increasing (Delano, 2007). Similar to their peers, educational curriculum and interventions implemented for the academic achievement of students with ASDs are legally mandated

to be aligned with state and federal educational standards (Delano, 2007). Students with ASDs have differences in their visual, motor- and visual-motor integration processes that may necessitate interventions that are targeted toward utilizing their strengths and minimizing the negative effects of their weaknesses (Frith, 1970; Milne, Griffiths, Buckley, & Scope, 2009; Ming, Brimacombe, & Wagner, 2007; Novales, 2006; Provost, Heirnerl, & Lopez, 2007; Volker, Lopata, Vujnovic, et al., 2010). Improving a student's performance on academic tasks may positively affect self-esteem, and decrease student anxiety, all of which may decrease disruptive behaviors (MacDonald, 2010). It is important that the academic needs of students with ASDs be considered due to their increased presence in general education classrooms and other inclusive settings. There is also research to suggest that the academic engagement of children with ASDs can lead to decreased behavioral difficulties in the classroom (Whitby et al., 2009). Reducing these behaviors can have positive social impacts on the students (Johnson et al., 2007); as well as increasing a student's time in class, if the behaviors had been severe enough to warrant removal (Whitby et al., 2009).

The Role of the School Psychologist

School psychologists are expected to be knowledgeable about diagnostic issues and effective intervention practices in order to aid in analyzing student difficulties, communicating effective intervention plans to teachers, and aiding in the evaluation of interventions (Decker, Bolt, & Triezenberg, 2006). School psychologists are valuable as consultants to teachers and other members of the multidisciplinary team working with students who have an ASD by providing assessment information that is used to help determine a student's educational needs (National Association of School Psychologists

[NASP], 2010). School psychologists also are expected to provide insights to the various educational strengths and weaknesses associated with many ASDs, and communicate that information to teachers effectively (Decker et al., 2006). As consultants, school psychologists help teachers and other members of the multidisciplinary team identify and develop appropriate interventions and methods of evaluating those interventions in the classroom (Hosp, 2006). School psychologists are supportive members of the multidisciplinary team who are able to not only assess a student's strengths and weaknesses, but also help with researching and developing interventions that can help students with ASDs in the classroom (Hosp, 2006).

The purpose of this article was to discuss the impact of visual-motor integration, visual perception, and motor processing abilities on the academic achievement of students with ASDs. Visual, motor, and visual-motor integration skills affect a student's ability to complete daily academic tasks, and it is important to assess and intervene in these areas to improve achievement. This article will conclude with intervention strategies for school psychologist and educational professionals to provide support for students with ASDs to help promote academic success in the educational environment.

Visual-Motor Integration

Visual-motor integration is the process of perceiving patterns and using one's hands in coordination with a response to the visual percept (Sanghavi & Kelkar, 2005). Visual-motor integration skills are important due to their contribution to the normal development of manual dexterity, coordination, speed, balance, and writing (Dawson & Watling, 2000a). Many of the academic tasks that students with ASDs encounter in school are based on the integration of visual and motor skills as opposed to visual or motor processing in isolation (Erhardt & Meade, 2005; Ratzon et al., 2009). For

example, in order to produce or reproduce written patterns one must translate what one sees into specific motor output (Sanghavi & Kelkar, 2005). Identification of students who have ASDs with poor visual-motor integration skills is an important skill for school psychologists. Often school psychologists help suggest appropriate reading, writing, and spelling interventions used improve difficulties.

Individuals with ASDs appear to have differing abilities in the area of visual-motor integration, and the visual perception and fine-motor processes that are related. Novales (2006) found that individuals with an ASD performed significantly lower on visual-motor integration tasks than typically developing peers. Beversdorf (2001a) suggested that individuals with ASDs exhibited macrographia in copying tasks. These results suggest that the visual-motor integration process for students with ASDs is impacted by a tendency to enlarge figures during copying tasks, which may affect the amount of time students need to write, as well as the space for writing. School psychologists should note differences in handwriting speed, legibility of writing, and copying may affect a student's ability to complete academic task (such as essays on a test and note-taking) that rely on the coordination of visual-motor ability.

Individuals with ASDs may have difficulties in visual, motor, and visual-motor processing that impact their writing, and ability to meet social and academic goals. Although there is little research on visual motor-integration skills in students with ASDs, the academic difficulties described in the isolated areas of visual and motor processing contribute to those seen in visual-motor integration (Ratzon et al., 2009). For this reason, it is critical to review the literature on visual perception and motor difficulties of students with ASDs and the subsequent academic outcomes.

Visual Perception

Visual perception includes both receiving and interpreting visual stimuli (Barry, 1997). During the visual perception process, the brain receives signals from the environment and works to create meaning that results in the image that is perceived (Barry, 1997). Visual perception is a complex system with many parts including the anatomy of the eyes and brain, as well as the functioning of neurotransmitters (Carlson, 2007; Karlsdottir & Stefansson, 2002). Clinical evaluation of visual perception typically falls under three areas: acuity, efficiency, and information processing (Karlsdottir & Stefansson, 2002). Visual acuity refers to sharpness of vision; visual efficiency refers to accommodating vision to depth and distance, binocular alignment, and eye movements; and information processing refers to the organizing of visual stimuli (Karlsdottir & Stefansson, 2002). The process of visual perception described is important to the completion of academic tasks involving writing, reading, sequencing, and memory (National Center for Learning Disabilities [NCLD], 2003). School psychologists should be aware that students with visual perception difficulties may have academic problems that include discriminating between letters, numbers and shapes; finding specific information in the presence of competing visual stimuli; ordering words and keeping one's place while reading; and recognizing words and adhering to conventional spacing between letters in a word and also spacing between words (Pennington, 2009).

Visual perceptual abilities are important to the success of all students including children with ASDs. There are multiple aspects involved in visual perception; however, near point convergence and local-global processing are the focus of this article, because of their direct impact to academic achievement. Visual convergence is the measure of sharpness and focus when using both eyes together (Carlson, 2007). Difficulties in visual

convergence might cause physical discomfort of the eyes, and an unwillingness to continue tasks that require an individual to sustain visual attention over time and alternate quickly between visual stimuli. The problems in near point convergence could contribute to the visual symptoms associated with ASDs such as looking out the corner of one's eyes, and poor eye contact (Coulter, 2009). These visual preferences might affect a student's ability to perceive visual stimuli appropriately in the classroom, and lead to focusing on irrelevant visual information. An individual's ability to focus, and maintain that focus for extended periods of time, is important for completing the near point visual tasks required in reading, writing, and spatial activities (Ponsonby et al., 2009). During an observation, school psychologists may observe students exhibiting off-task, refusal/non-compliance, and stereotypical behaviors during academic tasks that require sustained visual attention such as reading (Milne et al., 2009).

In addition to convergence research, research by Frith (1989) indicated that individuals with ASDs process visual information in a detail-focused manner. This differed from neurotypical individuals who had a tendency to process information using a holistic or gestalt approach (i.e., employing central coherence) (Grinter et al., 2009; Morgan, Maybery, & Durkin, 2003; O'riordan, 2004; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). Neurotypical individuals tended to see the whole object and processed information based on the central theme or idea, sometimes to the disregard of specific details, whereas individuals with ASDs did the opposite (Best, Moffat, Power, Owens, & Johnstone, 2008; Bölte, Holtmann, Poustka, Scheurich, & Schmidt, 2007; Brosnan, Scott, Fox, & Pye, 2004; Lopez, Leekam, & Arts, 2008; Pellicano, Maybery, Durkin, & Maley, 2006; Shah &

Frith, 1993; South, Ozonoff, & McMahon, 2007; Wang et al., 2007). Researchers describe this local processing bias as the tendency to perceive the smaller parts that make up that picture and then the whole (Kimchi, 1992; Kimchi & Palmer, 1982; Plaisted, Swettenham, & Rees, 1999). Bölte et al. (2007) also found that individuals with ASDs were less likely to use the gestalt principles of similarity, proximity, and closure than the comparison groups. The data collected from individuals with ASDs in the areas of gestalt processing and central coherence indicated that there may be a reliable distinction in the performance of these tasks (Bölte et al., 2007; Brosnan et al., 2004; Lopez et al., 2008).

Academically, school psychologists will find that students with ASDs may have difficulty regularly meeting classroom demands (Mayes & Calhoun, 2007). Students with an ASD may have difficulty attending to the appropriate parts of visual instructions, or become overwhelmed processing information in discrete parts rather than holistically (Landry, Mitchell, & Burack, 2009; Mayes & Calhoun, 2007). Students might have difficulty correctly completing work if they focus on superfluous material rather than the appropriate prompts (Whitby et al., 2009). For instance, in math word problems students could answer incorrectly if they attended to the wrong or extra details rather than the information necessary to answer the question. The local processing bias may make it difficult for students with an ASD to accurately plan and accomplish academic tasks that rely on more gestalt processing such as comprehending what has been read and writing essays and reports, without teacher intervention (Whitby et al., 2009).

However, academic strengths include the student's ability to perceive the parts, and can be used to regulate the possible negative academic impacts. In the example with

word problems, students with a tendency toward local-global processing can be taught how to appropriately interpret pieces that will allow them to draw the same conclusions rather than being taught to capitalize on understand the gist of the question for guidance. Students with an ASD would be skilled at finding key words and using those paragraph map things. Students with an ASD will be at risk for easy frustration when tasks are long and require not only that they sustain visual attention, but that they are able to move from the local processing to global understanding while doing so. Teachers may report to school psychologists that the student has difficulty staying on-task, becomes disruptive in the classroom, or gives up easily, which may stem from difficulties with visual comprehension, visual distractability, and sustained near point focus.

Motor Processing

Motor processing includes an individual's gait, balance, manual dexterity skills, graphomotor abilities, and contribute to higher-order skills such as imitation, and movement planning and execution (Provost et al., 2007). Motor processing may impact a student's ability to coordinate physical movements necessary for writing, playing, grooming, and speech development (Jackman & Stagnitti, 2007; National Center for Learning Disabilities, 2006). Gross and fine motor processing such as gait, manual dexterity, and balance have been a focus of research examining motor processing in ASDs (Hilton et al., 2007; Noterdaeme, Mildenberger, Minow, & Amorosa, 2002); difficulties with these processes impacted academic tasks that children are faced with in the school environment. Motor difficulties can further impact a student's ability to interact confidently with peers and affect self-perception (Piek, Baynam, & Barrett, 2006), as well as influence academic achievement (Feder & Majnemer, 2007) resulting in additional learning problems (Sullivan & McGrath, 2003).

According to researchers (Ghaziuddin, Butler, Tsai, & Ghaziuddin, 1994; Green et al., 2002; Hilton et al., 2007; Manjiviona & Prior, 1995; Matson, Mahan, Fodstad, Hess, & Neal, 2010) both gross and fine motor skills in individuals with ASDs were significantly lower than comparison groups (i.e., neurotypical, language disorders, and motor disorders). In addition, research indicated that individuals with ASDs may have difficulties reaching developmental motor milestones within typical time frames, clumsiness and coordination problems, difficulties with motor control and planning, problems with motor imitation, and fine motor movement difficulties (Ming et al., 2007; Provost et al., 2007). Individuals with ASDs also may have poor coordination and difficulty with manual dexterity task such as writing and cutting paper (Hilton et al., 2007; Manjiviona & Prior, 1995; Noterdaeme et al., 2002).

Green et al. (2002) studied the gross motor abilities of 11 students with Asperger Syndrome and nine students with significant motor delays and found that all the participants with Asperger Syndrome displayed clinically significant motor delays. Hilton et al. (2007) examined the relationship between severity of ASD and motor skills, and their results indicated a positive relationship between the severity social impairments in ASDs and gross motor difficulty (manual dexterity, ball skills, and static and dynamic balance). The recorded motor difficulties observed in ASDs suggest that in addition to classroom intervention and assessment provided by school psychologists, the involvement of an occupational therapists and/or a speech-language pathologist may be necessary to fully meet their educational needs (Ponsonby et al., 2009).

Students with an ASD might suffer academically because fine motor abilities are particularly important in order for teachers to evaluate what a student has learned,

because they affect handwriting (Feder & Majnemer, 2007; Jackman & Stagnitti, 2007). Handwriting is important because it is used in approximately 60% of a student's academic day (McHale & Cermak, 1992). School psychologists may observe that the effects of fine motor difficulties can significantly impact writing and result in problems with spelling, written expression, and reading (Feder & Majnemer, 2007; Lahav, Apter, & Ratzon, 2008; Pennington, 2009). The poor coordination, difficulty with manual dexterity, and poor fine motor planning can affect legibility and speed, which are the two most important aspects of written expression (Feder & Majnemer, 2007). It is important for a student to be able to meet the classroom demands of writing quickly, but it also is important that both the student and the instructor be able to read what has been written. The difficulty of meeting these classroom demands might cause students with an ASD additional stress and behavioral problems when they are not able to meet academic goals (Feder & Majnemer, 2007).

When students have problems in these areas, school psychologists may get reports that the students walk and run with a different gait than their peers, there is interference with the students' ability to efficiently complete tasks without falling or dropping objects, and it takes students too long to complete tasks (Floet & Maldonado-Durán, 2010). School psychologist should be aware that students with motor processing difficulties (i.e., developmental coordination disorder, dyspraxia, or motor skills disorder) might struggle in many of the areas mentioned above. These difficulties may affect their academic achievement, as well as their ability to initiate and maintain positive social relationships with teachers and peers (Jackman & Stagnitti, 2007; Noterdaeme et al., 2002; Piek et al., 2006).

Interventions for Students Who Have ASD

The accurate integration of the visual-motor process is critical for academic success (Marr, Windsor, & Cermak, 2001). All students use visual-motor processing to meet the classroom requirements of taking notes from a board, learning to write letters, and copying from text books (Feder & Majnemer, 2007; Kulp, 1999; Sanghavi & Kelkar, 2005). Students with an ASD have unique patterns of visual and motor difficulties that may impact their classroom performance on visual, motor, and visual-motor tasks (Novales, 2006; Volker, Lopata, Vujnovic, et al., 2010). These processes are important for the academic success of students with ASD and school psychologists should incorporate assessments and interventions for these difficulties. Multiple types of interventions helpful in assisting students with an ASD in meeting classroom goals include allowing students to use computers, record lectures, present oral rather than written reports, and providing written notes to students ahead of time (NCLD, 2003). The intervention strategies provided target skill building and easing the sensory demands associated with tasks, which are affective with students who have ASDs (Tan, 2007). The figures described within the text detail accommodations that teachers can use to ease sensory demand of academic tasks or develop compensatory strategies, and teach skills more intensively or break them into smaller components to teach more effectively. It is important that school psychologists, and others working with the student, take the unique visual, motor, or visual-motor processing difficulty into account when planning specific intervention for students with an ASD.

Visual-Motor Difficulties and Intervention Strategies

Although there is a lack of research on the impact of visual and motor ability on the visual-motor process, academically it is the integration of these abilities that impact

most tasks that students are required to perform to achieve success in school (Erhardt & Meade, 2005; Ratzon et al., 2009). As students progress through school, the need for interventions that address the process of visual-motor integration becomes important, because the assessment of learning becomes increasingly dependent on written expression skills (Asaro-Saddler & Saddler, 2010; Pennington, 2009). In order to meet academic goals, students are required to interpret visual stimuli into written material while taking class notes from overheads, note-taking from books, written expression activities (e.g., essays, sentence completion, written responses to reading), math, and geometry (Dawson & Watling, 2000b; Marr et al., 2001; Sanghavi & Kelkar, 2005).

Written expression is one of the most important academic skills used by all students to demonstrate knowledge (Asaro-Saddler & Saddler, 2010; Pennington, 2009), and is greatly impacted for students with ASD (Pennington, 2009; Whitby et al., 2009) and visual-motor integration difficulties (Erhardt & Meade, 2005; Ratzon et al., 2009; Tseng & Chow, 2000). According to Kurth and Mastergeorge (2010) 26% of the academic goals for students with ASDs in the general education classroom are in the area of writing. Students with ASDs typically have difficulties with imagining and elaborating on the future, organizing, and self-regulation (Asaro-Saddler & Saddler, 2010). Additionally, their expression can be affected by poor planning (Asaro-Saddler & Saddler, 2010; Ming et al., 2007). All of which can be further impacted when visual-motor integration difficulties exist (Beverdors, 2001a; Novales, 2006).

As consultants, school psychologist can be involved in suggesting multiple evidence-based strategies for teachers to use when intervening with a student who has an ASD and visual-motor difficulty, which have been included on Figure 1. School

psychologists can suggest that students use computers to ease the motor demands associated with handwriting during classroom activities such as essay writing or note taking (Pennington, 2009). School psychologists also can encourage teachers to develop handouts that increase the student's ability to follow lectures without spending too much attention on the process of viewing written information on the board and then writing it themselves (Koenig, Bleiweiss, Brennan, Cohen, & Siegel, 2009; MacDonald, 2010; Pennington, 2009). This can be an important helping tool for students with ASDs and visual-motor integration difficulties because they allow the student access to the important class information, and help the student visual see what is important in an audible lecture. Teachers can be encouraged to allow students to present verbal answers to questions as opposed to a written essay (Pennington, 2009). Teacher can assess oral responses and written essays similarly for understanding of material, accuracy of response and clarity.

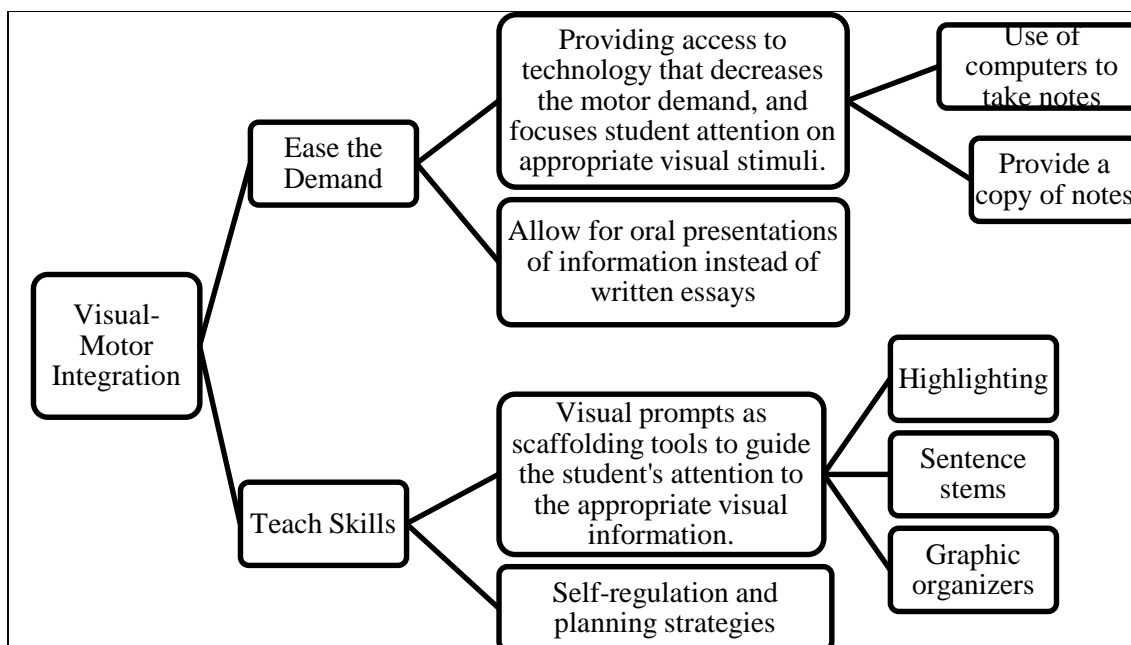


Figure 1. Visual-Motor Integration Strategies. This figure illustrates intervention

strategies that can be suggested to ease the demand of visual-motor integration tasks or teach students skills that will promote independence.

School psychologists may consult with teachers on ways to scaffold skills and better prepare students with ASDs and visual-motor integration for later challenges. Visual prompts, such as highlighting are useful in helping students understand what to focus on when reading a textbook to answer questions appropriately (Griffin, Griffin, Christine, Albera, & Gingras, 2006). School psychologists may suggest using sentence stems to help students figure out how to organize responses, visually identify important information within the text that is associated with the answer, and teach them to provide clear written responses. Graphic organizers (e.g., story maps, math organizers, note-taking maps) also are useful in helping students understand the parts of a task and breaking them apart into smaller, more accomplishable parts (Griffin et al., 2006).

Teaching students to use graphic organizers will allow them more independence in their work; and graphic organizers are readily available on the internet. School psychologists also should encourage teachers, and others working closely with students, to teach strategies for planning, writing, revision (Pennington, 2009; Whitby et al., 2009), and self-regulation strategies (Asaro-Saddler & Saddler, 2010; Delano, 2007) which have been shown to be beneficial for students with ASDs. Interventions that incorporate teaching students who have ASDs strategies for completing visual-motor integration activities provide them with tools that increase independent work by giving explicit step-by-step instructions on how to complete tasks, and allowing the students time to practice or repeat tasks while they are completing academic assignments (Floet & Maldonado-Durán, 2010).

Visual Difficulties and Intervention Strategies

Research indicates that students with ASDs have visual difficulties in the areas of visual acuity and convergence (Carlson, 2007); in addition to a tendency toward local-global processing (Bölte et al., 2007; Kimchi, 1992; Morgan et al., 2003; Wang et al., 2007). In order to intervene appropriately, teachers, school psychologists and others working with these students need to be aware of behavioral signs that might indicate problems in these areas. Identifying these difficulties, and how they affect academic performance, will allow educational personnel to apply the most appropriate interventions to suit the student's needs. This section describes specific behavioral and performance difficulties that may be observed in a range of school settings (e.g., individual testing, transition time, classroom) by school personnel as well as the intervention strategies to address these difficulties.

During an observation or assessment, a student with an ASD and convergence difficulties may vocalize complaints of blurred vision during reading activities, math activities, or while looking at the board; these complaints are not related to a need to wear glasses (American Association of Certified Orthoptists, 2011). It is important for school psychologists to involve the school nurse and other individuals who can adequately, and accurately, measure the student's visual abilities during assessments in order to rule out poor vision as a cause for the complaints.

Teachers may observe that the student does not complete assignments within given periods, or refuses to complete work once they have begun. Over time, teachers and others working with the student may note refusal to begin tasks. During assessments, school psychologists might observe students with ASDs and visual acuity and convergence difficulties might becoming more distractible during reading and writing tasks, as well as visual memory and problem solving tasks. It is important for school psychologist to note that these difficulties do not indicate that students will have difficulty accurately completing visual assessment activities, rather the length of time or the continuation of the activities may become frustration for these students, and resistance may become a concern over time.

Researchers suggest that students with ASDs have a tendency to process information in parts rather than the whole (Bölte et al., 2007). This compounds visual acuity and convergence difficulties because students will require more time than their peers to visually decipher information (Wang et al., 2007). As a weakness, the local-global processing tendency may increase the difficulty and overwhelming nature of academic tasks that rely on gestalt processing and visual attention, because students

might struggle with understanding how to begin and continue tasks, as well physical frustration from eye strain (Kimchi, 1992; Kimchi & Palmer, 1982; Plaisted et al., 1999).

Due to these unique difficulties, teachers, school psychologists, or other professionals may notice that a student with ASDs has increased difficulty with academic tasks such as reading and writing that require sustained visual attention (Milne et al., 2009). Academically, this might affect a student's ability to participate in class reading activities, reading comprehension, successfully completing tests without breaks, and other classroom tasks that rely on continued visual attention without breaks (Goodman & Williams, 2007). These abilities are important for a student's academic success across the curriculum (Pennington, 2009; Whitby et al., 2009). Additionally, students with ASDs may suffer from low frustration tolerance for these tasks; increasing noncompliance, self-soothing behaviors such as rocking, verbal-disruptions, and escape behaviors (Patterson, Smith, & Jelen, 2010). The following sections will address specific interventions for the difficulties described above.

School psychologist should be aware that orthoptic exercises (e.g. visual fixation exercises) specifically performed to increase the sustainability of visual acuity and convergence are the most direct methods of intervention (Ponsonby et al., 2009). Appropriate visual assessments should be completed, and the involvement of an orthoptist who was trained to provide interventions that specifically target ocular motility and vision related problems might be the method of most direct intervention. There are also academic intervention strategies that can benefit the student's day-to-day performance on classroom assignments. The recommendations listed in Figure 2 are suggested to reduce the visual demands of academic tasks, and to provide strategies that

prepare students with ASDs for difficult tasks in the future (Asaro-Saddler & Saddler, 2010; Griffin et al., 2006). School psychologists might suggest that teachers provide students with one written direction at a time in order to decrease the amount of visual stimuli present (Williams, 1995). This would allow the student the opportunity to process one directive and decrease the likelihood of becoming overwhelmed. School psychologists may recommend giving the students assignments that had more white space, which would decrease the amount of visual information on one page that the student with ASDs would have to process (Griffin et al., 2006). School psychologist also might suggest giving students more time during tasks that require reading or writing for longer periods. This will allow the student an opportunity to have the task broken into parts, and the chance to take breaks from the visual stimuli and decrease the strain and frustration.

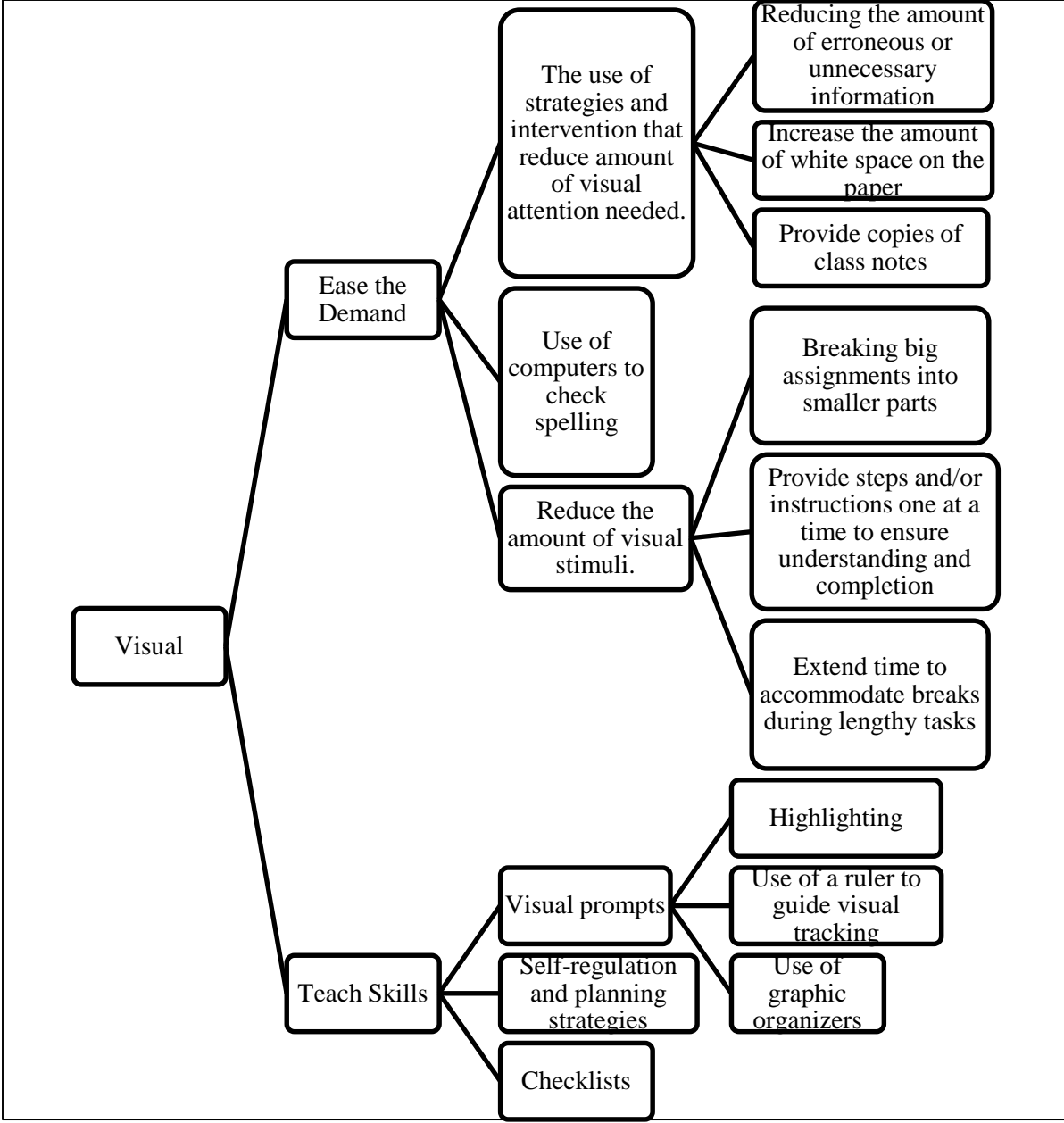


Figure 2. Visual Strategies. This figure illustrates intervention strategies that can be suggested to ease the demand of visual tasks or teach students skills that will promote independence

The recommendations listed in Figure 2 that can be used as strategies to help prepare students use the local processing bias often seen in ASDs as a strength for the intervention development. Intervention strategies that include explicitly teaching students how to appropriately dissect reading and writing tasks that may decrease the need for extra time, by teaching students what aspects are important to focus on (Hsu-Min & Yueh-Hsien, 2007; Lerman, Vorndran, Addison, & Kuhn, 2004). School psychologists may note that many successful interventions for students with ASDs include the use of visual schedules, breaking assignments into smaller components, and the use of graphic organizers and story maps (Griffin et al., 2006; Koenig et al., 2009). These types of interventions help students understand not only the activities of the day, but also the sequencing of those activities while using local processing bias as a strength when completing global tasks (Koenig et al., 2009; National Center for Learning Disabilities, 1999). Additionally, there is structure provided with visual schedules and graphic organizers that allow the student to see and understand the smaller parts that need to be accomplished to complete the task, and a reduction in the amount of visual attention needed to dissect and organize this information themselves (Goodman & Williams, 2007). This structure helps the student to stay focused on the appropriate elements, and potentially decreases the likelihood of frustration (Koenig et al., 2009).

Motor Difficulties and Intervention Strategies

Appropriate motor development and abilities are important to a student's successful completion of writing tasks, can impact spelling, written expression, and reading (Feder & Majnemer, 2007); as well as a student's ability to interact with peers and affect self-perception (Piek et al., 2006). School psychologist should be sure that the

student's motor abilities are appropriately assessed by an occupational therapist and addressed if they are significant enough to warrant more intensive intervention than can be provided in the classroom. In addition to orthopedic exercises and occupational therapist interventions, additional classroom interventions can be utilized to help with the completion of academic tasks in the interim. This section describes specific behavioral and performance difficulties that may be present for students who have ASDs in addition to motor difficulties, as well as the intervention strategies to address these difficulties.

School psychologists working with students with ASDs should pay particular attention to teacher observations of poor handwriting, refusal to write, difficulty with manual dexterity tasks such as paper cutting, and gluing and taping. Students may exhibit difficulty completing fine motor tasks in the classroom, or completely refuse to do them. Difficulty with fine motor skills may negatively affect a student's ability complete paper and pencil tasks such as worksheets, bookwork, create projects, and write stories. In addition, many norm-reference tests that student's take such as the criterion referenced competency tests require students to bubble in answers, and maintain fine motor control as to not make stray marks that could decrease their scores on the assessments. As students with ASDs get older and the academic demands change, students are required to attend to a board or overhead for pertinent information, take notes while listening to a teacher talk, and write in various forms to exhibit their knowledge of a subject area.

The types of motor demands change academically over time, and it is important that school psychologists suggest interventions that are age and grade appropriate to ensure their effectiveness (MacDonald, 2010). In earlier grades, a student with an ASD may need their motor planning and control addressed, however in upper grades written

expression interventions may be primary. School psychologists can work with teachers to help make recommendations that allow the student to display information in an acceptable, academic, age appropriate way, and help the teacher to reduce motor demands that might impede this goal.

Unfortunately, the nature of motor difficulties often causes students to avoid the very activities they need to do in order to improve, practice. Fine motor skill development typically requires that the student practice fine motor movements. Figure 3 provides intervention strategies that can reduce the motor demand of tasks, as well as prepare and improve a student's ability in the future. School psychologists could suggest that teachers provide pre-made parts to cut and paste assignments. This allows the student with and ASD to participate and learn the appropriate information without the frustration of not being able to complete motor task that do not directly relate to learning. School psychologists also might suggests that teachers provide students with necessary materials, such as a personal copy of notes, references to book page numbers, and note-taking maps to help the student stay involved during class lectures (MacDonald, 2010). For students who have ASDs and motor planning problems, the classroom demand of note-taking and attending to auditory information may be difficult and cause students frustration, they might miss important information, fall behind, and experience anxiety (MacDonald, 2010). In order to decrease the motor demands necessary to write papers, school psychologists can suggest that students be taught to type on a computer (typing on a computer introduces different types of fine motor demands), or use speech-to-type software (NCLD, 2006; Pennington, 2009). Writing tasks in upper grades typically involve planning and sustained attention. Students with ASDs would also benefit from

more time to complete in-class writing activities (MacDonald, 2010). This increased time will allow the students with opportunities to take motor breaks.

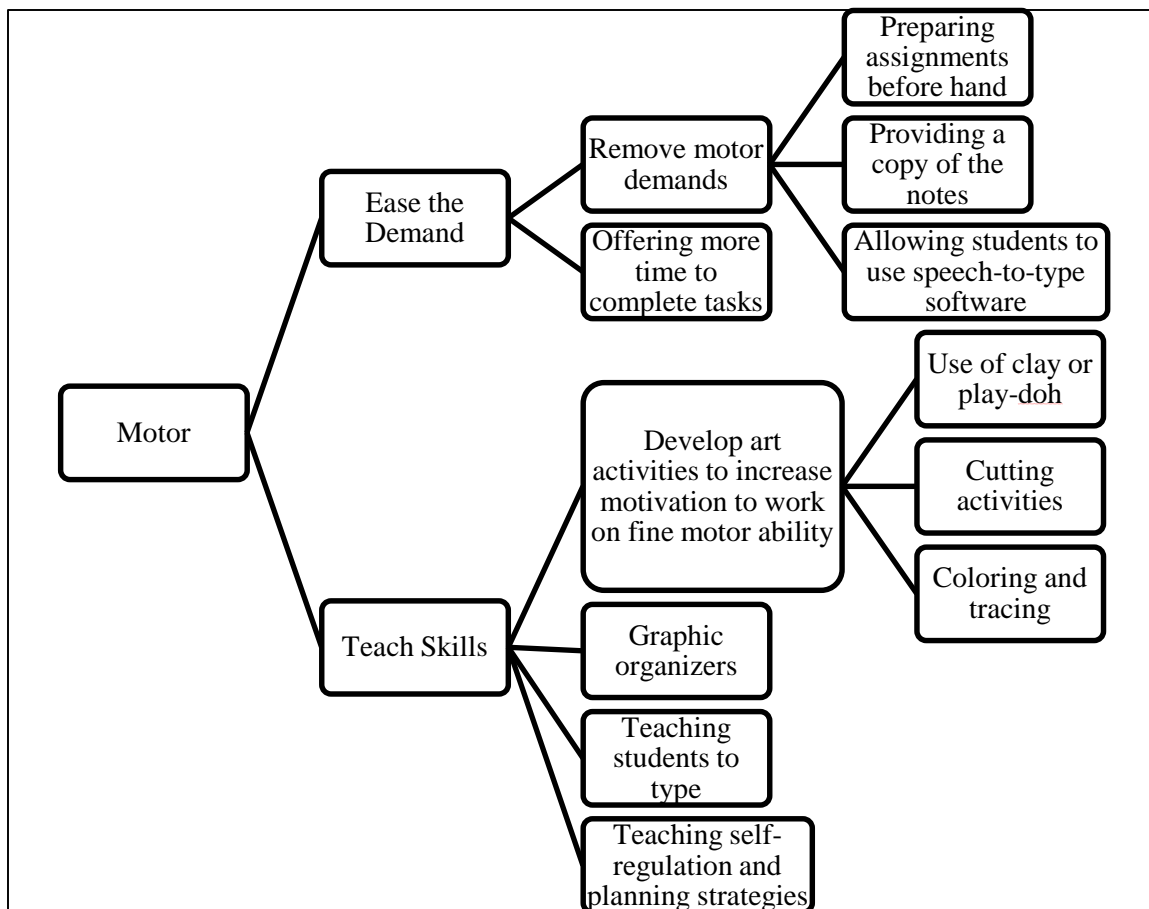


Figure 3. Motor Processing Strategies. This figure illustrates intervention strategies that can be suggested to ease the demand of motor tasks or teach students skills that will promote independence.

School psychologists also should encourage teachers to provide intervention strategies that will improve fine motor skills, and teach students to work more independently with similar tasks in the future. School psychologists might recommend exercises that address this fine motor difficulties in more appealing ways, for example include art activities such as origami, making things in play-doh, and completing mazes. These activities can be tailored to the interest of the student making the activity more

appealing (e.g., mazes can be created that use favorite characters, or they could be asked to make related items out of play-doh or clay). These activities are likely to remain engaging to the student and result in the manual practice needed to gain strength in the student's fine motor planning and control (Ratzon et al., 2009). As strength increases the student's compliance should also increase as these activities will be less physically demanding. When students with ASDs are involved in activities of interest their motivation increases. As the students gain strength in these areas, fine motor writing tasks will become easier in that they will tire less quickly. It is important to note that writing tasks can still be impacted by the visual difficulties that have been described, and therefore even as motor planning and control increases students may still struggle with writing tasks that require sustained visual attention. School psychologists can suggest teaching students to utilize story maps as an intervention for written expression difficulties (Pennington, 2009). Story maps will provide a student who has an ASD with an external, visual method of planning the parts necessary to complete written responses. This planning tool should help the student maintain focus and decrease the amount of writing necessary to formulate a response. Teachers also can be encouraged to providing students with a note-taking map that helps them to focus their attention on the appropriate information. Note-taking maps, similar to story maps, provide a framework that guides the student's attention to the appropriate information decreasing distraction and helping the student stay on track with decreased frustration.

Academic Strategies for students with ASDs

In addition to focusing on the processing areas when providing intervention suggestions, school psychologists should be mindful in using strategies that are appropriate to the academic area of concern. An intervention might be appropriate for

motor difficulties, but not be appropriate for intervening in the academic areas of reading comprehension or math. Figures 4-6 illustrate the relationships between particular processing interventions and specific academic areas.

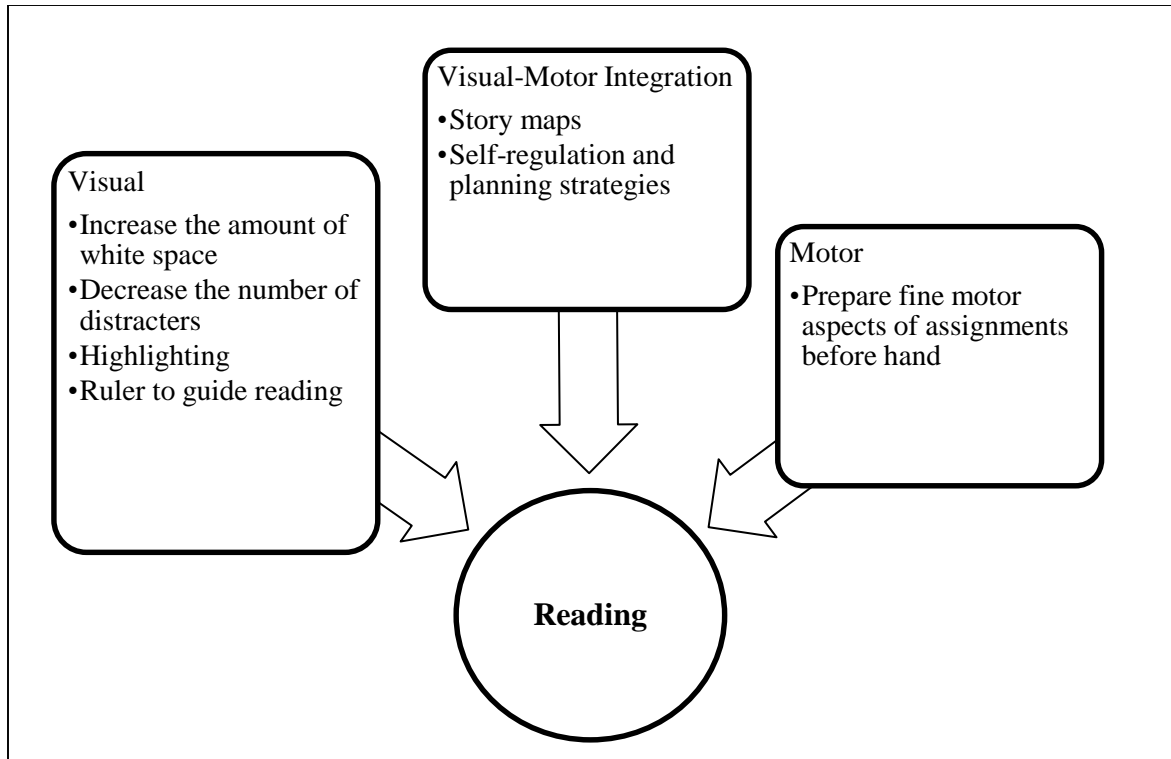


Figure 4. Visual, Motor, and Visual-Motor Intervention Strategies for Reading. This figure illustrates intervention strategies that apply specifically to the academic area of reading.

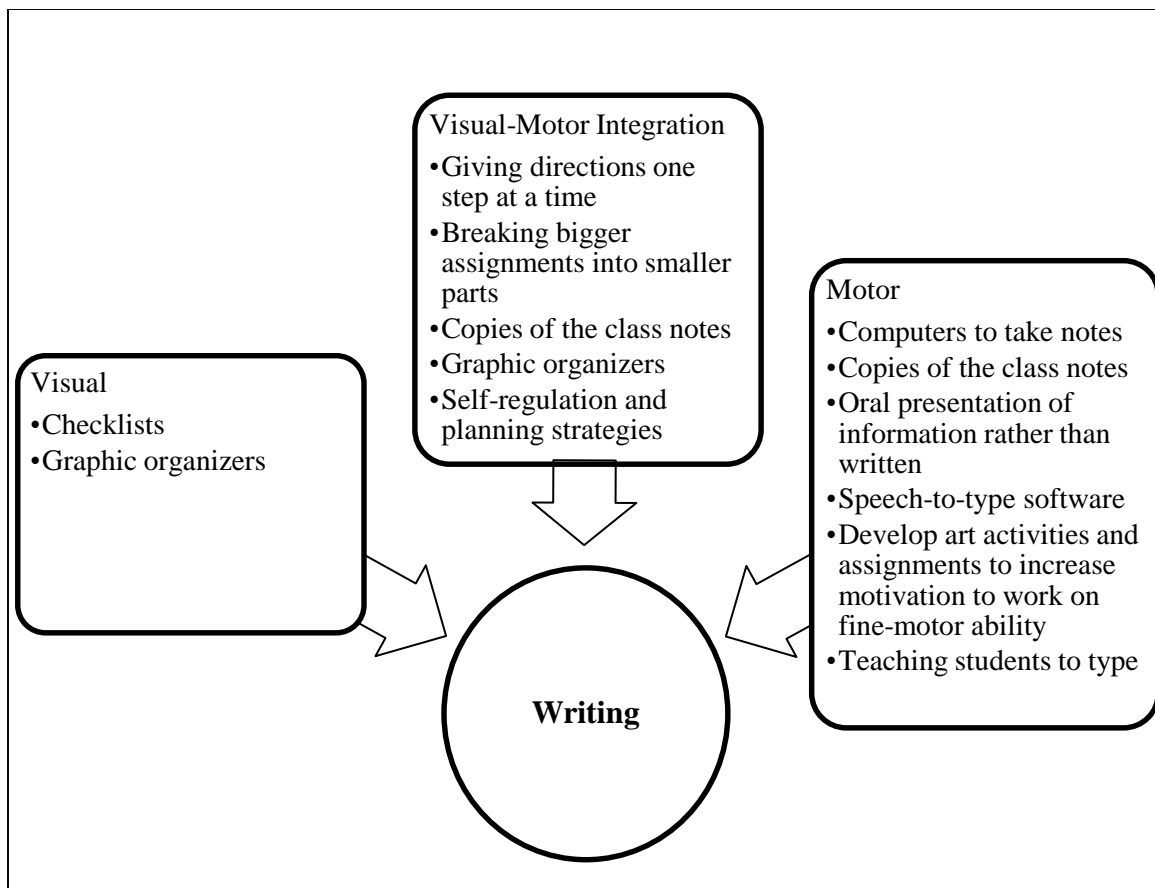


Figure 5. Visual, Motor, and Visual-Motor Intervention Strategies for Writing. This figure illustrates intervention strategies that apply specifically to the academic area of writing.

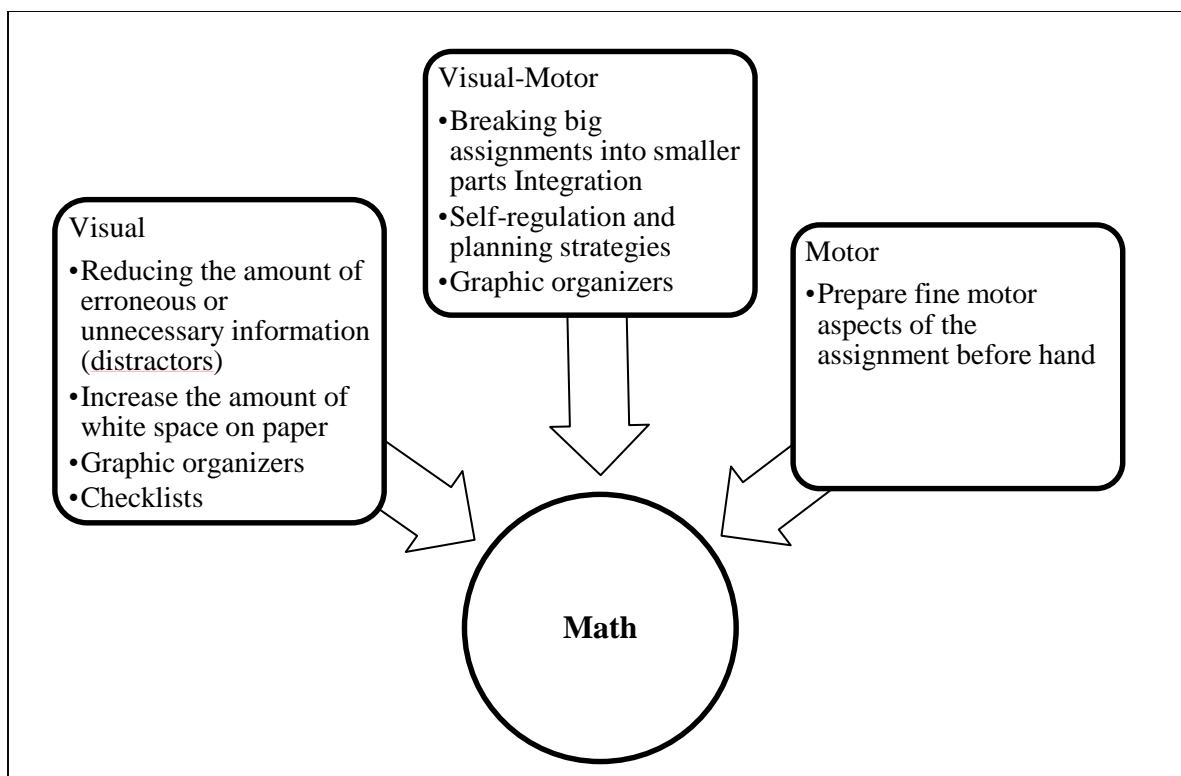


Figure 6. Visual, Motor, and Visual-Motor Intervention Strategies for Math. This figure illustrates intervention strategies that apply specifically to the academic area of math.

Conclusion

Visual perception, motor functioning, and VMI skills are an important factors for students' academic success, and students with ASDs are at risk for additional difficulties in the areas of academic achievement affected by these processes due to their unique profiles. It is important for school psychologist to be aware of both the strengths and weaknesses associated with visual, motor, and visual-motor integration processes when working with students who have an ASD.

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CHAPTER 2

VISUAL MOTOR INTEGRATION AND ACADEMIC ACHIEVEMENT IN STUDENTS WITH AUTISM SPECTRUM DISORDERS

Recently there has been a 1,342% increase in the number of students serviced in the public school system who meet the Autism eligibility criteria (Sansosti et al., 2010). According to the U.S. Department of Education (2009) the percentage of children with Autism Spectrum Disorders (ASDs) who spend 80% of their school day in general education classrooms has increased from 4.8% in the 1990-1991 school year to 29.1% in the 2003-2004 school year. The necessity for teachers and other educational professionals to be informed about the symptoms of ASDs, and academic interventions for educational progress and behavioral difficulties, has increased correspondingly (Whitby et al., 2009). ASDs are neurological and developmental disorders that impact a student's social, communicative, and behavioral functioning (American Psychological Association [APA], 2000; Centers For Disease Control and Prevention [CDC], 2010). Researchers have indicated that in addition to the core diagnostic areas (social, communication, and behavioral functioning), students with ASDs also have differences in their sensory and perceptual processes when compared to typically developing peers (Akshoomoff et al., 2002; Brasic & Gianutsos, 2000). Visual, motor, and visual-motor integration skills are among the sensory systems that students with ASDs show difficulty (Beverdors, 2001b; Novales, 2006), and are the focus of the proposed study due to their potential to impact academic achievement in the classroom (Sanghavi & Kelkar, 2005).

Visual-Motor Integration, Visual, and Motor Processes in ASDs

Visual-motor integration skills are the visual perception of patterns and use of one's hands in coordination to produce a response to that visual percept. Visual

perception is a complex system which includes receiving and interpreting visual stimuli through the coordination of the eyes and brain (Barry, 1997), that impacts the visual-motor integration process. For the purposes of this study a specific visual process referred to as the local processing bias (a tendency to process the parts of visual stimuli at the expense of the whole) is the focus. Fine motor skills refer to the coordination of finger and hand movements that has been found to be impaired in children with ASD (Ming et al., 2007; Noterdaeme et al., 2002).

The Impact of VMI on the Academic Achievement of Students with ASDs.

It is important for practitioners to be aware that visual-motor-integration skills have the potential to directly impact a student's academic success (Sanghavi & Kelkar, 2005), however few studies have assessed the characteristics of these skills in students with ASDs specifically (Beverdors, 2001b; Novales, 2006; Volker, Lopata, Vujnovic, Smerbeck, Toomey, Rodgers,... Thomeer, 2010). Novales (2006) and Volker, et al. (2010) assessed the visual-motor integration skills of school-aged students. Novales' sample included 63 children 8 – 17 years old, and Volker et al. used a sample of 106 children (60 ASD and 46 typically developing) 6 – 14 years old; the researchers found that students with ASDs scored significantly lower than the standardization group and the typically developing comparison groups on tests of visual-motor integration. However, neither study explored the relationship between visual-motor integration and academic achievement, or the relationship between visual-motor integration and its core components (i.e., visual perception and fine motor ability), for students with ASDs. This information is important for practitioners when developing and implementing interventions (Feder & Majnemer, 2007; Kulp, 1999; Sanghavi & Kelkar, 2005).

Visual-motor integration plays such an integral role in a student's ability to exhibit the necessary handwriting skills to communicate written ideas and take notes, and to do so with sufficient speed and legibility (Erhardt & Meade, 2005; Ratzon et al., 2009; Tseng & Chow, 2000). The importance of visual-motor integration skills on academic achievement are often observed in the daily demands of note-taking from a board, handwriting, and copying for typically developing students in a general education classroom (Feder & Majnemer, 2007; Kulp, 1999; Sanghavi & Kelkar, 2005). Legible handwriting is vital for academic success, because students spend approximately 60% of the school day engaged in these fine motor activities (McHale & Cermak, 1992). As students' progress through school, the need for interventions that address the process of visual-motor integration becomes important, because the assessment of learning becomes increasingly dependent on written expression skills (Asaro-Saddler & Saddler, 2010; Pennington, 2009). In order to meet academic goals, students are required to interpret visual stimuli into written material while taking class notes from overheads, note-taking from books, written expression activities (e.g., essays, sentence completion, written responses to reading), math, and geometry. According to Kurth and Mastergeorge (2010) 26% of the academic goals for students with ASDs in the general education classroom are in the area of writing. Although there is research indicating the importance of handwriting on academic success, there are few studies that examine the impact of visual-motor integration difficulties on academic performance in students that have ASDs.

In addition to impacting handwriting skills and written expression, researchers have indicated that difficulties with visual-motor integration skills can negatively impact a student's success in reading and mathematics (Mayes & Calhoun, 2007). Mayes and

Calhoun (2007) study of 1,035 children 6 – 16 years old (ADHD = 724, depression/anxiety = 25, oppositional defiant disorder = 19, autism = 118, and typical controls = 149) investigated the relationship between academic achievement, attention, visual-motor integration, and processing speed, and found that children with ASDs had significantly lower scores in the areas of attention, visual-motor integration, and processing speed when compared to all other groups except students with ADHD. Using a stepwise linear regression analysis to predict academic achievement, Mayes and Calhoun (2007) reported that attention, visual-motor integration, and processing speed were significant predictors of reading, written expression, and math. There is limited research about the relationship between visual-motor integration skills and reading and mathematics indicating that this is an area that would benefit from further study for both typically developing students and those with ASDs.

Visual Perception in Students with ASDs and the Impact on the Academic Achievement

Students with ASDs have a tendency to focus on the discrete details of visual information as opposed to processing information in a more holistic or gestalt approach, which is described as a local processing bias or weak central coherence (Frith, 1970; Kimchi, 1992; Landry et al., 2009; Mayes & Calhoun, 2007; Pellicano et al., 2006). The local processing bias manifested in students with ASDs is important because research indicates that learning is most successful when students process information with global bias (Antes, Penland, & Metzger, 1981; Katagiri, Kasai, Kamio, & Murohashi, 2013; Kong & Schunn, 2007). Several studies indicated that individuals with ASDs were statistically more likely to exhibit a local processing bias when compared to typically

developing peers (Best et al., 2008; Kimchi, 1992; Kimchi & Palmer, 1982; Plaisted et al., 1999; Wang et al., 2007). Best et al. (2008) conducted a study of individuals in Edinburgh, Scotland between the ages of 12 and 22, to assess whether weak central coherence, theory of mind, and executive dysfunction were associated with ASD traits or specifically related to the severity necessary to qualify for an ASD diagnosis. The sample included 60 participants, and used the Social Communication Questionnaire to classify participants as likely to have an ASD ($n = 34$) and unlikely to have an ASD ($n = 26$). The researchers found that an increase in the severity of an ASD was associated with decreased performance on theory of mind and executive functioning tasks, and increases in weak central coherence (Best et al., 2008). Plaisted et al. (1999) assessed the weak central coherence (i.e., local processing bias) in 17 high-functioning children with ASDs and 17 typically developing children between the ages of 6 and 16 years old. The results of their study were similar to those found by Best et al. (2008), and indicated that children with ASDs were statistically more likely to exhibit weak central coherence compared to the typically developing children (Plaisted et al., 1999). These studies provide evidence of a local processing bias in individuals between the ages of 6 and 22 with ASDs.

The research is important for practitioners because it implies that learning is typically more successful when students process information first holistically (i.e., global), then in discrete detail (i.e., local). The local processing bias observed in students with ASDs may significantly impact academic achievement (Zelazo & Müller, 2011). Specifically, the research implies that the local processing bias may impact the student's ability to attend to appropriate visual prompts (Whitby et al., 2009), plan and accomplish

comprehension tasks such as reading and essay writing (Whitby et al., 2009), and maintain extended visual focus (Milne et al., 2009). Any students, with or without ASD, that exhibit difficulty with perceiving the larger idea in exchange for the parts may have difficulty with following classroom procedures, reading comprehension, and understanding complex mathematical problems (Lufi, 2001; Zelazo & Müller, 2011). The local processing bias in ASDs has been documented through research; however, the educational impact of this relationship goes unaddressed. Therefore the unique role of local processing bias in students with ASDs on academic achievement warrants further research.

Fine Motor Ability Students with ASDs and the Impact on the Academic Achievement.

Fine motor control greatly impacts handwriting which is critical for students to meet most of the academic goals in a classroom (Feder & Majnemer, 2007; Jackman & Stagnitti, 2007; Rosenblum, Weiss, & Parush, 2003) and as a method of written communication (Hamstra-Bletz & Blote, 1993). Students with ASDs typically have difficulty with coordination, motor control and planning, motor imitation, and fine motor movements (Ming et al., 2007; Provost et al., 2007). Appropriate motor development and abilities are important to a student's successful completion of writing tasks, can impact spelling, written expression, and reading (Feder & Majnemer, 2007; Floet & Maldonado-Durán, 2010); as well as a student's ability to interact with peers and affect self-perception (Piek et al., 2006). Difficulty with fine motor skills may negatively affect a student's ability complete paper and pencil tasks such as worksheets, bookwork, create projects, and write stories. In addition, many norm-referenced tests that students take

such as the criterion-referenced competency tests require students to bubble in answers, and maintain fine motor control as to not make stray marks that could decrease their scores on the assessments. Practitioners often are tasked with the responsibility of collecting data that will lead to effective interventions for students with handwriting problems (Decker et al., 2006; Hosp, 2006; National Association of School Psychologists [NASP], 2010).

Matson, Mahan, Fodstad, Hess, and Neal (2010) studied the fine and gross motor skills of 397 toddlers (17 – 36 months old) with autistic disorder, PDD-NOS, and atypical development not associated with an ASD using the Battelle Developmental Inventory, and found that each group performed significantly below the normative mean in both fine and gross motor skills. Provost et al. (2007) found similar results in their study that included 38 toddlers between the ages of 21 and 41 months (19 in ASD group and 19 in the non-ASD developmental delay group). Similar results were found in the study by Lloyd, MacDonald, and Lord (2013), in a study of 162 toddlers between the ages of 12 and 36 months. The study by Lloyd et al. (2013) also included a cross-sectional study of 58 participants, and concluded that gap in both gross and fine motor skills continued to grow over time rather than decrease or remain stable. Researchers also reported that toddlers with Autistic Disorder had more significant motor delays than toddlers who did not meet the criteria of an ASD or met the diagnostic criteria for PDD-NOS (Matson et al., 2010). Green et al. (2002) compared the motor skills of 11 children with Asperger Syndrome (AS) to nine students with clinically significant motor delays between 6 – 10 years old. The researchers found that although none of the children with significant motor delays met the criteria for an ASD, all students with AS met the criteria for a

significant motor delay and had increased difficulties in the areas of manual dexterity and ball skills measured by the Movement Assessment Battery for Children (Green et al., 2002). Hilton et al. (2007) conducted a study of 107 children between the ages of 6 – 12 (AS = 51, typical controls = 56), and found that as the severity of ASD symptomology increased the motor ability scores reflected greater impairment. Ghaziuddin, Butler, Tsai, and Ghaziuddin (1994) conducted a study with 11 individuals with AS (mean age = 13 years) and nine individuals with Autistic Disorder (mean age = 12) and found that both groups had significant difficulties in motor coordination when compared with assessment norms from the Bruininks-Oseretsky test, but there were no significant between group differences. These studies provided strong evidence that students with ASDs often have comorbid fine motor difficulties. While researchers have demonstrated a link between fine motor difficulties and ASDs, there has not been research that shows the impact that fine motor difficulties have on students with ASDs. Additionally, studies that assess the academic impact of fine motor difficulties often do so through hand writing tasks, which may be influenced by visual ability. Research that assessed the discreet impact of fine motor ability, visual ability, and visual motor integration on academic achievement for students with ASDs would be an important contribution to the field.

Current Study

Students with ASDs have unique difficulties in their visual, motor, and visual-motor integration abilities that impact their academic achievement. Scores on normative instruments indicated that students with ASDs have significant difficulties in the areas of reading, writing, and mathematics when compared to children without disabilities and normative samples (Frith, 1970; Ghaziuddin et al., 1994; Green et al., 2002; Hilton et al.,

2007; Landry et al., 2009; Matson et al., 2010; Mayes & Calhoun, 2007; Milne et al., 2009; Ponsonby et al., 2009; Provost et al., 2007; Volker, Lopata, Vujnovic, et al., 2010).

The purpose of this study was to better understand the relationship and interaction between visual, motor, and visual-motor integration difficulties and differences; as well as the impact of visual, motor and visual-motor integration difficulties in the academic achievement of students with ASD when compared to typically developing same aged peers. This study intended to fill a gap in understanding the impact of the local processing bias and fine motor ability on visual-motor integration, as well as provide information about the impact of local processing bias, fine motor ability, and visual-motor integration on the academic achievement of students with ASDs compared to typically developing same aged peers. Research indicates that 8 – 14 years old is a critical developmental period for visual-motor integration skills (Feder & Majnemer, 2007); therefore visual-motor integration research for students with ASD in this age range is an important contribution to academic intervention recommendations. Research indicated that visual-motor integration skills are important, and contribute, to academic achievement. Therefore, there is a need for specific research that addresses the effects of visual perception, local processing bias, and fine motor ability on VMI; and the role these four skills play in academic achievement.

The following hypotheses were developed: (1) students with ASDs will be more likely to have a local processing bias and lower scores on a measure of visual perception than typically developing peers; (2) students with ASDs will have lower scores on the fine motor assessment than typically developing peers; (3) students with ASDs will have lower scores on two measures of visual-motor integration than typically developing

peers; (4) the local processing bias, lower visual perception, and lower fine motor scores will significantly impact visual-motor integration ability; (5) the local processing bias, and difficulties with visual perception, fine motor, and visual-motor integration skills will significantly impact reading, writing, and math achievement scores.

Methodology

Participants

This study included two separate samples; the first group consisted of students with ASD diagnoses, and the second group consisted of typically developing students. A total of 51 students were recruited to participate in this study, including 26 students with ASD and 25 typically developing (TD) students. Participants in both the ASD and TD samples were between the ages of 8 to 14 years old. Demographics for each sample are summarized in Table 1.

Table 1.
Demographic Information for Study Samples

	ASD (n = 22)	TD (n = 23)	Two-Tailed <i>p</i>
Age in Months – <i>M (SD)</i>	124.32 (21.59)	137.78 (24.18)	.06
Grade – <i>M (SD)</i>	4.5 (1.82)	5.78 (2.33)	.04*
Maternal education			.55
Less than 9 th Grade (%)	0 (0%)	2 (8.70%)	
High School (%)	3 (13.63%)	1 (4.35%)	
Some College (%)	3 (13.63%)	3 (13.04%)	
Bachelor's Degree (%)	9 (40.91%)	9 (39.13%)	
Graduate Degree (%)	7 (31.82%)	8 (34.78%)	
Household Income			.45
Under \$15,000	0 (0%)	0 (0%)	
\$25,000 to \$34,999 (%)	1 (4.55%)	2 (8.70%)	
\$35,000 to \$49,999 (%)	2 (9.09%)	0 (0%)	
\$50,000 to \$74,999 (%)	5 (22.73%)	7 (30.43%)	
Over \$75,000 (%)	14 (63.64%)	14 (60.87%)	
Number in Household – <i>M (SD)</i>	4.5 (1.03)	4.73 (0.94)	.41
KBIT-2 IQ – <i>M (SD)</i>	99.27 (17.55)	109.43 (14.24)	.03*
Gender			.03*
Male (%)	18(81.82%)	12 (52.17%)	
Female (%)	4 (18.18%)	11 (47.83%)	
Race			.06
Caucasian (%)	19 (86.36%)	17 (73.91%)	
African American (%)	1 (4.55%)	6 (26.09%)	
Other (%)	2 (9.09%)	0 (0%)	

*-*p* < .05

ASD Group. There were 26 participants recruited for the ASD group.

Participants in the ASD group, were required to have an overall IQ above the standard score 70 and an ASSQ score above 12. The data was removed for four participants who did not meet the criteria of the study (one participant's ASSQ score was below 12; three participants had overall IQ scores below 70). The final ASD group consisted of 22 participants, ages 8 – 14 years (*M* = 10.33, *SD* = 1.75). The majority of the sample was

male (81.81%) and Caucasian (86.36%). The Kaufman Brief Intelligence Test, Second Edition (KBIT-2) Full Scale IQ ranged from 70 to 134 ($M = 99.27$, $SD = 17.55$). Scores on the ASSQ ranged from 14 to 47 ($M = 27.68$, $SD = 9.83$). The ASD sample came from families with a high degree of education; the majority of participants' mothers reported that they had completed a bachelor's or graduate degree program (72.73%).

TD Group. There were 25 participants recruited for the TD group. Participants in the TD group were required to have an overall IQ above the standard score 70, an ASSQ score below 13, and no clinically significant behavioral concerns identified on the BASC-2. The data from two participants was removed from the analyses because of elevated BASC-2 scores, and a third participant had a diagnosis of ADHD and was removed. The final TD group consisted of 23 participants, ages 8 – 14 years ($M = 11.42$, $SD = 2$). The majority of the sample was male (54.17%) and Caucasian (73.91%). The Kaufman Brief Intelligence Test, Second Edition (KBIT-2) Full Scale IQ ranged from 84 to 128 ($M = 109.43$, $SD = 14.24$). Scores on the ASSQ ranged from 0 to 11 ($M = 2.95$, $SD = 3.07$). Reported maternal education indicated that the majority of participants' mothers had completed a bachelor's or graduate degree program (73.91%).

Between Group Comparisons. The demographics between each of the groups were assessed using Chi-Square and *t*-test analyses. The Chi-Square analysis determined whether significant differences existed between nominal demographic variables. These nominal demographic variables included race, maternal education, household income, and gender. Based on the results of the chi-square analysis, the percentage of participants in each group did not differ significantly based on race, $X^2(2, N = 44) = 5.52$, $p = .06$, maternal education $X^2(4, N = 45) = 3.05$, $p = .55$, or household income $X^2(3, N = 45) =$

2.65, $p = .45$. However, there was a significant difference in the gender $X^2(1, N = 45) = 4.45, p = .035$. There were significantly fewer female participants in the ASD group. Research indicates that the occurrence of ASD is higher in males than females (CDC, 2010), however when such variables are expected due their relationship with an independent variable it is not necessary to consider them as potential covariates as they do not meet the necessary assumptions (Dennis et al., 2009).

The t -test analysis determined whether significant differences existed between the demographic variables age, grade, and number of family members in the household. Based on the results of the t -test, the participants did not differ significantly based on age $t(43) = 1.97, p = .06$ or household size $t(41) = 0.84, p = .41$. However, there was a significant difference between the grade $t(43) = 2.05, p = .04$. The average grade for the TD group ($M = 5.7, SD = 2.3$) was higher than the ASD group ($M = 4.5, SD = 1.8$). Wagner (1995) reported that students with disabilities were more likely to be retained in earlier grades while receiving interventions. When comparing naturally occurring samples, researchers are discouraged from controlling for variables that are artifacts of the group (Evans & Anastasio, 1968; Miller & Chapman, 2001), which is the case with grade (Wagner, 1995). The sample was restricted to students within the same developmental timeframe, therefore this difference in grade is not a potential covariate.

Instruments

Visual Motor Integration Assessments. The Bender-Gestalt Test-Second Edition (BG II; Brannigan & Decker, 2003) and the Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition (VMI-V; Beery & Beery, 2004) were selected as measures of visual motor integration assessment because they are the most

frequently used to assessments in the educational field (Brannigan & Decker, 2003; Volker, Lopata, Vujnovic, et al., 2010). Research indicates that although these instruments both assess VMI skills, they often yield different results in research and practice (Beery & Beery, 2004; Brannigan & Decker, 2003; Shapiro & Simpson, 1995; Volker, Lopata, Vujnovic, et al., 2010). In a study by Volker, Lopata, Vujnovic, et al. (2010) that assessed the comparability of both assessments for students with ASDs aged 6 to 14 the researchers found significant differences in the scores of their participants. The researchers found that students with high-functioning ASDs had significantly lower scores on both measures when compared to neurotypical peers, and that scores on the VMI-V were significantly lower than scores on the BG-II (Volker, Lopata, Vujnovic, et al., 2010). Due to the differences in scores between the instruments both were chosen for use in this study. There is a lack of research about why there are differences in the scores on the instruments (Volker, Lopata, Vujnovic, et al., 2010), and since these two areas could potentially have differing effects on the instruments both are used to assess visual-motor integration skills.

Bender-Gestalt Test-Second Edition, Visual-Motor Subtest. The Bender-Gestalt Test- Second Edition (BG-II), Visual-Motor Subtest is an unstructured measure of visual-motor integration for individuals between the ages of 4 – 85+ years old (Brannigan & Decker, 2003). The BG-II consists of the 16 design cards and the administration is determined by the student's age (5-7 year olds are administered cards 1-13, 8+ years old are administered cards 5-16). The cards are presented one at a time to be drawn on a blank sheet of paper (Reynolds, 2007).

The KOPPITZ-2 Developmental Scoring System for the Bender Gestalt Test

(KOPPITZ-2) was used in this study (Reynolds, 2007). The KOPPITZ-2 used the same standardization sample as the BG-II, which consisted of 3,535 individuals between the ages of 5 to over 85 across the U.S., and included individuals with and without disabilities (including Autistic Disorder; Reynolds, 2007). The final scoring of the measure results in a standard score which will be used. The KOPPITZ-2 manual includes standard scores, percentile ranks, t-scores, z-scores, normal curve equivalents, stanines, and age equivalents that can be used to make normative comparisons (Reynolds, 2007). For the current study, the standard scores with a mean of 100 ($SD = 10$) were used to compare participant performance. The internal consistency reliability for the KOPPITZ-2 for the ages 8 – 14 years old were based on Cronbach's coefficient alphas between .84 and .91, which are considered diagnostically reliable (Reynolds, 2007).

Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition.

The Beery-Buktenica Developmental Test of Visual-Motor Integration, 5th Edition (VMI-V) is a structured measure of visual-perception and motor abilities for individuals between the ages of 2 – 18 years (Beery & Beery, 2004). The VMI-V is described as being culturally fair, and consists of 30 developmentally sequenced geometric forms, and can be administered in a group or individually taking approximately 10 to 15 minutes to complete (Beery & Beery, 2004).

The VMI-V used a standardization sample that consisted of 2,512 individuals between the ages of 1- 18 across the U.S. The final scoring of the measure results in a standard score which will be used in the study. The VMI-V reports normative scores as standard scores, scaled scores, stanines, normal curve equivalents, and percentiles (Beery & Beery, 2004). For the current study, the standard scores with a mean of 100 ($SD = 15$)

were used to compare participant performance. The VMI-V mean split-half internal consistency reliability coefficient was .88 across all ages, and it has a test-retest average reliability of .89 (Beery & Beery, 2004). Reynolds (2007) reported that the corrected correlation between the Koptiz-2 and the VMI-V was .46. This correlation indicates that while there is some overlap, the potential for finding differing results does exist; therefore both instruments were used.

NEPSY Second Edition, Finger Tapping Subtest. The NEPSY Second Edition (NEPSY-II; Korkman, Kirk, & Kemp, 2007) is a collection of 32 individually administered standardized subtests for students between the ages of 3 - 16 that measures neuropsychological development (Korkman et al., 2007). The NEPSY-II was constructed for the assessment of neurological development in six functional domains including attention, sensorimotor, and visuospatial processing; and is commonly used as a selective assessment (Korkman et al., 2007). As a selective assessment tool, it is appropriate to use subtests independently to gather specific information on neurological areas. The NEPSY-II can be used as a selective assessment tool and the focus on functional domains that are often used in the differential diagnosis of students with ASD and other developmental disorders (Brooks, Sherman, & Strauss, 2010; Korkman et al., 2007). The NEPSY-II manual includes normative scores as scaled scores and percentiles (Korkman et al., 2007). For the current study, the scaled scores with a mean of 10 ($SD = 3$) were used to compare participant performance. Finger Tapping was selected as a measurement of finger dexterity, motor speed, and rapid motor programming for the area of fine motor ability, and takes approximately 3 – 4 minutes to complete. This subtest provides an isolated assessment motor ability without requiring the integration any other

ability domains. The Finger Tapping Dominant Hand Combined Scaled Score was used to assess the student's ability in this study. The Pearson r used to calculate test-retest reliability for the selected subtest was reported to be greater than .75 (Brooks et al., 2010).

Test of Visual Perceptual Skills-3, Visual Discrimination Subtest. The Test of Visual Perceptual Skills-3 (TVPS-3; Martin, 2006) was developed to provide a reliable measure of perceptual abilities in individuals between the ages of 4 and 19 years. The TVPS-3 uses black and white stimuli and a multiple choice response format for all the items. The TVPS-3 was chosen as a motor free test of visual perception (Martin, 2006). The TVPS-3 used a standardization sample that consisted of 2,008 students, at 83 sites, in 80 cities across the United State. There were 140 test items given during the test standardization, and through the use of the Classical Test Theory and Item Response Theory analyses, the final TVPS-3 consisted of 16 test items and two examples for the seven subtests. The Visual Discrimination subtest was selected as the measurement of perceptual ability in this study. It assesses the student's ability to discriminate between dominant features, position, shape, form, and color, which rely heavily on the ability to process information globally. Therefore, students with ASD are suspected to score lower when compared to typically developing peers. The final scoring of the measure results in a scaled score with a mean of 10 ($SD = 3$) which was used to compare participant responses.

Navon Task. The Navon Task (Navon, 1977) was designed to assess whether an individual has a local or global processing bias. The Navon Task consists of hierarchical figures that consist of a global letter or shape, made up of local elements. Typically, the

letters are paired with letters, and shapes are paired with shapes. The Navon Task is administered individually, with the use of a computer. The participant is required to make a response that is recorded by the computer that indicates the reaction time and accuracy of their first and immediate impression of the object that they see. During the version of the Navon Task used in this study, participants were shown a larger letter made of smaller letters. All participants were seated in front of the computer, 15 inches away from the screen. The participants were administered 10 practice trials, before the 36 experimental trials were administered. The participants were allotted an unlimited amount of response time, and only moved forward to the next item when they pressed a key on the keyboard. Research indicates that individuals with ASDs responded incorrectly by choosing the local choice more often, and had slower reaction times than other groups due to a local processing bias (Navon, 1977, 1981, 1983; Plaisted et al., 1999). The percentage correct and response time in seconds were used to assess whether or not the individual has a tendency toward local or global information processing. There are currently no norms or psychometric information for the Navon Task.

Kaufman Test of Educational Achievement, Second Edition, Selected

Subtests. The Kaufman Test of Educational Achievement, Second Edition (KTEA-II; Kaufman & Kaufman, 2004) is a measure of achievement for students 4 – 25 years old, which includes a measure of reading, math, writing, and oral language that takes approximately 80 minutes to complete. For the purposes of this study participants were given the Letter & Word Recognition, Reading Comprehension, Written Expression, Spelling, and Math Computation Subtests. Composite scores in the areas of reading and writing, and the math subtest score, were used to assess student academic achievement in

these areas. The final scoring of the measure results in a standard score which was used in this study. KTEA-II achievement test which was standardized on a normative sample of 3,000 individuals between the ages of 4 – 25 years old and 2,400 individuals in grades K through 12 across the U.S., and reports normative scores as standard scores, percentile ranks, normal curve equivalents, stanines, and grade and age equivalents. The normative samples included individuals with and without disabilities. The KTEA-II reported split-half reliability coefficients as measures of internal reliability that were between .81 and .99 for all grades and ages assessed in this study.

Kaufman Brief Intelligence Test, Second Edition. The Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2004) is an individually administered test of cognitive ability for individuals between 4 – 90 years old. The purpose of the KBIT-2 is to screen intellectual abilities using three subtests that measure expressive language, word knowledge, and conceptual knowledge. The KBIT-2 takes approximately 15 – 30 minutes to complete and results in a verbal ability score, nonverbal ability score, and an overall intellectual ability score. The KBIT-2 was standardized on a normative sample of 2,120 individuals between the ages of 4 – 90 across the U.S., and reports normative scores as standard scores, percentiles, and age equivalents. The final scoring of the measure results in a standard score with a mean of 100 ($SD = 15$) which was used in this study. The KBIT-2 reported an internal consistency between the .80s and .90s using the split-half reliability coefficients based on the Spearman-Brown formula across all ages, and test–retest reliability coefficients of .88 to .93 for all ages.

Behavior Assessment Scale for Children, Second Edition; Parent Rating

Scales. The Behavior Assessment Scale for Children, Second Edition (BASC-2; Reynolds & Kamphaus, 2004) is a commonly used standardized rating system that assesses both adaptive and problem behaviors through parent, teacher and self-report (Reynolds & Kamphaus, 2004; Volker, Lopata, Smerbeck, et al., 2010). The BASC-2 is described as a multimethod and multidimensional assessment tool for behaviors in children (Reynolds & Kamphaus, 2004). For this study, the parent rating scale (PRS) was used to collect information about the behavioral functioning of all participants in the study. The BASC-2 was chosen to screen participants for any symptomology indicative of a psychological diagnosis because it is often used in practice when gathering a holistic view of a student's behavioral difficulties (Kamphaus, Petoskey, & Rowe, 2000). The PRS takes approximately 10-20 minutes to complete and uses a four-point scale to measure frequency that ranges from "Never" to "Almost Always" (Reynolds & Kamphaus, 2004).

The psychometric properties reported in the BASC-2 manual are considered strong (Volker, Lopata, Smerbeck, et al., 2010). According to the manual internal consistency reliability coefficients for composite area scores on the PRS ranged from .90 to .95 (Reynolds & Kamphaus, 2004). PRS standard scores in the clinical range above the 95th percentile in the clinical scales (aggression, anxiety, attention problems, atypicality, conduct problems, depression, hyperactivity, somatization, withdrawal, adaptability, anger control, bullying, developmental social disorders, emotional self-control, executive functioning, and negative emotionality) were considered indicative of

risk for a disorder, and these individuals were excluded from the typically developing sample.

Autism Spectrum Screening Questionnaire. The Autism Spectrum Screening Questionnaire (ASSQ; Ehlers, Gillberg, & Wing, 1999) is a 27-item rating scale used to identify students between the ages of 6 – 17 who may be on the autism spectrum. The items are rated on a three point Likert scale that compares the students' behaviors to that of other children their age with a total score ranging between 0 to 54 (Ehlers, Gillberg, & Wing, 1999). The ASSQ can be used with both parents and teachers to assess ASDs in children. For the purposes of this study the ASSQ was used to confirm ASD diagnoses, and only parents/guardians completed the ASSQ. The ASSQ assesses social interaction, communication, restricted and repetitive behaviors, and motor clumsiness (Ehlers et al., 1999). Ehlers and Gillberg's (1993) initial research on the instrument as a screening tool indicated that it reliably identified individuals with ASDs and symptomology in random sample of students in first to ninth grade. In a follow up study on the use of the ASSQ as a reliable and valid screening tool for ASDs in a clinical setting, the sample included 110 children between the ages of 6 and 17. This research is described due the use of this tool as a screener for ASD in a pre-identified or clinical sample, in the current study.

According to Ehlers et al. (1999), the test-retest reliability of the ASSQ scores for parents in a clinical setting was calculated using the Pearson r over a 2-week period and found to be $r = .96$. In order to determine appropriate cut-off scores with maximum specificity and sensitivity, a ROC analysis and likelihood ratios were conducted to examine the instruments ability to differentiate ASD from other disorders and typical individuals (Ehlers et al., 1999). Based on their results, a cut-off score of 13 for parents is reasonable

for identification of social impairment and identified 90% of ASD cases in the sample population, and was used to confirm ASD diagnoses in this study.

Procedure

Students were recruited from organizations, parent support groups, and list-servs, some of which specifically communicate with families of children who have an ASD and others that were more broadly targeted to parents. Parents also responded to fliers and electronic advertisements from pediatrician's offices and social media outlets. Written parental consent and participant assent were obtained from all participants and their guardians prior to participation in the study along with a parent completed demographic information sheet (e.g., date of birth, age, and possible special education services). Parents/guardians were asked to complete the BASC-2 and ASSQ for all participants. Students were determined eligible to participate as part of the ASD sample based on previous diagnoses from a licensed psychologist, pediatrician, or psychiatrist. This diagnostic symptomology of ASDs was confirmed using the Autism Spectrum Screening Questionnaire. The TD sample was screened using the Behavior Assessment Scale for Children, Second Edition; students with scores in the clinically significant range on the attention problems, atypicality, conduct problems, depression, hyperactivity, developmental social disorders, emotional self-control, executive functioning, externalizing, and internalizing scales were not included in the study.

All study participants were individually administered the BG-II, VMI-V, KBIT-2, subtests from the KTEA-II, the Navon Task, and NEPSY-II Finger Tapping subtest according to standardized procedures in one evaluation session. Testing took place in the participants' homes, and all locations met the criteria of an appropriate testing

environment as defined by the assessment standardization. The BG-II and VMI-V were administered in counterbalanced order to minimize potential effects of completing two visual-motor integration tasks that are similar in nature (Volker, Lopata, Vujnovic, et al., 2010). The NEPSY-II Finger Tapping subtest was administered first to ensure that the performance of this subtest was not impacted by possible fatigue caused when completing the VMI-V, BG-II, and writing tasks. All other measures were given in a random order at the time of administration.

Results

Hypotheses 1 – 3. The first three hypotheses evaluated whether students with ASDs would be more likely to have a local processing bias, visual perception deficits, fine motor difficulty, and visual motor integration difficulty when compared to typically developing peers. Means, standard deviations, and t – test results related to comparisons across the ASD and TD samples are reported in Table 2.

Table 2.

Independent T-Test Results Comparing TD (n = 23) and ASD (n = 22)

Test	ASD		Typically Developing			Two-Tail <i>p</i>	Cohen's <i>d</i>
	M	SD	M	SD	<i>t</i>		
Navon Percentage of Global Responses	93	7	95	4	.36	.73	.22
Navon Task Completion Time (secs)	1135.57	536.50	633.08	172.67	-2.83	.01*	1.42
TVPS-3; Visual Discrimination (ss)	8.68	4.11	8.39	2.89	-.27	.78	.08
NEPSY-2, Dom Hand Finger Tapping (ss)	9.55	2.91	12.05	1.32	3.46	.00*	1.18
BG-II (SS)	98.90	19.62	104.22	21.33	.87	.39	.26
VMI-V (SS)	87.77	17.70	95.35	15.95	1.51	.14	.45
KTEA-II Reading Comprehension (SS)	100.27	17.46	108.00	15.25	1.58	.12	.47
KTEA-II Written Language (SS)	87.00	15.16	104.91	18.77	3.51	.001*	1.05
KTEA-II Math Computation (SS)	96.18	15.41	105.09	16.77	1.85	.07	.55

Note. “Navon % represents Navon Percentage of Global Responses; “Navon Time” represents Navon Task Completion Time; TVPS-3 represents TVPS-3; Visual Discrimination; NEPSY-II Represents NEPSY-II Dominant Hand Finger tapping
* $p < .01$

Hypothesis 1. The first hypothesis stated that students with ASDs would be more likely to have a local processing bias and lower scores on the visual perception test than TD peers. The scores for both measures are continuous and each one was analyzed using an independent samples t-test, comparing TD and ASD on each of the visual measures. The local processing bias was measured using an adaptation of the Navon Task (Navon, 1977). The number of global choices was calculated for each group yielding the percentage of answers reflecting global processing, and the completion time in seconds was recorded. Students with ASDs did not have a local processing bias when compared to TD peers based on the scores from the Navon Task $t(43) = 0.36, p = .72$, and therefore, the results did not support the hypothesis. However the completion time on the Navon Task was longer for students with ASD $t(43) = -2.83, p = .01$. The Visual Discrimination subtest of the TVPS-3 also was used to measure visual perceptual differences. The

subtest resulted in a standard score for each participant that was used to compare the participants' performances. There was no difference between the scores of students in the ASD and TD group on the TVPS-3 $t(43) = -.28, p = .78$; these results did not support the hypothesis. Based on the finding, Completion Time on the Navon Task will be used to analyze the impact of local processing bias in later analyses.

Hypothesis 2. The second hypothesis was that students with ASDs will have lower scores on the fine motor assessment than TD peers. Fine motor ability was assessed using the Finger Tapping subtest of the NEPSY-II. The subtest yielded a scaled score for each participant's dominant hand that was used to compare the participants' performances. The scores are continuous and were analyzed using an independent samples t-test. The results of the independent t-test, $t(43) = 3.46, p < .001$, indicated that students with ASD ($M = 9.56, SD = 2.91$) did have significantly lower scores on the fine motor assessment when compared to the TD group ($M = 12.05, SD = 1.32$). The results of the analysis supported the hypothesis.

Hypothesis 3. The third hypothesis was that students with ASDs would have lower scores on VMI assessments than TD peers. Visual-motor integration was measured using the BG-II and the VMI-V measures. As described, there is research suggesting that both instruments may yield different and important information about the visual motor integration process (Volker, Lopata, Vujnovic, et al., 2010). Both standardized measures were individually administered and the results of each assessment were analyzed separately. The standard scores from both measures are continuous variables that were analyzed using independent samples t-tests. Based on the results of the BG-II $t(43) = .87, p = .39$, scores were not significantly lower for students with ASD

($M= 98.90$, $SD= 19.63$) than TD students ($M= 104.22$, $SD= 21.33$). The results also indicated that the scores were not significantly lower scores on the VMI-V ($t(43) = 1.509$, $p = .14$) for students with ASD ($M= 87.77$, $SD= 17.70$) than TD students ($M= 95.35$, $SD= 15.95$). The results of the analysis did not support the hypothesis; although students with ASDs had lower scores on both measures of visual-motor integration, these differences were not significant in this study.

Hypotheses 4 – 5. Hypotheses 4 and 5 evaluated the relationships between local processing bias (Navon Completion Time, TVPS-3), fine motor difficulties (NEPSY-Finger Tapping), visual motor integration (BG-II, VMI-V), and academic achievement (KTEA-II Reading, Writing, Math) using an “all possible subsets” multiple regression model, with results in Tables 3 – 6. The “all possible subsets” multiple regression was completed using SPSS 21. The utilization of SPSS to run “all possible subsets” multiple regressions is a new feature originally introduced in SPSS 20.

Table 3.
Results of the “All Possible Subsets” Multiple Regression Analyses for Visual-Motor Integration Instruments

	AICC	R^2	Adjusted R^2	Mallows' C_p ($ C_p - (k + 1) $)
BG-II				
Model 1 TVPS-3	472.89	.16*	.16	3.13 (1.13)
Model 2 Navon Time	478.32	.19*	.05	2.27 (0.27)
Model 3 NEPSY-II	480.59	.08	-.00	5.14 (3.14)
Model 4* TVPS-3 Navon Time	472.85	.28*	.18	2.11 (0.89)
Model 5 TVPS-3 NEPSY-II	474.22	.19*	.15	4.23 (1.23)
Model 6 Navon Time NEPSY-II	480.52	.20*	.03	3.99 (0.99)
Model 7 TVPS-3 Navon Time NEPSY-II	475.22	.28	.16	4.00 (0)
	AICC	R^2	Adjusted R^2	Mallows' C_p ($ C_p - (k + 1) $)
VMI-V				
Model 1** TVPS-3	454.41	.21	.17	5.62 (3.62)
Model 2 Navon Time	465.42	.23	.19	5.11 (3.11)
Model 3 NEPSY-II	467.73	.00	-.02	11.91 (9.91)
Model 4 TVPS Navon Time	455.03	.35*	.28	3.41 (0.41)
Model 5 TVPS-3 NEPSY-II	456.63	.22	.13	7.50 (4.50)
Model 6 Navon Time NEPSY-II	467.71	.26	.17	6.29 (2.29)
Model 7 TVPS-3 Navon Time NEPSY-II	457.38	.40	.24	4.00 (0)

Note. There were three predictor variables included in the analyses: TVPS-3, Navon Completion Time (Navon Time), and NEPSY-II Finger Tapping Dominant Hand (NEPSY-II). In addition to the Mallows' C_p , the $|C_p - (k + 1)|$ calculation is provided. BG-II Adequate $R^2 = .13$, VMI-V Adequate $R^2 = .27$

* Indicates Mallows' C_p with $R^2 >$ Adequate R^2

**Denotes best subset model based on AICC.

Table 4.

Results of the “All Possible Subsets” Multiple Regression Analyses for Reading Comprehension

	AICC	R^2	Adjusted R^2	Mallows' C_p ($ C_p - (k + 1) $)
Reading Comprehension				
Model 1** VMI-V	450.63	.20*	.16	2.21 (.21)
Model 2 VMI-V, BG-II	452.47	.31*	.23	1.45 (1.55)
Model 3 VMI-V, NEPSY-II	452.57	.21*	.13	3.75 (.75)
Model 4 VMI-V, TVPS-3	452.86	.26*	.19	2.49 (0.51)
Model 5 VMI-V, Navon	452.88	.20*	.11	4.20 (1.20)
Model 6 VMI-V, BG-II, NEPSY-II	454.62	.31*	.19	1.00 (2.99)
Model 7 VMI-V, NEPSY-II, Navon	454.75	.22*	.10	5.56 (1.56)
Model 8 VMI-V, BG-II, Navon	454.77	.31*	.20	3.32 (.68)
Model 9 VMI-V, BG-II, TVPS-3	454.86	.36*	.25	2.15 (1.85)
Model 10 VMI-V, NEPSY-II, TVPS-3	454.93	.27*	.15	4.34 (.34)

Note. There were five predictor variables included in the analyses: TVPS-3, Navon Completion Time (Navon Time), and NEPSY-II Finger Tapping Dominant Hand (NEPSY-II), VMI-V, and BG-II. In addition to the Mallow's C_p , the $|C_p - (k + 1)|$ calculation is provided. Reading Full Model Adequate $R^2 = .16$,

* Indicates Mallow's C_p with $R^2 >$ Adequate R^2

**Denotes best subset model based on AICC.

Table 5.
Results of the “All Possible Subsets” Multiple Regression Analyses for Written Language

	AICC	R^2	Adjusted R^2	Mallows' C_p ($ C_p - (k + 1) $)
Written Language				
Model 1** VMI-V, NEPSY-II	452.79	.40*	.34	1.21 (1.79)
Model 2 VMI-V	454.66	.25	.21	3.41 (1.42)
Model 3 VMI-V, NEPSY-II, TVPS-3	454.75	.40*	.30	3.21 (.80)
Model 4 VMI-V, NEPSY-II, Navon	455.17	.40*	.30	3.19 (.81)
Model 5 VMI-V, NEPSY-II, BG-II	455.20	.44*	.35	2.02 (1.98)
Model 6 VMI-V, Navon	456.01	.29*	.21	4.35 (1.35)
Model 7 VMI-V, TVPS-3	456.70	.26*	.19	5.13 (2.13)
Model 8 VMI-V, BG-II	456.91	.36*	.29	2.43 (.58)
Model 9 VMI-V, NEPSY-II, TVPS-3, Navon	457.25	.40*	.26	5.18 (.18)
Model 10 VMI-V, NEPSY-II, TVPS-3, BG-II	457.29	.44*	.31	4.02 (.98)

Note. There were five predictor variables included in the analyses: TVPS-3, Navon Completion Time (Navon Time), and NEPSY-II Finger Tapping Dominant Hand (NEPSY-II), VMI-V, and BG-II. In addition to the Mallows' C_p , the $|C_p - (k + 1)|$ calculation is provided. The Written Language Full Model Adequate $R^2 = .26$,

* Indicates Mallows' C_p with $R^2 >$ Adequate R^2

**Denotes best subset model based on AICC.

Table 6.

Results of the “All Possible Subsets” Multiple Regression Analyses for Math Computation

	AICC	R^2	Adjusted R^2	Mallows' C_p ($ C_p - (k + 1) $)
Math Computation				
Model 1** VMI-V, BG-II	439.30	.55*	.50	1.95 (1.05)
Model 2 VMI-V, TVPS-3	439.50	.36	.29	9.76 (6.76)
Model 3 VMI-V	439.73	.30	.26	10.01 (8.01)
Model 4 VMI-V, BG-II, TVPS-3	439.88	.58*	.52	2.60 (1.40)
Model 5 VMI-V, NEPSY-II	440.31	.33	.26	10.62 (7.62)
Model 6 VMI-V, TVPS-3, NEPSY-II	440.36	.37	.27	11.03 (7.03)
Model 7 VMI-V, BG-II, NEPSY-II	440.44	.55*	.48	3.94 (.06)
Model 8 VMI-V, BG-II, TVPS-3, NEPSY-II	441.22	.59*	.49	4.58 (.42)
Model 9 VMI-V, TVPS-3, Navon	411.26	.37	.27	10.59 (6.59)
Model 10 VMI-V, Navon	441.34	.33	.26	10.71 (7.01)

Note. There were five predictor variables included in the analyses: TVPS-3, Navon Completion Time (Navon Time), and NEPSY-II Finger Tapping Dominant Hand (NEPSY-II), VMI-V, and BG-II. In addition to the Mallows' C_p , the $|C_p - (k + 1)|$ calculation is provided. The Math Computation Full Model Adequate $R^2 = .47$,

* Indicates Mallows' C_p with $R^2 >$ Adequate R^2

**Denotes best subset model based on AICC.

The data were analyzed to ensure that they met the assumptions necessary for generalization. The predictor variables were checked to ensure that they did not have zero variances, the variance of the residual terms was constant, that errors were normally distributed, and there was linearity in the outcome variables. The variance inflation factors were calculated to ensure that there was no multicollinearity between the variables (Mansfield, 1982). Three external variables were identified as potentially correlated to the predictors: age, grade, and intelligence (IQ). Restricting the sample to students within

the same developmental timeframe for visual-motor integration skills controlled the potential covariates of age and grade (Feder & Majnemer, 2007). Although there was a significant difference between the grades, this appears to be an artifact of the ASD group; students were more likely to be retained in earlier grades while receiving interventions for their disability (Wagner, 1995). Therefore grade does not meet the necessary assumptions to be considered a covariate (Dennis et al., 2009). Research indicates that IQ meets the necessary assumptions to be considered a covariate for academic achievement and visual-motor integration development and was controlled for in the regression analyses (Beery & Beery, 2004; Deary, Strand, Smith, & Fernandes, 2007; Dennis et al., 2009).

In order to complete the “all possible subsets” multiple regression in SPSS the Automatic Linear Modeling Regression was selected. A standard model consisting of the best subsets was chosen. The data are automatically prepared by the SPSS program; outliers are identified and removed by calculating the studentized residuals and calculating and comparing the Cook’s distances (Cook, 2000; Field, 2009; Paul & Fung, 1991). The studentized residual was chosen because it provides a more precise estimate of error when compared to the unstandardized and standardized residuals (Cook, 2000; Field, 2009). The Cook’s distance measures a case’s overall effect on the model, and cases with values greater than 1 are removed (Field, 2009).

The “all possible subsets” multiple regression assesses the statistical relationship between all possible combinations of the independent variables, and by comparing adjusted R^2 , Mallows’ C_p , and Akaike’s Information Criterion corrected (AICC), it allows the researcher to determine the model with independent variables that best predicts the

dependent variable (Beal, 2007; Field, 2009; Hocking & Leslie, 1967; Mallows, 1973). The adjusted R^2 is the percentage of the variability accounted for by the independent variables and ranges between zero and one. Mallows' C_p relies on the calculation of the sum of squares of the error (SSE) to determine the best model using the full model SSE, the number of observations, the number of independent variables, and intercept. The model with the smallest absolute value for $C_p - (k + 1)$, where k is the number of predictors, is considered the best model (Mallows, 1973; Siniksaran, 2008). The AICC is used to determine the best model by calculating the number of observations, the SSE, the number of independent variables, and the intercept; and penalizes the models for increases in the independent variables. The corrected version which is used for this research study has been described as a better statistic for choosing the best subset model in sample sizes smaller than 100 (Fujikoshi & Satoh, 1997; Hurvich & Tsai, 1995). In addition, the R^2 that is not statistically different from the R^2 for the full mode, called adequate R^2 , was identified for any reduced model. The R^2 , adjusted R^2 , Mallows' C_p , and the absolute value of the $C_p - (k + 1)$ calculation, were reported for the Top 10 models for comparability, however the model with the smallest AICC will be considered the best model as this statistic is the better fit for the data.

Hypothesis 4. The fourth hypothesis states that local processing bias, visual perception, and lower fine motor scores will significantly impact visual-motor integration ability. An “all possible subsets” multiple regression was conducted to determine whether local processing bias, visual perception, and fine motor ability scores predicted the scores either on the BG-II or on the VMI-V. The results of the analysis are presented in Table 3. Data from two participants from the TD group (T010, and T015), and one

participant from the ASD group (A008) were removed from the BG-II analysis because they were identified as outliers. Based on this analysis, according to the AICC criterion, the best regression model for the BG-II contained the TVPS-3 and Navon Completion Time as predictors, $R^2 = .28$, $F(2,42) = 5.84$, $p = .006$. This model was also supported by Mallow's C_p and adequate R^2 . The multiple regression was conducted in order to find the best possible subset for the VMI-V. Data from one participant in the TD group (T009) and one from the ASD group (T025) were identified as outliers and removed from the VMI-V analysis. According to the AICC criterion, the best regression model for the VMI-V consisted of the TVPS-3 as a predictor, $R^2 = .21$, $F(1,43) = 15.24$, $p < .001$. Mallow's C_p and adequate R-square criteria also suggested that the model that contains TVPS-3 and Navon time was also a possible model, $R^2 = .35$, $F(2,42) = 8.52$, $p = .016$.

Hypothesis 5. The fifth hypothesis is that the local processing bias, fine motor difficulties, and visual-motor integration difficulties will negatively impact reading, writing, and math achievement scores. The results of the analyses are presented in Table 4 – 6.

The data for four participants in the ASD group (T025, A012, A020, A004) were identified as outliers and removed from the reading analysis. Based on this analysis, according to the AICC criterion, the best regression model for reading consisted of the VMI-V as a predictor $R^2 = .20$, $F(1,43) = 19.61$, $p < .001$. This model was also supported by the Mallow's C_p and adequate R^2 . The data for one participant in the TD group (T015) and two participants from the ASD group (A012 and A004) data were identified as outliers and removed from the writing analysis. Based on this analysis, the best regression model for writing is made up of the VMI-V and NEPSY Finger Tapping

Dominant Hand as predictors $R^2 = .40$, $F(2,42) = 18.88$, $p < .001$. A model that adds TVPS-3 and Navon to VMI-V and NEPSY was also a possible model according to Mallow's Cp $R^2 = .40$, $F(4,40) = 2.845$, $p = .05$. Finally, data from one participant in the TD group (T009) was removed from the math analysis. Based on the AICC, the best regression model for math achievement was determined to consist of the VMI-V and BG-II as predictors $R^2 = .55$, $F(2,42) = 18.71$, $p < .001$. A model that adds NEPSY-II is also a possible model according to Mallow's Cp, $R^2 = .55$, $F(3,41) = 7.35$, $p = .002$. The results indicate that visual-motor integration, as measured by the VMI-V, was consistently a significant predictor of academic functioning across reading, writing, and math, and part of all of the best fit regression models.

Discussion

The purpose of this study was to expand on prior research by examining the impact of visual and motor ability on visual-motor integration skills. Specifically, this study aimed to note whether or not one skill plays a more significant role in visual-motor integration, and if so to identify that skill. This study intended to build on the research about the impact of visual, motor, and visual-motor integration on specific areas of academic achievement (Akshoomoff et al., 2002; Beversdorf, 2001b; Brasic & Gianutsos, 2000; Sanghavi & Kelkar, 2005), furthering the knowledge of researchers and practitioners on the importance of all three skills on academic achievement. The results comparing the visual performance of students with ASDs with TD peers did not support that hypothesis that students with ASDs had a local processing bias that inhibited their performance on global processing tasks (Best et al., 2008; Kimchi, 1992; Kimchi & Palmer, 1982; Plaisted et al., 1999; Wang et al., 2007). The results did support the

research that suggested students with ASDs have slower completion times than their TD peers (Navon, 1977, 1981, 1983; Plaisted et al., 1999) on a task of global processing.

The results of this study were consistent with previous research indicating that students with ASDs have more difficulty with fine motor skills than TD peers (Ghaziuddin et al., 1994; Green et al., 2002; Hilton et al., 2007; Lloyd et al., 2013; Matson et al., 2010; Provost et al., 2007). However, the results did not support previous finding that students with ASDs perform lower on measures of visual perception or visual-motor integration (Beversdorf, 2001b; Mayes & Calhoun, 2007; Novales, 2006).

Based on the results of the study, some hypotheses were supported while others indicated that there were no differences between students with ASDs and TD students. The researchers found that the scores on the TVPS-3 ($p=.72$) and the Navon Task ($p=.78$) were not significantly different for students with ASDs when compared to TD students, in contrast to the prediction of deficits on this tasks, based on the literature. However, the Navon Task completion time was significantly longer ($p = .01$) for students with ASDs compared to their TD peers. Students with ASDs also were found to have increased difficulty on the NEPSY-II fine motor assessment ($p = .01$), which supported the second hypothesis, and concurred with previous research. Both the BG-II and VMI-V were administered to test the third hypothesis, and contrary to previous research (Novales, 2006; Volker, Lopata, Vujnovic, et al., 2010) the results indicated that there was no significant difference between students with ASDs and their TD peers for either the BG-II ($p = .39$) or the VMI-V ($p = .14$).

The study also examined the relationships between local processing bias, fine motor difficulty, visual-motor integration skills, and academic achievement. The AICC

results showed that the TVPS-3 and Navon Task completion time were the best predictors of visual-motor integration performance on the BG-II ($p < .001$). For the VMI-V, the AICC results indicated the TVPS-3 as the best predictor ($p < .001$). Although there is a relationship between the three skills, these results suggest that researchers and practitioners should pay particular attention to the development of visual processing skills when students have difficulty with visual-motor integration. Specifically, these results suggest that the time it takes to process global information may have a significant impact on the visual-motor integration skills. It is noteworthy that another possible best subset model for the VMI-V identified by the Adjusted R^2 suggests that the Navon Task completion time could be included along with the TVPS-3. This is the first study to explore the impact of a visual processing skill (local processing bias) and motor skills on the visual-motor integration. The significant findings indicate that this is both an important area for future research, and important for practitioners to consider when working with students with ASDs.

The fifth hypothesis analyzed the predictive relationship of visual, motor, and visual-motor integration skills on academic achievement in the areas of reading, writing, and math. The results of the AICC indicated that the VMI-V scores were the best predictors of reading ability ($p = .00$). Another possible best subset model using the Mallows' C_p statistic suggested that a model including the VMI-V, BG-II, and Navon Task completion time might be the best. Both models show that visual-motor integration skills are important for success in reading. The fact that the Navon Task completion time is part of a best subset model option suggests that slower processing of global information may have negative impacts on academic achievement (Zelazo & Müller,

2011). The results of the AICC indicated that the VMI-V and NEPSY-II Finger Tapping Dominant Hand scores were the best predictors of writing ($p = .00$). This model supports the importance of both visual-motor integration and fine motor skills on writing ability identified in previous research (Asaro-Saddler & Saddler, 2010; Feder & Majnemer, 2007; Hamstra-Bletz & Blöte, 1990; Kulp, 1999; McHale & Cermak, 1992; Pennington, 2009; Rosenblum et al., 2003; Sanghavi & Kelkar, 2005). The results of the AICC indicated that the VMI-V and BG-II scores were the best predictors of math ($p < .001$). These results supported previous research suggesting that visual-motor integration skills have a significant impact on academic achievement in the area of mathematics (Mayes & Calhoun, 2003). Across the analyses, visual-motor integration was a part of the best subset model. Additional influences on academic achievement, such as fine motor ability, and slower performance time for global processing, imply a need for continued research to understand the complexity of these relationships, and awareness of practitioners that problems in visual-motor integration are not the only contributor to academic problems.

Primary Contributions of the Study

The findings that address the relationship between visual, motor, and the visual-motor integration skills represent this study's most unique contribution to the literature. Visual, motor, and visual-motor integration skills are separate but related processes, and to better serve students with ASDs it is important to gather information about these skills that will formulate the most efficient interventions. This is the first study to analyze and compare the impact of global processing time and fine motor ability on visual-motor integration. As a result of this study, it is clear that the slower global processing time

observed in students with ASDs (Frith, 1970; Landry et al., 2009; Pellicano et al., 2006) has a negative impact on visual-motor integration performance. Although students with ASDs were able to accurately complete the global processing tasks, it took longer for the students to respond when compared to their TD peers. The findings suggest that global processing time may play a stronger role in visual-motor integration success than fine motor ability. The results of the “all possible subsets” multiple regression make it apparent that while both visual and motor ability impact visual-motor integration, individuals are negatively impacted on visual-motor integration when they take longer to process global information. These results suggest that providing students with ASDs more time for processing information, and visual perceptual interventions targeting the local processing bias may prove to be more efficient in positively improving academic areas impacted by visual-motor integration in students with ASDs; such as handwriting and written expression skills (Asaro-Saddler & Saddler, 2010; Feder & Majnemer, 2007; Kulp, 1999; McHale & Cermak, 1992; Pennington, 2009; Sanghavi & Kelkar, 2005). Although more studies are needed to fully understand the relationship between these three skills, this study’s results identify and global processing time as playing a larger role in the visual-motor integration tasks than fine motor ability. These results confirmed how important it is for practitioners to assess the relationships between a student’s global processing speed, motor, and visual-motor integration skills, and be aware of their academic impact when developing interventions. The results of this study also identify a critical area for future research.

The results of the visual perception analyses are another important contribution to the visual perception literature provided by this research. The results from the

assessments used to measure the local processing bias this study indicated that students with ASDs performed with the same accuracy as TD students; however, they did take significantly longer to process this information as indicated by the Navon Task completion time. This data suggests that the negative impact of the local processing bias on visual-motor integration skills, and academic tasks is related to the speed of visual information processing, more so than accuracy. The students were able to process the information globally, which is important for academic success (Zelazo & Müller, 2011); however, they were taking significantly longer to process visual information holistically than their peers. This is important because in academic tasks that involve writing and reading, the speed of information processing has a significant impact on performance (Erhardt & Meade, 2005; Ratzon et al., 2009; Tseng & Chow, 2000). The results suggest that practitioners working with students with ASD who have visual-motor integration difficulties would benefit from interventions that are designed to provide time to process the information and interpret the tasks, rather than just allowing a student extended time to complete work interventions should focus on provided additional direction and checking in with the student to ensure understanding. Researchers may want to explore the utility of interventions that teach the discreet skills necessary for efficiently interpreting a visual task, or the typical expectations around visual interpretation.

Additional Contributions

This study also examined the impact of visual, motor, and visual-motor integration processes on academic achievement. As expected, visual-motor skills had a significant impact on academic achievement, which is consistent with previous research (Asaro-Saddler & Saddler, 2010; Pennington, 2009). Visual-motor integration

performance was consistently part of the best subset predictor models for all academic areas measured, indicating continued support that visual perception and spatial awareness are important for reading comprehension, written expression, and mathematic ability. There also is a lack of research documenting the discreet importance of the local processing bias and fine motor ability on academic achievement. As evidenced by Tables 4-6, each of these processes has a unique and significant impact on academic achievement as it related to reading, writing, and mathematics. These results indicate that gathering information about a student's visual and fine motor strengths and weaknesses could be useful in developing comprehensive interventions to address academic problems because they have a significant impact on achievement areas.

Additionally, this study used the "all possible subsets" multiple regression (Hocking & Leslie, 1967) to analyze the data collected. By using this regression model of comparing all possible subset combinations of independent variables, it is possible to make determinations about the best model. The ability of the SPSS software program to complete "all possible subsets" multiple regression that calculate comparable Mallows' C_p , adjusted R^2 , and AICC is a new function of the data analysis software (IBM SPSS Statistics 21, 2012). The "all possible subsets" multiple regression is likely to have a positive impact on social research because it broadens the analytic ability of researchers on their data by computing all possible combinations of the independent variables and calculating a statistic that allows the comparison of all the models. This multiple regression type allows researcher to apply what they know about prior research as well as several statistical measures of comparison to deduce the best subset model. The "all possible subsets" multiple regression takes into account that the model with all significant

variables, or the full model, has the greatest statistical significance (Hocking & Leslie, 1967); however, the analysis also allows the researcher to determine what is the best subset of independent variables in relation to the full model. The “all possible subsets” multiple regression option will help researchers determine which variable, or set of variables, provides the most significant amount of information for the dependent variable. Although other regression models can show the added significance of variables (i.e. stepwise, forward, or backward), these are less helpful for exploratory studies that may not have previous information or research to support the entry method of the independent variables.

It also is important to note that this is the first study that compared the Koppitz-2 scoring of the BG-II and VMI-V for students with ASDs and TD peers. These findings are a unique contribution for practitioners and researchers seeking information about the comparability of the two instruments. The multicollinearity test conducted to insure that no independent, or predictor, variables were very highly correlated prior to performing the multiple regression, suggest that more research should be done about the relationship between these two instruments. The results of the best subset analysis also suggest that visual and motor skills may not have the same relationship on both instruments. Specifically, the results indicated that both the TVPS-3 and Navon Task completion time were part of the best predictor model for the BG-II scores, however only the TVPS-3 was significant for the VMI-V. Both instruments may be generally measuring the same construct (Shapiro & Simpson, 1995; Volker, Lopata, Vujnovic, et al., 2010), however this study proposes that slower global processing has a negative impact on the BG-II that may not be present on the VMI-V. The replication of these results, and further research

on the relationship of visual and motor skills on visual-motor integration, will be important in research that seeks to understand the comparability between these two instruments.

Limitations

There are several limitations in the current study. The study consisted of a homogenous sample, and this lack of variability is a possible limitation of the study. The study's sample consisted mainly of Caucasian participants, many of the ASD participants were male, and most participants lived in a household where the income was greater than \$35,000 a year. Although, there is no current research suggesting that the symptoms identified in ASDs differently impact students of different races, ethnicities, or socioeconomic statuses (Mandell et al., 2009). However, future researchers may want to investigate whether or not income, which lacked variability in the study as well, plays a mediating or predictive role in any of the relationships presented in this study (Thomas et al., 2012). Additionally, many of the participants in the TD sample were siblings of the participants in the ASD group contributing to the homogeneity. It is important to note however, that in this study no ASSQ score indicated risk for an ASD in the TD siblings, and there were no significant differences between siblings and non-siblings in the TD group on any of the measures used in the analyses.

Participants for this study were recruited through list-servs and parent groups. The families recruited for participation were connected in their communities to special services that addressed the social and academic difficulties of their children. It is important to note that successful intervention and student progress may be one explanation for the lack of significance in the group differences.

Future Research and Practical Application

In replications of this study, and other studies that seek to understand the impact of the local processing bias on visual-motor integration skills and academic achievement, researchers should continue to include tools that measure response time. The results indicated that students with ASDs had a longer response time on the Navon Task, and future research studies may benefit from incorporating more instruments that measure response time in their studies.

As discussed, few studies have examined the relationship between visual perception and fine motor ability on visual-motor integration. This research study indicated that there might be a complex relationship between the local processing bias, fine motor ability, and visual-motor integration that should be accounted for when making intervention choices in schools. Researchers should also continue to examine the impact of visual, motor, and visual-motor integration skills on academic achievement, as there is still information to uncover. For example, researchers can explore whether other forms of visual processing and motor difficulties like fatigue have differing or similar affects on academic achievement. As well as other aspects of visual processing and motor development that might impact visual-motor-integration skills. Future studies in this area should gather data on the characteristics of interventions that can enhance academic achievement when students have difficulty with visual, motor, and visual-motor integration skills.

Practitioners should be aware of the strong relationship between visual, motor, visual-motor integration and academic achievement, because they are tasked with the responsibility to collect data that will lead to effective interventions (Decker et al., 2006;

Hosp, 2006; National Association of School Psychologists [NASP], 2010). Often, practitioners suggest interventions that target fine motor muscles and development in order to help improve students' visual-motor integration and handwriting skills (Floet & Maldonado-Durán, 2010; Pennington, 2009; Whitby et al., 2009). It is evident from this study that interventions targeting global processing time may have a more significant impact on handwriting and other visual-motor integration tasks than only targeting fine motor skills. Practitioners may find suggesting interventions that utilize visual prompts like highlighting, tools like graphic organizers and story maps, and teach self-regulating skills to be more effective on visual-motor integration development (Pennington, 2009; Whitby et al., 2009). Practitioners are encouraged to collect data on visual and fine motor skills in addition to visual-motor integration, so they are aware of whether the relationship between the visual and fine motor skills to academic achievement is also impacting a student's performance.

Furthermore, because this study was the first to compare the Koppitz-2 scoring of the BG-II to the VMI-V for students with ASDs with TD peers, a replication of these results is suggested. Future research should investigate the different variables contributing to success on both the Koppitz-2 scoring of the BG-II and the VMI-V. This study suggests that although each instrument does test a component of visual-motor integration there continue to be questions about the variables that are responsible for the differences noted (Volker, Lopata, Vujnovic, et al., 2010). Practitioners should be aware that if a student has reading, writing, or math difficulties, a visual motor-integration assessment might provide important insight into underlying deficits impacting these academic tasks.

Additionally, there has been research to suggest that students with ASDs may have higher instances of sensory integration disorder (Ben-Sasson et al., 2009; Bhat, Landa, & Galloway, 2011). Sensory integration disorder is described as a difficulty processing and modulating sensory input (Ben-Sasson et al., 2009), and it is important for future research to examine the potential relationship between difficulties with sensory regulation and the impact it may have on fine motor and visual-motor integration abilities.

Conclusion

In conclusion, given the increase of students with ASDs being served in schools, it is important to understand how the differences and difficulties associated with this disorder impact academic achievement (Whitby et al., 2009). This study advances ASD research by investigating the relationship between the local processing bias, fine motor, and visual-motor integration skills, and the impact of these skills on reading, writing, and mathematic achievement. The results of this study revealed a newly researched relationship between the time it takes to complete global processing tasks and visual-motor integration skills, and the on reading achievement. Future research should continue to explore the relationships between global processing time, discrete fine motor ability (i.e. finger tapping), and visual-motor integration skills, investigate the effectiveness of interventions that address these skills, and collect more data about the impact of these sensory processes to academic achievement. Practitioners should be aware of the relationship between specific visual processing skills, fine motor performance, and visual-motor integration on academic achievement, in order to suggest effective interventions.

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