# An Examination of Effectiveness and Visual Attention to Visual Instructional Supports for Children with Autism Spectrum Disorder

by

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Abstract

Individuals with autism spectrum disorder (ASD) display widespread motor deficits in addition to the core social-communication and behavioral deficits. Children and adolescents have consistently demonstrated poor performance on commonly used clinical and standardized batteries of motor performance. It is unclear to what extent poor performance is related to administration instruction and/or known impairments in sensory information processing in this population.  Individuals with ASD have difficulty processing sensory information, but demonstrate a relative strength in communicating through visual versus auditory means such as using pictures to help express and receive information. For this reason, visual supports such as picture cards, schedules, and videos are frequently implemented to aid communication and instruction in this population. Studies show that video modeling is an effective intervention to improve communication, social, and cognitive skills in individuals with ASD. Video modeling may have promise as a support for motor skill instruction in ASD. In this dissertation, we conducted two studies to address this issue. First, we conducted a meta-analysis examining the efficacy of video modeling to teach movement-related tasks in individuals with ASD. The results indicate that video modeling is associated with significant improvement in movement performance. Results also indicate study bias, such that studies that utilized a smaller number of samples/observations yielded larger effects of video modeling. The findings from this meta-analysis support the use of video modeling.

The second study explored visual attention using of eye tracking to monitor gaze behavior participants with and without ASD in two visual support conditions (video and task card). Participants watched one series of skills presented as a video and another series presented as series of static images at different phases of the movement (i.e., task cards) while wearing eye-tracking glasses. Visual attention, as measured by horizontal gaze predictability and normalized fixations on the model in visual support conditions, did not differ by group, nor were there any group by condition interactions. A main effect of condition indicated that horizontal gaze was more predictable in the video condition. These results suggest that visual attention to the supports used in this study did not differ by group and that the dynamic nature of video condition may guide attention more than static presentation

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# I. Introduction

## Motor Impairments in ASD

Individuals with autism spectrum disorder display widespread motor impairments including: postural control, locomotion, and gait (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Gepner & Mestre, 2002; Jansiewicz et al., 2006; Pan, Tsai, & Chu, 2009; Rinehart et al., 2006), difficulties in motor planning, action correction, and reaction time (Forti et al., 2011; Hughes, 1996; Nazarali, Glazebrook, & Elliott, 2009; Schmitz, Martineau, Barthélémy, & Assaiante, 2003; Turner, Frost, Linsenbardt, McIlroy, & Müller, 2006), and poor performance of ball skills (Pan et al., 2009; Staples & Reid, 2010). Individuals with ASD also exhibit impaired fine motor coordination and dexterity needed for activities of daily living and school such as buttoning/zipping clothing, self-feeding, and writing (Beversdorf et al., 2001; Dyck, Piek, Hay, Smith, & Hallmayer, 2006; Green et al., 2002).

These motor impairments may be due to comorbid cognitive and learning disabilities (Morin & Reid, 1985), impaired language (Noterdaeme, Mildenberger, Minow, & Amorosa, 2002), and/or differences in neural structure and function (Forti et al., 2011; Just, Keller, Malave, Kana, & Varma, 2012; Schmitz et al., 2003). However other research suggests motor deficits observed in ASD may be related to impaired processing of sensory information (Baranek, David, Poe, Stone, & Watson, 2006; Bhat, Landa, & Galloway, 2011; Kern et al., 2006; Liu, 2013; Minshew, Goldstein, & Siegel, 1997).

## Sensory Processing Impairments in ASD

Children with ASD have difficulty processing sensory information such as tactile, olfactory, auditory, visual, proprioceptive and vestibular input (Baranek et al., 2006; Benson, Piper, & Fletcher-Watson, 2009; Rogers & Ozonoff, 2005). Of specific interest to the current research is reduced ability to process visual information with increasing complexity (Au-Yeung, Benson, Castelhano, & Rayner, 2011; Benson et al., 2009; Bertone, Mottron, & Faubert, 2004). Despite these difficulties in visual processing, individuals with ASD demonstrate a relative strength in communicating through visual versus auditory means such as using pictures to help express and receive information (American Psychiatric Association, 2000; Lord & McGee, 2001; Tissot & Evans, 2003). For this reason, visual supports such as picture cards, schedules, and videos are frequently implemented to aid communication and instruction in this population. These communication aids may help reduce the complexity and amount of information presented, compared to live demonstrations.

**Use of Visual Supports in ASD**

Visual supports direct attention to relevant stimuli and facilitate successful completion of the task. These supports have been successfully implemented during movement instruction in physical education and therapeutic settings (Berkeley, Zittel, Pitney, & Nichols, 2001; Bertone et al., 2004; Bhat et al., 2011; Quill, 1997). A form of frequently used visual supports are picture task cards, which provide simplified graphic representation of objects, places, people or actions (Flippin, Reszka, & Watson, 2010; Rao & Gagie, 2006; Tissot & Evans, 2003; Welton, Vakil, & Carasea, 2004). However, task cards only provide a snapshot of the task, which may not convey sufficient information with respect to the process of the movement. This would be particularly important in cyclical skills like skipping or running, where there is no discrete starting and end point of the movement.

Another effective instructional method for individuals with ASD is video modeling, in which the learner views a video of a task being performed before that individual attempts the targeted task (Bellini & Akullian, 2007). Video modeling allows the learner to observe the behavior multiple times without requiring another person to repetitively model that behavior (Charlop-Christy, Le, & Freeman, 2000). Therefore, video modeling can be used to enhance consistency of demonstration across multiple observations and learners (Plavnick & Hume, 2014). Research examining the effectiveness of video modeling frequently focuses on social and communication tasks and to a lesser extent activities of daily living (LeBlanc, 2010). Although visual supports are commonly used during instruction of goal-oriented movement for individuals with autism, the mechanisms underlying the effectiveness of these supports are poorly understood. One possible reason these support are effective is that they guide visual attention to pertinent aspects of the information displayed.

**Eye-tracking as a Measure of Learning**

Visual attention may be assessed via devices that track the fovea of the retina during eye movements (Lai et al., 2013; Liversedge, Gilchrist, & Everling, 2011). This approach is rooted in the "eye-mind" hypothesis (Just & Carpenter, 1976), which suggests eye movements indicate the location of one's cognitive attention within a visual display. There are three types of eye movements measured by eye tracking devices: saccades, which are fast, large movements that are made to maintain the fovea on a moving visual target; smooth pursuit, which are gradual and small movements that maintain the fovea on a moving target; and fixations, in which the fovea is stationary on a visual target to allow for visual processing (Duchowski, 2007; Liversedge et al., 2011). When viewing a static scene or reading information, the eyes move through a series of saccades and fixations. When viewing a moving stimulus, the eyes engage in all three types of eye movements.  Information is gathered or "encoded" during periods of fixations, which last on average 250ms, but range 100 to 500ms (Poole, Ball, & Phillips, 2005; Rayner, 1998, 2009). Fixation duration is indicative of the amount of processing applied to the object(s) within the area of fixation (Poole et al., 2005). The fixation count is the total number of fixation within an area of interest (AOI) or during a task and is strongly correlated with fixation duration. Fixation count can be a proxy measurement of information processing during a task (Lai et al., 2013).

Lai and colleagues (2013) recently conducted a systematic review of studies that employed eye-tracking methods to understand how eye movements have been used to investigate cognitive processes of learning. Across the 113 studies included, temporal measures were used most frequently used (e.g., total fixation duration, average fixation duration, gaze duration, and total reading time) followed by count measures (e.g., total fixation count, average fixation count, and probability of fixation count), and spatial measures (e.g., fixation position, fixation length, saccade length, and scanpath pattern). In addition to examining frequency of eye movement measures across studies, the researchers identified the following seven learning themes: (1) patterns of information processing – 53 studies, (2) effects of instructional strategies – 26 studies, (3) reexaminations of existing theories – 14 studies, (4) individual differences – 15 studies, (5) effects of learning strategies – 9 studies, (6) social/cultural effects – 3 studies, and (7) decision making patterns – 3 studies.

Within the themes of effects of learning strategies and information processing, only four studies targeted psychomotor learning outcomes. Increased application of eye-tracking methods in this area could create a wealth of information regarding how information processing of learning strategies may vary across populations, activities, and level of skill and sport expertise. Such knowledge could be particularly impactful for motor skill and physical activity instruction in individuals with cognitive and developmental disability.

**Application of Eye-tracking in ASD**

The vast majority of eye tracking studies have focused on differences in processing social and non-social stimuli, in individuals with ASD. For example, individuals with ASD demonstrate increased attention to non-social objects such as tools, electronic devices, vehicles, or other objects related to their restricted interests (Kanner, 1943; South, Ozonoff, & McMahon, 2005) and decreased attention to social stimuli such as human voice, gestures, and faces (Dawson, Webb, & McPartland, 2005; Sasson, Elison, & Turner-Brown, 2011). When comparing attention to light-point animation displays of biological (e.g., children's games such as 'pat-a-cake' and 'peek-a-boo') vs. non-social (e.g., inverted point-light animation shown in reverse order), two-year-olds with ASD exhibited preferential visual attention to the non-social animations (Ami Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Several studies examining emotion recognition from photographs or videos of human facial expressions suggest abnormal gaze with increased fixation on the mouth compared to eyes (Dalton et al., 2005; A Klin, Jones, Schultz, & Volkmar, 2002; Pelphrey et al., 2002; Sasson et al., 2011; Spezio, Adolphs, Hurley, & Piven, 2007). As more salient information regarding emotion expression comes from the eyes, differences in allocation of visual attention may underlie impairments in the detection of these salient (emotional) features in those with ASD. These studies suggest that deficits in social and emotional functions may be due, in part, to abnormal visual attention to relevant aspects of social or emotional stimuli. To further decompose the aspects of a visual stimulus that are of interest to individuals with ASD, Wang and colleagues (2015) conducted an investigation of spontaneous allocation of visual attention using complex natural scenes to simulate real-world free viewing (Wang et al., 2015). Stimuli were static scenes containing multiple dominant social and non-social objects of interest within the image. Objects in these images were characterized using a three-level saliency model, which included object-level (e.g., shapes), semantic-level (e.g., faces), and pixel-level (e.g., contrast) attributes. As in prior studies, individuals with ASD attended to objects that had a mechanical purpose or could be manipulated more readily than to faces compared to controls. This behavior suggests that information regarding operability is more salient than semantic information for individuals with ASD. Participants with ASD also exhibited increased focus at the center of images regardless of the presence of an object in other regions of the image. Additionally, participants with ASD exhibited less fixation on regions conveying object-level and semantic-level saliency less and great fixation towards regions of pixel-level saliency. Taken together, individuals with autism appear to focus attention on central objects with particular attention to basic components (e.g., pixel-level attributes).

Consistent with this study, others have hypothesized that impairments in visual attention exhibited by those with ASD is not necessary due to poor allocation of attention but an impairment of processing complex information (Minshew et al., 1997). In an examination of the effect of task instruction (social versus material) on examination of a picture, typically developing (TD) participants modulated their eye movement according to task instruction, such that TD participants increased time viewing objects in the scene when given material instructions (i.e. 'Estimate the material circumstances of the family') and more time viewing people when given social instructions ('Estimate how long the unexpected visitor has been away') (Benson et al., 2009). In contrast, participants with ASD did not demonstrate changes in eye movements with changes in task instruction. To ensure response in participants with ASD was not due to difficulty understanding task instructions, comprehension of task instructions was assessed following each visual inspection. Appropriate response by all participants signify that the lack of modulation of eye behavior is a function of impaired ability to process the complex information for task.

To further examine differences in eye movements with respect to task complexity, AuYeng and colleagues (2011) compared sequences of eye movements TD and individuals with ASD while viewing complex pictures in a simple “spot the difference” and a complex “Which One’s Weird” task (Au-Yeung et al., 2011). The goal of the “spot the difference” task was to identify a missing detail, which requires a concrete decision that could be made using visual pattern matching.  Conversely, the “Which One’s Weird” task required participants to make decisions regarding which picture look weird or odd. To perform this task, participants had to use previously acquired knowledge (top-down information) to make a judgment of novel information (bottom-up visual information). No group differences in eye movement were observed for the simple task.  However, for the complex task, individuals with ASD exhibited more fixations before entering the targeted area of interest, took longer to begin inspecting the area of interest, and took longer to identify targeted information within the area.  Together, these findings support the notion of impaired processing of complex information in ASD proposed by Minshew et al. (1997).

The impairments in eye movements and visual attention previously reported in lab-based settings suggest that individuals with ASD may experience greater difficulty processing complex stimuli, particularly biological stimuli, in a classroom or real-world setting. These types of impairments may lead to difficulty in both the instruction and assessment that use live demonstrations. Of particular importance for the present study is that motor skill instruction tends to occur in environments containing highly complex temporal and spatial information (e.g., moving people and objects) and distracting stimuli (e.g., loud auditory stimuli, bright lights), which may affect visual attention to relevant stimuli. Consistent with the research supporting the efficacy of video modeling and task cards for motor skill instruction, the presentation of a skill demonstration through a video or series of static images could reduce extraneous environmental information, increase saliency of key movement aspects, and may reduce cognitive attentional demands on individuals with ASD. However, research investigating the effectiveness of visual supports for motor skill instruction and examining underlying mechanisms is severely lacking.

**Purpose Statement**

This dissertation consists of two studies that examine visual supports for movement instruction in individuals with autism spectrum disorder. The first study is a meta-analysis of research examining the efficacy of video modeling to teach movement-related tasks in individuals with ASD. The second study is an examination of eye behavior while viewing two types of instructional supports (videos and static images). In this study, children and adolescents with and without ASD viewed videos and static images for motor skill instruction while wearing eye-tracking glasses. The primary aim was to examine differences between groups (ASD vs. controls) and conditions (video vs. task card) with respect to the following dependent measures of visual attention: a) the percentage of view time the participant's gaze fixated on predetermined areas of interest (i.e., normalized fixation time); and, b) spatial predictability of gaze patterns (i.e., autocorrelation of gaze) during the visual stimulus presentation. A secondary aim was to examine factors that might influence visual attention (i.e. normalized fixations and spatial predictability of gaze) such as inhibitory control (i.e., Flanker task), motor proficiency (i.e., BOT-2 scores), and skill knowledge. A tertiary aim was to examine if group or condition differences in visual attention (i.e., normalized fixations and the magnitude of the gaze autocorrelation) were mediated by motor skill performance (TGMD-3 score).

## II. Study 1: Efficacy of Video Modeling to Improve Movement-related Tasks in ASD: A Meta-analysis

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that impacts 1 in 68 children in the US (American Psychiatric Association [APA], 2013). It is characterized by impairments in social-communication and social interaction as well as restricted, repetitive patterns of behavior, interests, or activities (Centers for Disease Control and Prevention [CDC, 2014]). In addition to these core deficits, individuals with autism also exhibit widespread motor impairments including motor planning, action correction, (Forti et al., 2011; Hughes, 1996; Nazarali et al., 2009; Schmitz et al., 2003; Turner et al., 2006), postural control, gait, and locomotion (Fournier et al., 2010; Gepner & Mestre, 2002; Jansiewicz et al., 2006; Pan et al., 2009; Rinehart et al., 2006)

### ASD and Visual Supports

Compared to typically developing peers, individuals with ASD exhibit both quantitative and qualitative differences in communication. Many individuals with ASD never develop complete fluency in verbal communication and/or exhibit idiosyncratic use of words and phrases, echolalia (repeated speech), and difficulty initiating and sustaining conversation and retaining information conveyed verbally (Lord, 2000). However, individuals with ASD demonstrate relative strength in processing information through visual stimuli (Hodgdon, 1995; Tissot & Evans, 2003; Quill, 1997). Consequently, the use of visual supports for communication and instruction in ASD has received considerable attention.

Pictoral exchange communication systems (PECS) utilize simplified visual images (e.g., cartoon images) to convey task or item information designed specifically for children with ASD (Frost & Bondy, 2002). PECS allows children with ASD to initiate requests for preferred items or respond to other questions. For instance, the child can respond to the question "Which activity do you want to do?" by show the adult a picture of the activity (e.g. coloring, playing outside, etc). In addition to communicating requests, pictures can be used as visual prompts or instructions. Activity Schedules, in which sequence of tasks is depicted as a list or sequence of steps with pictures or simplified images, help children with ASD complete tasks with greater independence across multiple settings. For example, the activity schedule could be implemented in helping a child get dressed for the day with a pictures for putting on underwear, putting on pants, putting on a shirt, putting on socks, and then putting on shoes.

**Modeling and Video Modeling**

Another effective visual strategy used to improve performance of targeted behaviors is modeling. Modeling is the use of a visual demonstration as a means of conveying information about how to perform a task. During in-vivo or live modeling, the learner watches another person perform the task and then practices the task with or without feedback on performance. One limitation of in-vivo modeling is the requirement of having an appropriate model available to provide repeated demonstrations as needed. Another limitation is the risk of drift in consistency across demonstrations. Recently, video modeling (VM) has been used to provide modeling of tasks that may be watched repeatedly. In VM, the learner views a recorded demonstration of the targeted behavior. This allows the learner to observe the behavior multiple times without requiring another person to repetitively model that behavior (Charlop-Christy et al., 2000). Additionally, the ability to replay the same recording enhances consistency of the demonstration across multiple observations and learners (Plavnick & Hume, 2014).

The efficacy of VM to improve behaviors in ASD has received much attention in domains of social, affective, and communication tasks and to a lesser extent activities of daily living (LeBlanc, 2010). Application of VM in physical activity and education settings has been posited (Case & Yun, 2015) and preliminary work has examined the use of VM for fundamental motor skills in typically developing preschoolers and middle school children with intellectual disabilities (Brunsnikova & Cavalier, 2017a; Brunsnikova & Cavalier, 2017b). However, research examining the efficacy of VM for improving motor skills in children with ASD is lacking. The purpose of this study is to measure the efficacy of VM to improve performance of movement-related tasks in individuals with ASD. We conducted a meta-analysis of VM interventions targeting movement-related tasks in ASD to: 1) compute the overall effect size of interventions across studies and 2) determine if VM efficacy was influenced by participant age.

## Method

### Search Strategy and Study Selection

Figure 1 depicts the search strategy consistent with the PRISMA guidelines (Moher, 2009). The following databases were queried: Academic Search Premier, ERIC, MEDLINE, PsycINFO, and SPORTDiscus. Search phrases included: (1) “Autism” OR “ASD” AND “observational learning” (2) (“autism” OR “ASD”) AND “Ob* learn*” AND (“motor” OR “move*”). Search parameters included: 1) date range: all studies until October 29, 2015; 2) peer-reviewed articles; and 3) English language publications. Note: MeSH terms for ASD were incorporated to capture all previous definitions of this disorder (e.g., PDD-NOS, autism, Asperger’s). A total of 552 articles met these initial search criteria.

Once duplicates were removed, 436 records were screened for study eligibility. Study inclusion criteria were: 1) participants had a diagnosis of autism spectrum disorder (ASD); 2) participants were taught movement tasks; and, 3) the intervention required observational learning through video modeling. For this study, movement-related tasks included self-care skills such as making a sandwich or toileting; occupational skills such as cleaning restrooms or packing and shipping products; or play actions involved in role-playing (e.g., teacher or doctor) or manipulating toys (e.g., pushing cars or feeding a baby doll). The primary author screened articles by title and abstract according to inclusion criteria. A second review of the title and abstracts was conducted to confirm inclusion/exclusion of studies. A total of 107 were then screened for inclusion by full-text review. A total of 48 studies met all inclusion criteria based on full-text review (see Figure 1.1 for details regarding study exclusion).

Of the 48 eligible studies only 3 studies employed a group design. As such, we focused the meta-analysis on studies that employed a single-subject design. All single-subject designs were screened according to additional quality indicators for single-subject designs (Horner et al., 2005); these quality indicators are presented in Table 1.1. Twelve studies out of 45 employing a single-subject design met inclusion criteria based on these quality indicators.

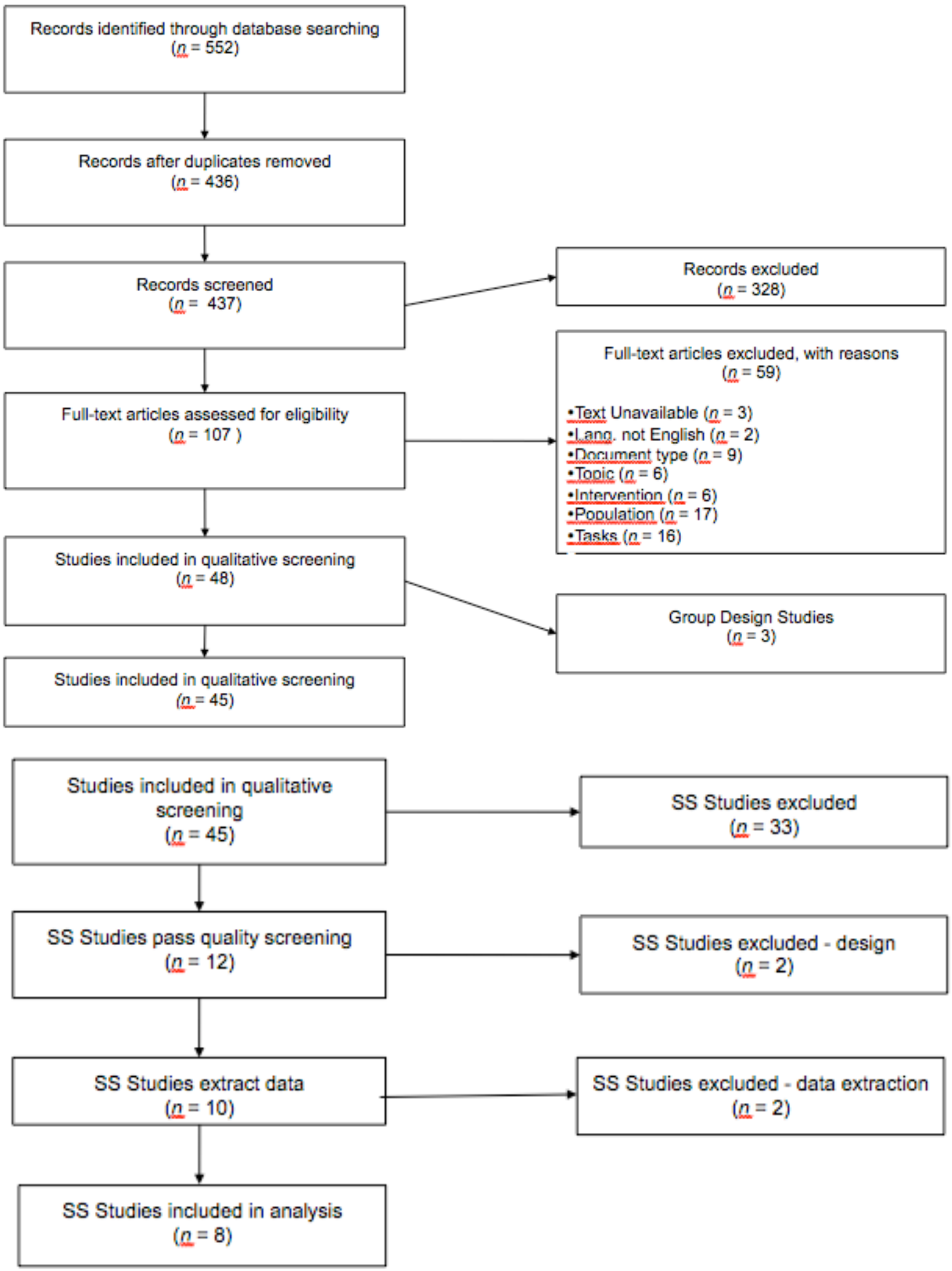


*Figure 1.1*. Screening of articles. Presented here is the PRISMA flow diagram indicating the number of studies identified, screened, eligible, and included in the quantitative analysis.

Table 1.1

Quality Indicators of Single-Subject Research from Horner et al., (2005).

| Quality Indicator | Description |
|---|---|
| Description of Participants and Settings | Participants and setting have been described such that future studies may select similar participants and settings with replicable precision. |
| Description of Dependent Variable (DV) | DVs are operationally defined; DVs are quantifiable. DVs are valid and described to allow replicable precision. DVs are measured repeatedly over time. Inter-observer agreement is measured and meet minimal standards. |
| Baseline | The study includes a baseline phase in which the DV is measured repeatedly to demonstrate a stable pattern of response. The conditions of this phase are described with replicable precision. |
| Experimental control | The design controls for common threats to internal validity and demonstrates experimental effect at least three times at three different time points (i.e., functional relation). For example, the demonstration of effect or functional relation may be observed for three different individuals performing the same task or the same individual tested in three different settings. The result of the intervention exhibits a pattern that demonstrates experimental control (i.e., a change in behavior across the different phases that aligns with changes in phase design). |
| External Validity | Experimental effects are replicated across participants, tasks, materials, and settings. |
| Social Validity | The researcher(s) have demonstrated that the dependent variable is socially important and that the magnitude in change in DV is socially important. Implementation of the intervention is both practical and cost effective. This criterion is usually assessed through interviews and surveys of parents, teachers, graduate students, or research assistants involved with the project. |

## Data Extraction

The corresponding authors of these studies were contacted via email to request individual data in order to compute the magnitude of the intervention effects. Seven of the authors provided data files and imageJ (Rasband, 2016) was used to extract data from the figures of the remaining studies. Of the five studies that required data to be exacted using imageJ, we were unable to extract data accurately from the figures for two studies (Blum-Dimaya, Reeve, Reeve, & Hoch 2010; Sancho, Sidener, Reeve, & Sidener, 2010). In these studies, the y-axis was not precise enough to differentiate data points accurately and/or the intervention points overlapped such that distinction between different interventions could not be established. Consequently, these studies were excluded from future analyses. One study had two participants with ASD and one with the intellectual disability but not ASD; data for the participant with intellectual disability were not included in the present analysis. For studies involving multiple interventions ($n$ = 2), only data related to video modeling was extracted. For studies that utilized a phase change design ($n$ = 2), only data from baseline and intervention phase were extracted; data from maintenance or generalization phases were not included. For studies that utilized multiple baseline designs across participants ($n$ = 6), data were extracted for baseline to intervention for each participant or task separately. To obtain equivalent data structures across studies (i.e., a single baseline and single intervention phase), for studies in which participants performed multiple tasks with different number of observations per task ($n$ = 6), data were combined as follows: a) data were extracted such that the observations for each task were aligned for each phase starting with the last observation for that phase; b) starting from the end of the phase, data were averaged point-by-point across different outcomes. For example, in Kellems and Morningstar (2012), one participant was assessed on three tasks with three baseline/four intervention observations for cleaning bathroom, four baseline/four intervention observations for vacuuming, and five baseline/five intervention observations for cleaning outside. For this participant, the average of the last three baseline observations for each task and the average of the last four intervention observations for each task were obtained. The final spreadsheet was comprised of a single set of baseline observations and a single set of intervention observations for each participant for each study. This allowed us to calculate the changes in performance due to video modeling from the baseline to intervention observation (the estimated effect of phase) for each study for each individual. A summary effect size was computed across all data, while accounting for repeated measures from individuals (e.g., multiple tasks measured) or multiple individuals within a study.

**Statistical analysis**

All analyses were conducted using R Studio (version 3.2.4, 2016, The R Foundation for Statistical Computing). Linear mixed effects modeling (packages lme4 [Bates, 2010], lmerTest [Kuznetsov, Brockhoff, & Christensen, 2013]) was used to: 1) determine the magnitude of differences between baseline and intervention for each participant for each study; and, 2) assess overall effects of video modeling on behavior outcomes controlling for the nested structure of these data (e.g., observations within a phase within a participant within study). Table 1.2 provides the step-wise model comparison.

Table 1.2

Step-wise Procedure for Testing Regression Models for Effect Size

| Model | Statistical Model | Descriptions |
|---|---|---|
| 0 | y = 1+(1\|Study/Participant/Phase) | Random intercepts model |
| 1 | y = 1+(1+Trial\|Study/Participant/Phase) | Random slopes and intercepts model |
| 2 | y = 1+Phase.c+(1+Trial\|Study/Participant/Phase) | Fixed effect of phase (baseline–intervention) |

Note: All models used maximum likelihood estimation.

First, a random intercepts model (model 0) was used to determine the variance accounted for by participants within a study. Next, we incorporated a random slope to account for the number of trials (repeated measures) within a phase for each participant within a study (model 1). Lastly, we estimated the fixed effect of phase (baseline vs. intervention) to determine the efficacy of the video modeling for each study (model 2). The models were compared using the Akaike Information Criterion (AIC) and Wald tests for the change in deviance with $\alpha = 0.05$ (Long, 2012). The best fitting model was used to calculate effect size (e.g., fixed effects of phase) of video modeling after accounting for the nested-structure of the data.

Bias can be estimated as the degree to which the effect size is influenced by the sample size (Borenstein, Hedges, Higgins, & Rothstein, 2009). In studies using a group design, sample size is regarded as the number of participants in the study as each data point comes from a different participant. In studies using single-subject design, the analogue to sample size is the number of observations for each task (i.e., more trials leads to better approximation in much the same way that more participants leads to better approximation). Therefore to examine bias in our analysis, we modeled the fixed effect of number of observations, while controlling for participants within a study.

Lastly, we also examined if the effect size of a video model was influenced by participant age. To do this, we modeled the fixed effect of participant age while controlling for participants within a study.

**Results**

Of the 48 studies using a single-subject subject design, eleven studies were excluded for not establishing external validity, ten for not reporting social validity, and an additional six for failing to meet both criterions. One study did not meet baseline criteria and an additional study met neither baseline nor external validity criteria. Lastly, two studies were rejected for failing to meet both baseline and social validity criterion.

A total of twelve studies passed the quality screening for single subject design, however two studies were excluded from the statistical analysis because they employed a design that prevented the independence of performance of the measured task across study phases. For example, Shrestha, Anderson, and Moore (2012) employed a multiple-baseline approach in which the performance during one phase was subsumed into the next (i.e., phase 1 consisted of performing steps 1 through 4, phase 2 consisted of performing steps 1 through 10, and phase 3 included performing steps 1-13). Rosenberg, Schwartz, and Davis (2010) compared the use of a commercial video to a custom video for improving independent hand washing in two participants. As the study design lacked a withdraw (or washout) phase between the two VM interventions and did not counter-balance the order of video presentation. Thus, carry-over effects could not be accounted for in the second intervention phase. The characteristics of the remaining 10 studies included in the meta-analysis are presented in Table 1.3. A total of 22 participants, ranging in age from 3 years, 9 months – 28 years were included.

Table 1.3

Study Characteristics

| Reference | Participant Psuedonym | Age | Target Behavior | Task Domain |
|---|---|---|---|---|
| Burke et al, 2013 | Zeke<br>Tom<br>Ric<br>Dan | 22 years<br>21 years<br>19 years<br>28 years | Product packing and shipping process | Occupational |
| Cardon & Wilcox, 2011 | Evan<br>Isaac<br>Aaron | 33 months<br>43 months<br>33 months | Imitation of modeled play actions | Play |
| Cihak & Schrader, 2009 | Ryan | 21 years | Sending a fax<br>Making copies | Occupational |
| | Ronald | 16 years | Making copies<br>Sending a fax | |
| | Phil | 17 years | Preparing family packs<br>Preparing first-aid kits | |
| | Alan | 20 years | Preparing first-aid kits<br>Preparing family packs | |
| Drysdale, Lee, Anderson, & Moore, 2015 | Tim | 4 years, 1 month | Toileting - Walking & Undressing<br>Toileting - Sitting & Eliminating<br>Toileting - Redressing & Flushing | Self-Care |
| Kellems & Morningstar, 2012 | Sam | 20 years | Cleaning public restrooms<br>Vacuuming lobby<br>Cleaning sidewalk | Occupational |
| | Alex | 22 years | Filling out vending machine order book to identify needed refills<br>Taking inventory of items to restock<br>Filling a crate with items to restock vending machine | |
| | Tom | 22 years | Cleaning employee bathroom<br>Emptying the garbage | |

| | | | |
|---|---|---|---|
| | Kyle | 22 years | Breaking down boxes/recycling cardboard<br>Cleaning Bathrooms<br>Cleaning glass display case |

Table 1.3

Study Characteristics (cont.)

| Reference | Participant | Age | Target Behavior | Task Domain |
|---|---|---|---|---|
| Moore et al., 2013 | Kiera | 5 years 5 months | Letter "a" | Academic/ Occupational |
| | | | Letter "r" | |
| | | | Letter "e" | |
| | | | Letter "i" | |
| | | | Letter "K" | |
| Ozen, Batu, & Birkan, 2012 | Uzan | 9 years | Role play - Cashier | Play |
| | | | Role play - Nurse | |
| | Cemil | 9 years | Role play - Canteen worker | |
| | | | Role play - Doctor | |
| | | | Role play - Teacher | |
| | Osman | 9 years | Role play - Customer | |
| | | | Role play - Patient | |
| | | | Role play - Student | |
| Yakubova & Taber-Doughty, 2013 | John | 16 years | Cleaning Mirror | Occupational |
| | | | Cleaning Sink | |
| | | | Sweep Floor | |
| | Tyler | 19 years | Clean Mirror | |
| | | | Clean Sink | |
| | | | Sweep Floor | |

Model comparisons, including the fit statistics, are presented in Table 1.4. Model 2 (random intercept, random slope, estimating the fixed effect of phase) yielded the best fit (AIC =1977.3) and was significantly better than the previous model (Model 2 vs. Model 1; $\chi^2_{(1)}$ = 19.764, $p < 0.001$). The estimated effect of phase ($\boldsymbol{\beta}$) and standard errors are presented in Figure 1.2. Estimated effect of phase for each participant data are color-coded by study. Overall, video modeling resulted in a significant improvement in behavioral outcomes with respect to baseline across all studies ($\boldsymbol{\beta}$ = 35.957, standard error = 5.575, $T(35.19)$= 7.969, $p < 0.001$).

Table 1.4

Effect Size Model Comparison Statistics

| Model | *df* | AIC | Deviance | $\chi^2$ | $\chi^2$ df | *p* |
|---|---|---|---|---|---|---|
| 0 | 5 | 2230.9 | 2320.9 | | | |
| 1 | 11 | 1995.1 | 1973.1 | 347.795 | 6 | $< 2.2e^{-16}$ |
| 2 | 12 | 1977.3 | 1953.3 | 19.764 | 1 | $8.763e^{-06}$ |

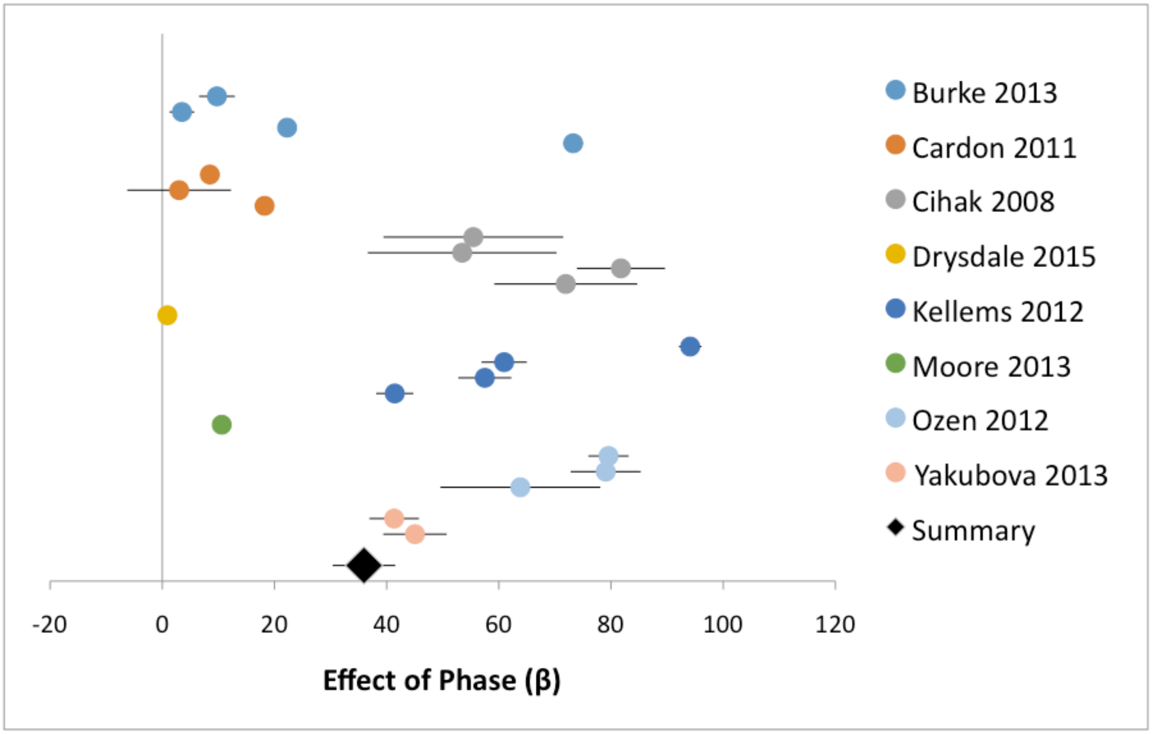


*Figure 1.2.* Estimated effects of phase (baseline vs. intervention) for each participant by study (colored circles). Error bars = standard error of the estimated effect. The summary effect is represented as the large black diamond.

There was a significant publication bias such that studies with fewer observations yielded a larger effect of phase for video modeling intervention ($\beta$ = -2.519, standard error = 0.899, $T(13.46) = -2.801$, $p < 0.015$). Model statistics for publication bias is presented in Table 1.5. Figure 1.4 displays the effect of phase of video modeling intervention for each participant as a function of number of observations assessed.

Table 1.5. Publication Bias Model Statistics

| | Estimate | Std. Error | *df* | T | *p* |
|---|---|---|---|---|---|
| Intercept | 74.1286 | 14.26 | 10.01 | 5.197 | 0.0004 |
| # of Data points | -2.5190 | 0.90 | 13.45 | -2.801 | 0.015 |

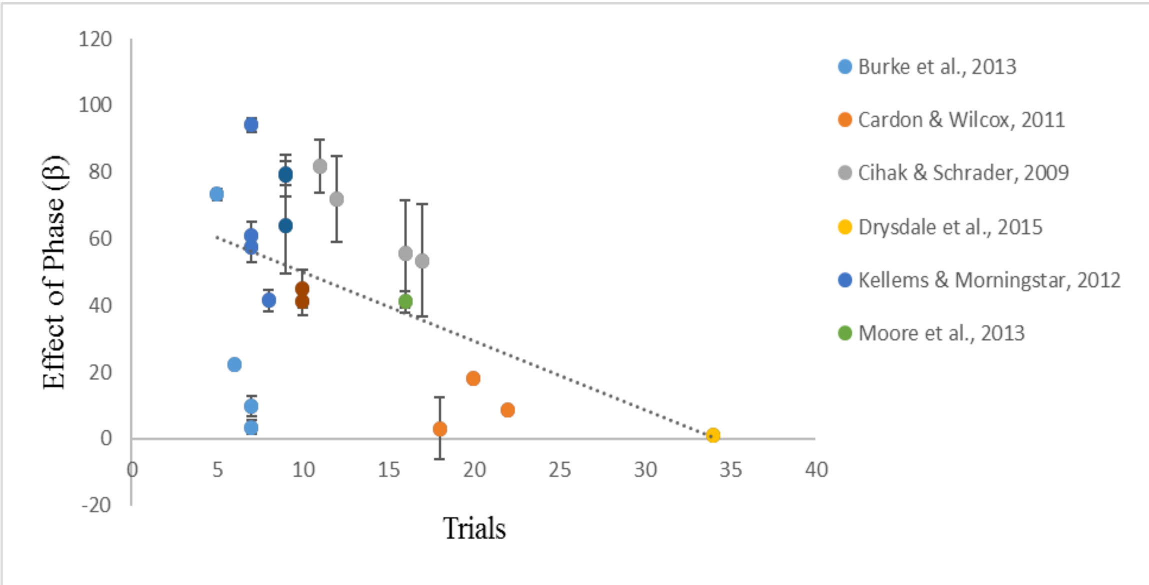


*Figure 1.3*. Publication bias assessed as the effect of phase as a function of number of observations used in calculation of effect size for each participant by study (colored markers).

Figure 1.4 shows the effect of phase of video modeling intervention for each participant as a function of participant age. The effect of participant age was not statistically significant (**β** = 1.50 ± 6.97, $t_{(11.7)}$= 1.5, $p$ = 0.160).

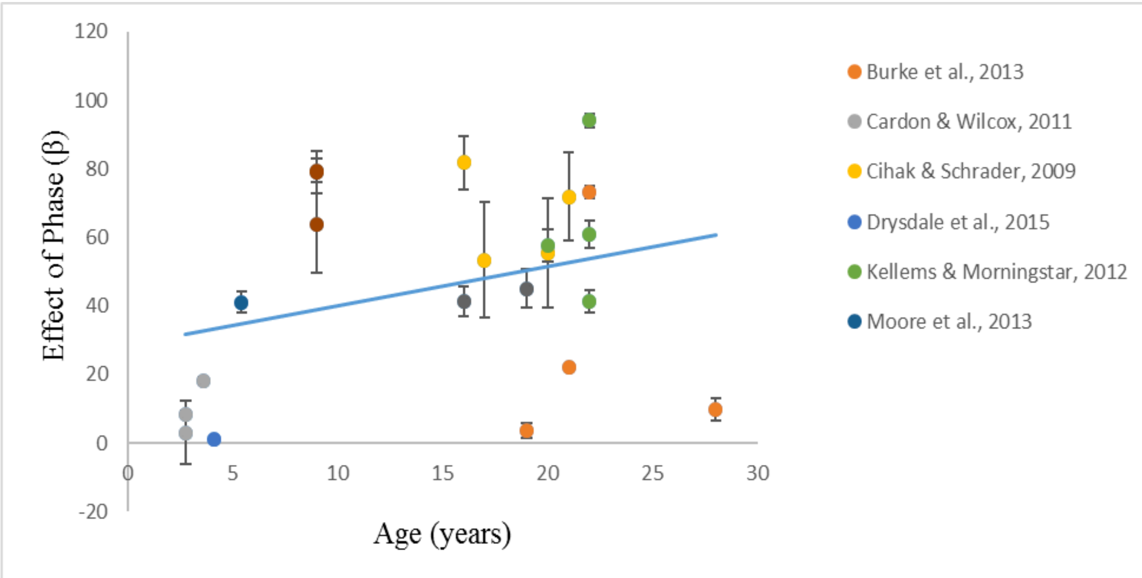


*Figure 1.4*. Effect of Phase by Age. This graph displays the effect of phase for each participant (colored by study) as a function of participant's age.

## Discussion

The current study is the first meta-analysis to systematically examine effectiveness of video modeling (VM) interventions on the performance of movement-related tasks in individuals with autism spectrum disorder. This study contributes to the current literature in the following key areas: (a) for well-designed studies (e.g., those that meet quality indicators for single-subject designs), VM is an effective means to improve performance of movement-related tasks; (b) the effects of video modeling were consistent across participant age; (c) the advanced statistical techniques were used to calculate effect sizes and meaningfully combine data across a range of single-subject designs.

### Statistical techniques

A unique strength of the current study is the statistical/analytic approach. In meta-analyses of group design studies, effect size (the magnitude of treatment effect) is usually calculated using inferential statistics such as means, correlations, or binary data (Borenstein et al., 2009). Conversely, single-subject research relies on visual inspection, an approach that involves plotting an individual participant's data and determining effects based on visual inspection of data plots and not statistical analysis.  Thus, the magnitude of an interventions' effects are not quantified (e.g., means and standard deviations) and the summary of effects across studies is problematic, particularly give the diversity of single subject designs. The recent increase in the use of single-subject design and emphasis of synthesizing data to create evidence-based practices highlights the need to combine visual inspection with quantifiable effect-sizes (Parker et al., 2005). Presently, there is a lack of consensus regarding acceptable procedures for calculating effect size and synthesizing results from single-subject research (Maggin, Swaminathan, Rogers, O'Keeafe, & Sugai, 2011; Parker &Hagan-Burke, 2007; Shadish, 2014).

Another potentially problematic aspect of single-subject designs is the violation of the assumption of independence in parametric statistical approaches. Data included in the present meta-analysis were nested, such that multiple behaviors were measured for the same participant and multiple participants were included from the same study. To control for the nested structure of these data, linear mixed-effects modeling was used as our statistical approach. This type of statistical approach allows one to partition variance in nested designs (e.g., multiple observations within a phase, multiple phases for each participant, multiple participants within a study). With this approach we were able to estimate the magnitude of differences between baseline and intervention for each participant for each study (effect size) and to quantify the overall effects of video modeling on behavior outcomes across all studies (omnibus effects).

The present statistical analysis was very useful given the heterogeneity of study designs and VM implementation in the studies included. Two studies employed a phase change design and six studies a multiple baseline design. Among studies that used a multiple-baseline approach, three were across participants, three were across tasks and one used an alternating treatment approach. Ozen, Batu, and Birkan (2012) used multiple-baselines across tasks and then withdrawn within task. Although differences in intervention design can provide meaningful insights to VM efficacy in ASD, these differences presented challenges for synthesizing the literature statistically with more commonly applied techniques employed for single subject design.

**Effect of video modeling on task performance**

Our analysis of single-subject studies found that video modeling resulted in a significant improvement in behavioral outcomes across all studies ($\beta = 35.957$, standard error = 5.575, $t(35.19) = 7.969$, $p < 0.001$). While this finding is consistent with previous work investigating the effectiveness of video modeling across multiple domains, these results also suggest limitations to this result, specially the moderating effects of bias.

Acar and Diken (2012) conducted systematic review of 31 VM interventions for individuals with ASD. Included studies were categorized in four categories: (a) interventions using only video modeling (*n =13)*, (b) interventions using video self-modeling (*n* = 3), (c) interventions using video modeling in conjunction with other practices (*n* = 8), and (d) comparative studies of video modeling (*n* = 8). Interventions in the thirteen studies included in the review of interventions using only video modeling targeted social skills (*n* = 3), play skills ( *n* = 8), perspective-taking skills (*n* = 1), and imitation skills (*n* = 1). Acar and Diken (2012) reported that studies in all categories suggested VM as an effective intervention for a wide range of skills in the 49 participants (3-11 years) included in the 31 studies.

Bellini and Akullian (2007) also conducted a meta-analysis to examine the effectiveness of video modeling and video self-modeling interventions in children and adolescents with ASD across three domains: social- communication skills, functional skills, and behavioral function. Effect size for this study was calculated using the percentage of non-overlapping data points (PND) analysis. This approach calculates effect size as the percentage of data points in the intervention phase that do not overlap with the best performance in the baseline phase (Scruggs, Mastropieri, & Casto, 1987). PND scores range from 0% - 100%, indicating intervention effectiveness as follows: > 90% very effective, 70% to 90% effective, 50% to 70% questionable, and scores <50% indicate no observed effect of intervention (Scruggs & Mastropieri, 1998). Results of the overall analysis of intervention suggest a moderate effect of video modeling across all domains (*n* = 22, *M* PND = 80%, range 29 to 100). Moderate effects were also found for behavioral function (*n* = 3, M PND = 76%, range 42 to 95%), social- communication skills (*n* =

15, M PND = 77%, range 29 to 98%), and functional skills ($n$ = 8, M PND = 89% range 43 to 100%). Although direct comparison of the current study results with those of Bellini and Akullian (2007) is limited due to differences in approach used to calculate effect size of included studies. However, both analyses report positive intervention effect across all included studies. Furthermore, the category that demonstrated strongest effect of intervention in the Bellini and Akullian (2007) study was functional skills, which included tasks most related to the tasks examined in the present study. Tasks in the functional skills category included skills related to self-care (e.g., hygiene, dressing, feeding) and life skills (e.g., purchasing behavior, mailing a letter, pet care). These tasks were most like those we classified as self-care and occupational tasks. While both studies indicate video modeling is very effective in functional tasks, the number of included studies in each category of our analysis was too small to compare effectiveness across task type.

**Effect of participant age on VM effectiveness**

In addition to task type, participant age could also influence the effects of video modeling interventions. Indeed, the present study had an age range wide enough (included participants age 3 to 28 years) to test the effects of age. Although, there appears to be a positive linear relationship for the effect of age on video modeling outcomes (see Figure 5), the statistical analysis revealed no significant effect of age ($\beta = 1.50 \pm 6.97$, $t_{(11.7)} = 1.5$, $p = 0.160$). This null result may be due to the small number of studies investigating young children with ASD. Alternatively, this result may indicate that video modeling may be an appropriate method of task instruction regardless of the participant's age. Bellini and Akullian's (2007) investigation also demonstrated that video modeling is effective across a broad age range not only for functional skills but also for behavioral function and social communication skills. Participants in the studies included in their meta-analysis by ranged from 3 to 20 years for the overall analysis, 5 to 20 years in studies examining functional skills, 3 to 15 years in studies examining social communication skills, and 5 to 11 years for studies examining behavioral function. Taken together, both meta-analyses support VM as an effective intervention method from early childhood to early adulthood across multiple domains. One aspect neither study examined was potential age by task interaction effect. Further work is needed to identify if a critical age window exists where VM is most effective in improving performance of specific skills. Furthermore, as chronological age is often used as a proxy for development (e.g., cognitive, social, or motor abilities), a potentially useful approach is to assess the effect of VM interventions with respect to performance on developmental assessments instead of chronological age alone.

**Limitations and Suggestions for Future Research**

One limitation of our meta-analysis is the presence of publication bias. Studies with fewer observations of task performance reported a larger effect of phase, while studies with greater observations of task performance reported a smaller effect of phase. Therefore, the study's overall summary effect should be interpreted conservatively. Our analysis supports that VM is effective in improving movement-related task performance in individuals with ASD but the magnitude of its effectiveness may be overinflated for some studies. Ultimately, this is an issue of sampling density that may be heavily influenced by the type of single-subject design used to assess VM efficacy. In future studies, researchers should be cognizant of how design selection and number of observations of performance impact confidence in the estimated intervention effectiveness.

The second limitation is the total number of studies included. The inclusion of 10 high-quality studies reduces the generalization of our results and our ability to conduct secondary analyses of study characteristics. Although video modeling in individuals with autism is commonly investigated using single-subject approach, very few of the studies that met our criteria for full-text inclusion adhered to established quality standards for this approach. Therefore, our ability to explore secondary analyses of included studies was severely restricted. One example of such a secondary analysis would be the effectiveness and comparison of video modeling by task type. Our analysis included tasks pertaining to self-care ($n$ = 1), movements associated with play activities ($n$ = 2), and occupational tasks ($n$ = 8). Further analysis within categories for self-care and play activities would be inappropriate given the low statistical power.

A third limitation was the ability to explore potential moderators of VM effectiveness was also limited by the small number of studies that met inclusion. One potential moderator that has received considerable attention in the literature is the type of model used (e.g., adult, peer, self). All model types were used in the current study. McCoy and Hermansen (2007) conducted a systematic review of the impact of the type of model used in video modeling interventions for individuals with ASD. Their analysis included 34 studies divided into five groups: adult models, peer models, self-model, or mixed models. Tasks in the included studies targeted language and communication skills, self-help skills, social skills, play, and appropriate behavior (e.g., decreasing disruptive behavior and priming participant for transitions). These authors found that VM was effective in improving target behavior regardless of model used but suggest that more work directly comparing models is needed. To this end, one study has examined children's preference of models (themselves, familiar adults, or familiar peers) for video of preferred activities and routine daily tasks (Mechling & Moser, 2010). Although group results indicated no clear model preference across tasks, three participants demonstrated a preferred model, but each participant exhibited a different preference (i.e., one preferred familiar adult, one preferred familiar peer, and the third preferred to watch himself). Comparison of model preference by task indicated that participants demonstrated a preference for an adult model for routine daily tasks and either themselves or a familiar peer for preferred activities. Again, additional studies are needed to determine if the use of preferred models confer added benefits of video modeling on task performance.

Lastly, task factors should be examined including the length of the video, how many times the video is viewed, and how the number and duration of views is determined. These task factors/parameters are relevant for any learning study. With respect to motor learning, the repetition, specificity, timing, and intensity of practice directly relate to the degree of behavioral and neurological changes during rehabilitation (Kleim & Jones, 2008). Moreover, future studies should examine the influence of individual factors such as cognition, symptom severity, imitation skills, and attention to models on VM effectiveness should also be further examined.

**Conclusion**

The focus of the present meta-analysis was to measure the efficacy of VM interventions for teaching movement-related task to individuals with ASD. Using Bandura's (1986) theory of social learning as their framework, Corebett and Abdullah (2005) suggest the following key factors of why VM works in ASD. The monitor or device used to view the video restricts the viewer's field of focus, thus facilitating attention to relevant stimuli. In addition, showing a pre-recorded demonstration allows the interventionist to remove extraneous visual or auditory stimuli. In video modeling, the individual may repeatedly view the same model and procedures necessary to successfully complete the task or behavior (Dowrick & Jesdayle, 1991; Thelen et al., 1979). This repeated exposure facilitates retention by helping the participant create and maintain the correct behavior in memory (Corebett & Abdullah, 2005). The third mediator proposed is the opportunity to practice the behavior following observation. The fourth mediator is that individuals with ASD exhibit an increased affinity towards technology particularly television and video viewing and thus, their intrinsic motivation may be greater when using videos to practice skills. Corebett and Abdullah (2005) suggest that because children with ASD exhibit increased reward from viewing a video they are more motivated to attend to a video versus a live model. However, literature comparing preference and effectiveness of video versus in vivo modeling reports mixed results (Charlop-Christy, Le, & Freeman, 2000; Dowrick, 1986; Geiger, LeBlanc, Dillion, & Bates, 2010). Thus, further research is needed to evaluate each of these explanations and how they relate to the magnitude of changes due to VM interventions.

## III. Study 2: Visual Attention to Instructional Supports in Autism Spectrum Disorder: A Case-Control Study

Individuals with autism spectrum disorder (ASD) have difficulty processing sensory information such as tactile, olfactory, auditory, visual, proprioceptive and vestibular input (Baranek, David, Poe, Stone, & Watson, 2006; Benson, Piper, & Fletcher-Watson, 2009; Rogers & Ozonoff, 2005). Furthermore, individuals with ASD demonstrate increasing difficulty processing visual information as complexity of the visual stimulus increases (Au-Yeung, Benson, Castelhano, & Rayner, 2011; Benson et al., 2009; Bertone, Mottron, & Faubert, 2004). Despite these difficulties in visual processing, individuals with ASD demonstrate a relative strength in communicating through visual versus auditory means such as using pictures to help express and receive information (APA, 2000; Lord & McGee, 2001; Tissot & Evans, 2003). For this reason, visual supports such as picture cards, schedules, and videos are frequently implemented to aid communication and instruction in this population. These communication aids may help reduce the complexity and amount of information presented.

Visual supports direct attention to relevant stimuli and facilitate successful completion of the task. These supports have been successfully implemented during movement instruction in physical education and therapeutic settings (Berkeley, Zittel, Pitney, & Nichols, 2001; Bertone et al., 2004; Bhat, Landa, & Galloway, 2011; Quill, 1997). Picture task cards are commonly used visual supports that provide a simplified graphic representation of objects, places, people or actions (Flippin, Reszka, & Watson, 2010; Rao & Gagie, 2006; Tissot & Evans, 2003; Welton, Vakil, & Carasea, 2004). However, task cards only provide a snapshot of the task, which may not convey sufficient information regarding the process of the movement. This would be particularly important in cyclical motor skills like skipping or running, where there is no discrete starting and endpoint of the movement.

Another effective visual support for individuals with ASD is video modeling, in which the participant views a video of a task being performed before attempting or practicing that task (Bellini & Akullian, 2007). Video modeling allows the participant to observe the behavior multiple times without requiring another person to repetitively model that behavior (Charlop-Christy, Le, & Freeman, 2000). Therefore, video modeling enhances consistency of demonstration across multiple observations and participants (Plavnick & Hume, 2014). Research examining the effectiveness of video modeling frequently focuses on social and communication tasks and to a lesser extent activities of daily living (LeBlanc, 2010). Interest in application of video modeling to improve fundamental motor skill competency in children with and without disabilities is growing (Brunsnikova & Cavalier, 2017a; Brunsnikova & Cavalier, 2017b; Case & Yun, 2015)

Although visual supports are commonly used during instruction of goal-oriented movement for individuals with autism, the mechanisms underlying the effectiveness of these supports are poorly understood. Thus, the focus of this study is to investigate if visual attention differs between two types of visual supports commonly used during skill instruction and the factors that might influence visual attention. To accomplish this goal, eye gaze was monitored using eye tracking glasses during two visual support conditions (videos and static images) for motor skill instruction in children and teens with and without ASD. In the video presentation condition, participants watched a video of a model performing the skills in real time. In the task card condition, participants viewed a series of static images depicting the key components of the movement (4 images per skill). Presentation time of each skill was equivalent across conditions.

**Specific Aims**

**Specific Aim 1 (SA1).** To examine differences between groups (ASD vs. controls) and conditions (video vs. task card) with respect to the following dependent measures of visual attention: a) the percentage of view time the participant's gaze fixated on predetermined areas of interest (i.e., normalized fixation time); and, b) spatial predictability of gaze patterns (i.e., autocorrelation of gaze).

***Hypothesis 1.1.*** Participants with ASD would have significantly fewer fixations in areas of interests (e.g., body vs. non-body) compared with controls for both visual conditions (i.e., group main effect), but this difference would be greater during the video condition compared to the task card condition (i.e., group x condition interaction).

***Hypothesis 1.2.*** Compared with controls, participants with ASD would exhibit less spatially predictable gaze patterns (i.e., lower gaze autocorrelation), suggesting difficulties in monitoring relevant stimuli for both visual conditions (i.e., group main effect). Additionally, spatially predictability of gaze patterns would be higher in the video condition than in the task card condition for both groups of participants (i.e., main effect of condition).

**Specific Aim 2 (SA2).** To examine the factors that influence visual attention (i.e. normalized fixations and spatial predictability of gaze) such as inhibitory control (i.e., Flanker task), motor proficiency (i.e., BOT-2 scores), and skill knowledge.

***Hypothesis 2.*** Better performance on an inhibitory control task (i.e., Flanker task), motor performance assessment (i.e., BOT-2), and test of skill knowledge would positively influence the percentage of fixation time in areas of interest (i.e., body vs. non-body) and the spatial predictability of gaze patterns (i.e., higher gaze autocorrelation). After accounting for the effects of these potential covariates, we predicted that measures of visual attention (i.e., gaze and normalized fixations) would be poorer in participants with ASD compared with controls (i.e., main effect of group).

**Specific Aim 3 (SA3).** To examine the potential mediation effects of visual attention (i.e., normalized fixations and the magnitude of the gaze autocorrelation) on the relationship between group and motor skill performance (i.e., TGMD-3 score). To examine potential mediation effect of skill performance on the relationship between group and visual attention.

***Hypothesis 3.1.*** Group differences in motor skills performance (i.e., TGMD-3 score) would be moderated by visual attention (i.e., normalized fixations and gaze autocorrelation) to instructional supports. Specifically, the magnitude of group differences would slightly decrease when participants' visual attention is taken into account.

***Hypothesis 3.2.*** Group differences in visual attention would be moderated by motor skill performance. Specifically, the magnitude of group differences in visual attention would slightly decrease when motor skill performance is taken into account.

## Method

All procedures were approved by the Institutional Review Board at Auburn University. Verbal and written explanation of the study were provided to the parent(s) or guardian(s). Informed consent for study participation was obtained from the parent(s) or guardian(s). Written assent was obtained from children ages 8 and older. Positive verbal assent was obtained by children ages 6 to 7 years.

**Participants**

Children/youth both with and without autism spectrum disorder (6 to 16 years of age) were recruited to participate in this case-control study. Recruitment efforts included contacting families who had previously participated in outreach programs hosted by the Pediatric Movement and Physical Activity Lab in the School of Kinesiology at Auburn University. Distribution of study flyers and posting of study information took place on social media such as Facebook and community support groups websites. Twelve male children with ASD (10.88 ± 2.00years) and twelve age-matched controls without ASD participated in this study (10.90 ± 2.04 years).

**Inclusion Criteria.** All individuals with ASD were receiving special education services under the classification of autism spectrum disorder prior to the study enrollment (e.g., from a physician or school). Additional criteria for all participants included: moderate receptive communication (i.e., ability to understand instructions), ability to tolerate wearing eye tracking glasses, ability to watch 10-min long video presentations, and ability to regulate behavior (i.e., no serious behavioral issues that impede ability to follow instructions, complete tasks, or would cause harm to self or others).

**Participant compensation.** At the end of study participation participants could select a small prize (under $5.00 value) or gift card of equivalent value. Summary reports from each assessment were provided upon request from caregivers. These reports included percentile ranking and age equivalence scores of the participant's performance on developmental assessments when appropriate (cognitive and motor skills).

**Procedures and Assessments**

Data collection occurred over two sessions lasting about 1.5 to 2 hours each scheduled on two separate days. In some instances, parents requested sessions to be held on the same day. In these instances, a long break was scheduled between tasks for session 1 and session 2 (e.g., participant would complete tasks for session 1 in the morning, take a 30 min break for lunch, and complete tasks for session 2 in the afternoon). Activities for the first session included: obtaining informed consent and assent, completion of the supplemental information survey and additional questionnaire for parents of participants with ASD, motor proficiency assessment (BOT-2), Flanker task, motor skill knowledge task, and introduction and familiarization of eye-tracking glasses. Activities for the second session included: eye-tracking task, motor skill performance assessment (), and selection of participant compensation prize. Throughout both session breaks were offered following each task, upon request, and/or as needed to prevent testing fatigue. The motor skill knowledge and eye-tracking tasks had two conditions each of which were counter balanced so that participants were randomly assigned to one of the four test-order conditions presented in Table 2.1.

**Visual Instructional Supports.** Participants viewed presentations of two motor skill instructional supports (video and task card) on a computer monitor while wearing eye-tracking glasses. The six skills were selected from the short form of the TGMD-3 (i.e., locomotor skills: run, gallop, and hop; object control skills: strike, kick, and throw). Each participant saw three skills presented as a video demonstration and the other three skills presented as a task card. Skills included in Video1 matched those in TaskCard2 and those in Video2 matched those in TaskCard1. Table 2.1 presents the order of the skill presentation for each of the visual supports.

Table 2.1

Eye-tracking skill presentation order by condition

| | Video 1 | Task Card 1 | Video 2 | Task Card 2 |
|---|---|---|---|---|
| Skill 1 | Strike1 | Run1 | Run1 | Strike1 |
| Skill 2 | Kick1 | Gallop1 | Gallop1 | Kick1 |
| Skill 3 | Hop1 | Catch1 | Catch1 | Hop1 |
| Skill 4 | Kick2 | Gallop2 | Gallop2 | Kick2 |
| Skill 5 | Hop2 | Catch2 | Catch2 | Hop2 |
| Skill 6 | Strike2 | Run2 | Run2 | Strike2 |
| Skill 7 | Hop3 | Catch3 | Catch3 | Hop3 |
| Skill 8 | Strike3 | Run3 | Run3 | Strike3 |
| Skill 9 | Kick3 | Gallop3 | Gallop3 | Kick3 |

***Video presentation***. Participants viewed one of two videos presenting demonstrations of three fundamental motor skills. Each video started by showing a fixation cross in the center of the monitor screen for 1 to 1.5 seconds followed by the first skill in real-time (~5 seconds per skill), another 1 to 1.5-second fixation cross, and the next skill. This process repeated until the participant had viewed each skill three times. All skills were performed from the left to right across the screen. The entire presentation was approximately 126 seconds (3 skills presented 3 times each).

***Task card presentation***. Participants viewed one of two conditions presenting 3 fundamental motor skills as a series of static images. First, a fixation cross was presented for 1 to 1.5 seconds. Then, a series of four images illustrating the key components of the movement will be displayed across the screen with the image representing the start position on the left of the screen and the final image on the right side (see Figure 2.1). As in the video condition, the pattern of fixation cross, skill, fixation cross, skill repeated until all three skills had been presented three times. The total presentation time for a series of images for any given skill was equivalent to the video presentation for the same skill (i.e., ~5 seconds) for a total duration of approximately 126 seconds (3 skills presented 3 times each).

A B

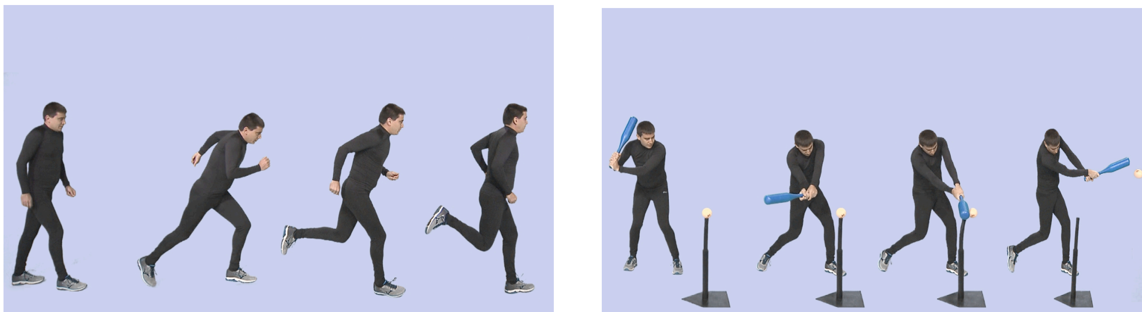

*Figure 2.1*. Examples of task card presentation images. The images show the task card images for (A) run and (B) strike.

**Eye-tracking Protocol**. Eye gaze behavior was measured using the Applied Science Laboratories (ASL) Mobile Eye XG eye-tracking system and ASL Results Plus version 1.8.3.15 software. This system uses a camera-system mounted on safety glasses to record both the participant's pupil and the visual scene within the individual's field of vision. The gaze on the visual scene was obtained from the pupil location.

At the end of the first session, participants were shown the eye-tracking system and tried on the glasses to familiarize the participants with the procedure, identify the correct size of glasses, and identify any calibration concerns prior to data collection trials. During the second data collection session, eye-tracking recordings were collected. Each participant completed the calibration procedures as outlined in the ASL Mobile Eye XG eye-tracking system. For this study, a 10-pt calibration was conducted using the PowerPoint slide provided in Figure 2.2. The participant was asked to look a cross on the screen identified verbally by the first author while a research assistant pointed to the cross on the screen. This process continued until the ASL software had successfully identified gaze at all 10 crosses. No specific order was followed. To ensure that the calibration process was successful, the participants were asked to follow the researcher assistant's finger around the screen as she pointed to different crosses. If the experimenter qualitatively judged the calibration to be poor, the process repeated. Once a good calibration was obtained, the presentation of the visual instructional support conditions began. Recordings of the Mobile Eye XG videos were saved for later analysis.

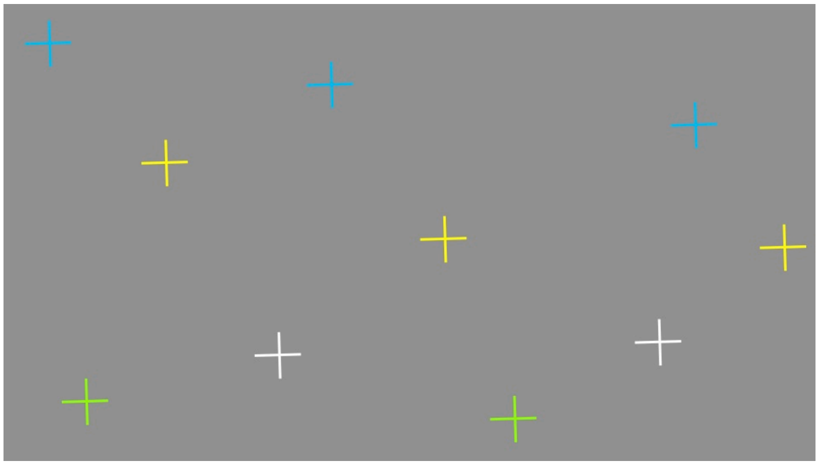

*Figure 2.2*. Calibration image. This image was used for eye-tracking calibration process.


*Figure 2.3*. Eye-tracking set-up.

## Motor Performance and Understanding

**Motor proficiency.** The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (Bruininks, 2005) was completed to assess fine and gross motor proficiency. This is a norm-referenced assessment for individuals 4 years to 21 years and 11 months of age. The BOT-2 includes eight subtests to assess (a) fine motor precision, (b) fine motor integration, (c) manual dexterity, (d) bilateral coordination, (e) balance, (f) running speed and agility, (g) upper-limb coordination, and (h) strength. These subtests provide composite scores for (a) fine manual control, (b) manual coordination, (c) body coordination, (d) strength and agility, (e) fine motor, and (f) gross motor. These subtests are combined into a total motor composite (Bruininks, 2005). This assessment provides age-based standard scores, percentile ranks, age equivalents, and descriptive categories. The subscale and total motor composite scores were used as indicators of motor proficiency in data analysis. Assessment time was approximately 60 to 90 min for the individuals with ASD and 45 to 60 min for typically-developing individuals.

**Motor skill knowledge**. To assess participant knowledge of fundamental motor skills included in the, participants completed two conditions of a computer task identifying motor skills. In the matching condition, an image of a child performing a motor skill was presented in each corner of the monitor and the name of the skill was presented in the middle of the screen (see Figure 2.4). Participants were given the following instructions: “In this task you will see four images and a word in the middle of the screen. Click on the image that matches the word. Go as fast as you can without making a mistake. If your answer is correct a green + will appear on the screen, if your answer is incorrect a red ‘X’ will appear on the screen.” A member of the research team also read the name of the skill as it was presented. In the non-matching task, three images were of the same skill and the participant was to select the image that did not match the skill named. The participants were given the following instructions: “In this task you will see four images on the screen. Click on the image that does not match the word. Go as fast as you can without making a mistake. If your answer is correct a green + will appear on the screen, if your answer is incorrect a red x will appear on the screen.” Responses were scored on accuracy and reaction time. Each condition presented six skills (i.e., kick, overhand throw “throw”, one-hand strike “strike”, two-hand catch “catch”, jump, and run). Each skill was presented four times and the image positions changed so that the correct response would be in a different corner for each presentation. Presentation of task conditions was counter-balanced amongst participants. Accuracy from each condition was highly correlated, as was response time, therefore remaining analyses only used variables from the non-matching task. These data were further simplified by combining the reaction time and accuracy data from the non-matching task into a single composite score. To do this, each variable was mean centered and normalized (MSK = mean centered median response time / standard deviation of the median response time). To compute a dependent variable that was indicative of both speed and accuracy, the following equation was used: (-1 * normalized response time + normalized percent correct)/2. In this way, values below zero represent both slow and inaccurate responses and positive values indicate fast and accurate responses. Using the composite measure not only reduces collinearity (as speed and accuracy were strongly negatively correlated), but it also simplifies the statistical models (as now we only need to include one variable instead of two).

A B


*Figure 2.4*. Motor skill knowledge stimuli. Images show example of slides from (A) matching and (B) non-matching conditions of the motor skill knowledge task.

**Motor skill performance**. The Test of Gross Motor Development – 3rd Edition was used to assess fundamental motor skill competency. The TGMD-3 is a norm-referenced process-oriented tool that measures the performance of fundamental motor skills in children 3 years old to 10 years and 11 months. It consists of 6 locomotor skills (run, gallop, slide, skip, hop, and jump) and 7 ball skills (one-hand strike, two-hand strike, kick, underhand throw, overhand throw, catch, dribble). Performance of two trials of each skill were filmed and later scored by a trained coder. Skill scores are summed to produce locomotor and ball skills subscale scores and an ove0rall gross motor sum. Since the study sample included participants aged beyond assessment norms as well as individuals with disabilities, raw scores were used for statistical analyses. Administration time for this assessment is approximately 45- 60 min for individuals with ASD and 30 to 45 min for typically developing children. For Specific Aim 3, the raw scores for the performance on the run, hop, gallop, kick, catch, strike were combined.

**Inhibitory Control.** The NIH Toolbox Flanker Inhibitory Control and Attention Test (Hodes, Insel, & Landis, 2013) was used to assess executive function. This test is appropriate for ages 3 to 85 and can be completed in approximately 3 min. During this task the participant was presented with 5 arrows (e.g., >>>>>, <<<<<, <<><<, or >><>>) and asked to indicate the direction of the middle arrow. Congruent (e.g., <<<<< or >>>>>) and incongruent (e.g., <<><< or >><>>) stimuli are presented 20 times each for a total of 40 trials. If they score ≥ 90% an additional 20 trials with the arrow stimuli are presented. Scores are based on a combination of accuracy rates and reaction times. When accuracy is less 80%, the participant's accuracy score represents his/her total score. For participants scoring at least 80% on accuracy, reaction time scores are combined with the accuracy score. This combined score is converted to a scale score with a mean of 100 and SD of 15. Uncorrected standardized scores were used in the data analysis for this study.

**Demographic Survey**. Caregivers completed a short survey providing additional information regarding demographics (i.e., level of caregiver education, participant's race) and development (i.e., full-term birth, birth weight, age of specified motor milestone achievement, and additional diagnoses). Caregivers of participants with ASD were asked to respond to additional questions related to participant's diagnosis (e.g., age of diagnosis, diagnosis provider, diagnostic assessments used, etc.).

**Statistical Analysis**

***Eye-tracking measures and data processing.*** Recordings of participants gaze were parsed by skill presented for the video and task conditions. This resulted in a total of 18 events for each participant (i.e., 9 events from video condition; 9 events from task card conditions). Results Plus software was used to create areas of interest (AOIs) to represent the model's body during all frames of the videos and each image of the task card presentations (see Figure 2.5). Regions outside this AOI were defined, as "Outside". ASL Results Plus software was used to compute fixations with respect to these areas of interest. Horizontal and vertical gaze coordinates (x and y samples) were obtained from participant's event data files.

A B

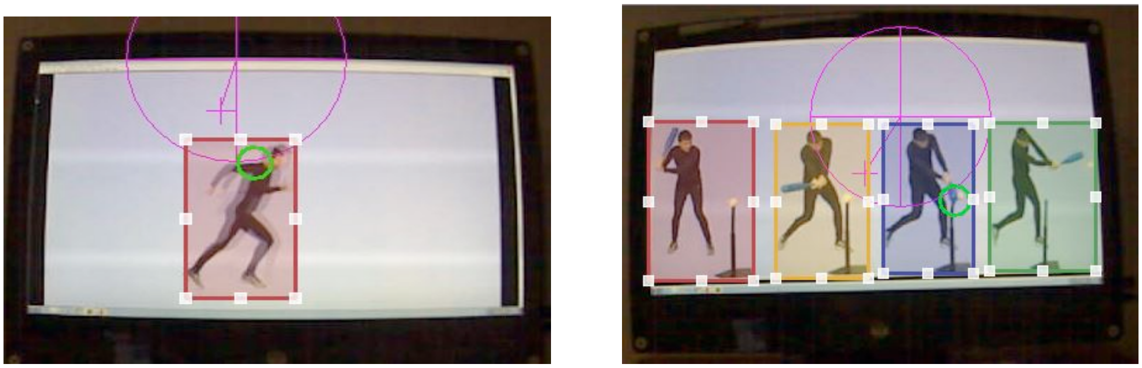

*Figure 2.5*. Example of AOIs. Images display AOIs drawn for (A) video and (B) task card conditions respectively. Videos had one AOI drawn for the body, which was adjusted as the body moved across the screen. Four AOIs were drawn for each task card; one for each segment of the skill displayed.

MATLAB (version 2014b, MATHWORKS™) was used to visualize raw fixation and gaze data, exclude outliers (i.e., defined as ±2 SD from the mean), compute normalized fixations, and gaze autocorrelations. Normalized fixations were computed for each AOI (Body or Outside) and defined as the number of fixations within a given AOI relative to the stimulus presentation duration for each event. The four body AOIs in the task condition (Body1, Body2, Body3, and Body4) were collapsed to form one "Body" AOI for fixation data analysis. In the video for the skill kicking, the location of the ball relative to the model warranted two AOIs, one for the model and one for the ball. Fixation data for these AOIs were collapsed into one AOI of "Body" as looking at the ball would still be appropriate viewing behavior. Normalized fixations were calculated for each skill so that participants had three fixation measures per AOI per skill corresponding to each presentation of that skill during the condition. The average of these measures was used for data analysis.

The autocorrelation of the horizontal and vertical gaze coordinates, defined as the correlation of the horizontal or vertical gaze signal with itself at different points throughout the signal duration (i.e., x position at time 1 and x position at time 2, etc.), was computed as a measure of similarity or predictability of the gaze coordinates for up to 20 time points. As with the fixation data, horizontal and vertical autocorrelations were calculated for each skill so that participants should have three measures per skill corresponding to each presentation of that skill during the condition. The average of these measures was used for data analysis.

***Statistical analyses.*** All analyses were conducted using R Studio (version 3.2.4, 2016, The R Foundation for Statistical Computing). One-way ANOVAs were used to test group differences in motor proficiency (BOT-2), inhibitory control (i.e., Flanker), motor skill knowledge, and motor skill performance (TGMD-3). Assumptions of normality were examined using the Shapiro-Wilk test. For variables that did not meet assumptions of normality, group differences were assessed using the Kruskal – Wallis test. To examine ***Specific Aim 1***, linear mixed-effects models with fixed-effects of group and condition and a random-effect of subject were used to: 1) determine differences in visual attention between groups and conditions; and, 2) assess group x condition interactions.

Due to noise in vertical gaze data due to calibration errors, only the horizontal component of gaze predictability was used for analyses for Specific Aims 2 and 3. ***Specific Aim 2*** examined the impact of motor proficiency (BOT-2 composite scores), inhibitory control (Flanker uncorrected standardized score), and motor skill knowledge on visual attention. All predictor variables used to investigate Specific Aim 2 were mean-centered and normalized using a z-transformation prior analysis. Motor skill knowledge was assessed with respect to response time and accuracy of responses in matching and non-matching tasks. Accuracy from each condition was highly correlated, as was response time, therefore remaining analyses only used variables from the non-matching task. The data were further simplified by combining the reaction time and accuracy data from the non-matching task into a single composite score. The sign of the normalized response time measure (unadjusted negative score indicates faster response/better performance) was reversed and then averaged with the normalized accuracy score to create a single normalized variable for motor skill knowledge (more positive scores mean better performance in both speed and accuracy in this composite measure). Using the composite measure not only reduces collinearity (as speed and accuracy were strongly negatively correlated), but it also simplifies the statistical models (as now we only need to include one variable instead of two). Correlations among the predictor variables were examined (see Table F.1 in Appendix E).

Specific Aim 2 was examined using the same series of three linear mixed-effect models for the different visual attention measures. The ***null model*** (m0) was the random – intercepts model, containing only a random-effect of participant (random intercept for each participant). The ***covariate model*** (m1) included a fixed-effect of the three covariates (normalized BOT, Flanker, and composite MSK scores) and a random-effect of participant. The ***interaction model*** (m2) included fixed-effects for the covariates, group, condition and the group by condition interaction with a random-effect of participants. These three models were compared for each visual attention measure (i.e., horizontal predictability, fixations within the body, and fixations outside the body). The Akaike Information Criterion (AIC) was used to determine model fit. The Bayesian Information Criterion (BIC) and Wald tests for the change in deviance are presented for completeness (Long, 2012). Table F.2 in Appendix E displays model comparisons for all variables. In the results below, only the details of the best-fitting model are presented for each visual attention measure.

***Specific Aim 3*** examined a potential mediation effect of visual attention in the relationship between group and motor skill performance. In this analysis, the raw scores for the performance on the run, hop, gallop, kick, catch, strike were combined. Model 1 tested the relationship between group and TGMD-3 skill performance. Model 2 added in the factor of condition (task card or video) and the group by condition interaction. Model 3 added to Model 2 by including a potential mediator of horizontal gaze predictability. Lastly, Model 4 added the potential mediator of normalized fixations within the model's body. As such, Models 3 and 4 are the mediation models and the critical comparison is between the effect of group in Model 2 and the effect of group in Models 3 and 4.

# Results

## Descriptive Statistics

Table 2.2 displays descriptive statistics and group difference for age and all assessments. T-tests were used for dependent measures that met normality assumptions, while $\chi^2$ tests were used for dependent measures that did not meet assumptions of normality.

Table 2.2

Descriptive Statistics and Group Differences for Behavioral Measures

| | *TD (n=12)* | | *ASD (n=12)* | | *Group Differences* | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *T or* $\chi^2$ | *P* |
| Age (in years) | 10.90 | 2.04 | 10.88 | 2.00 | $\chi^2 = 0.013$ | 0.908 |
| BOT2 Composite | 42.92 | 7.23 | 31.42 | 3.60 | $T = -4.931$ | <0.001*** |
| BOT2 Fine Motor Precision | 12.83 | 3.27 | 7.92 | 1.62 | $T = -4.666$ | <0.001*** |
| BOT2 Fine Motor Integration | 12.58 | 2.54 | 8.67 | 2.31 | $T = -3.953$ | <0.001*** |
| BOT2 Manual Dexterity | 10.42 | 2.31 | 8.08 | 3.00 | $T = -2.134$ | 0.044* |
| BOT2 Bilateral Coordination | 12.92 | 4.54 | 9.67 | 3.82 | $T = -1.897$ | 0.071 |
| BOT2 Balance | 11.58 | 3.58 | 7.25 | 3.62 | $T = -2.948$ | 0.007** |
| BOT2 Running Speed and Agility | 16.42 | 4.78 | 8.75 | 4.54 | $T = -4.032$ | <0.001*** |
| BOT2 Upper Limb Coordination | 13.83 | 4.45 | 6.08 | 2.07 | $T = -5.474$ | <0.001*** |
| BOT2 Strength | 15.42 | 4.62 | 7.92 | 2.78 | $T = -4.818$ | <0.001*** |
| TGMD3 Total | 116.92 | 23.09 | 85.08 | 23.50 | $\chi^2 = 8.508$ | 0.003** |
| TGMD3 Locomotor | 66.00 | 24.18 | 49.67 | 17.93 | $\chi^2 = 3.212$ | 0.073 |
| TGMD3 Ball Skills | 50.92 | 2.71 | 35.42 | 9.49 | $T = -5.439$ | <0.001*** |
| Flanker Uncorrected Standardized Score | 100.67 | 5.57 | 92.67 | 11.67 | $T = -2.143$ | 0.043* |
| Flanker Age Corrected Standardized Score | 101.50 | 11.16 | 91.17 | 12.84 | $T = -2.104$ | 0.047* |
| Motor Skill Knowledge Total | 0.38 | 0.55 | -0.38 | 0.87 | $T = -2.59$ | 0.012* |

X^2 is presented for measures that failed to meet assumptions or normality of residuals.

No group differences were observed for the following variables: age, BOT-2 bilateral coordination, and TGMD-3 locomotor score ($p > 0.05$ for all). Significant group differences were observed for all other dependent variables (see Table 2.2 for details).

Table 2.3 displays descriptive statistics and group difference the visual attention dependent measures. T-tests were used for dependent measures that met normality assumptions, while $\chi^2$ tests were used for dependent measures that did not meet assumptions of normality. No group differences were observed for any of the visual attention measures for the video or task cards ($p > 0.05$ for all).

Table 2.3

Descriptive Statistics and Group Differences for Visual Attention Measures

| | TD (n=12) | | ASD (n=11) | | Group Differences | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *T or* $\chi^2$ | *df* | *P* |
| **Video Condition** | | | | | | | |
| Horizontal Autocorrelation | 0.83 | 0.03 | 0.84 | 0.02 | $\chi^2$ = 0.095 | 1 | 0.758 |
| Vertical Autocorrelation | 0.72 | 0.27 | 0.82 | 0.09 | $\chi^2$ = 1.833 | 1 | 0.176 |
| Normalized Fixation - Body | 0.44 | 0.22 | 0.49 | 0.16 | $\chi^2$ = 0.095 | 1 | 0.758 |
| Normalized Fixation – Outside | 0.16 | 0.11 | 0.18 | 0.08 | $\chi^2$ = 0.640 | 1 | 0.424 |
| Task Card Condition | | | | | | | |
| Horizontal Autocorrelation | 0.78 | 0.06 | 0.78 | 0.05 | $\chi^2$ = 0.015 | 1 | 0.902 |
| Vertical Autocorrelation | 0.70 | 0.26 | 0.78 | 0.08 | $\chi^2$ = 0.186 | 1 | 0.667 |
| Normalized Fixation - Body | 0.41 | 0.21 | 0.46 | 0.18 | $\chi^2$ = 0.379 | 1 | 0.538 |
| Normalized Fixation – Outside | 0.14 | 0.09 | 0.16 | 0.09 | T = 0.596 | 1 | 0.557 |

**Specific Aim 1: Group Differences in Visual Attention**

Figure 2.6 depicts the main dependent measures by group and condition: a) horizontal gaze predictability; b) vertical gaze predictability, c) normalized fixations for the body; and, d) normalized fixations for outside the body. For horizontal gaze predictability, linear mixed-effect regression revealed a main-effect of condition ($\beta$ = 0.04 standard error = 0.005, $t(23) = 7.03$, $p < 0.001$), but no main-effect for group ($p < .05$), nor a group x condition interaction ($p < .05$) Similarly, for vertical gaze predictability, there was a main-effect of condition ($\beta$ = 0.02 standard error = 0.009, $t(23) = 2.376$, $p = 0.0262$), but no main-effect for group ($p > .05$), nor a group x condition interaction ($p > .05$). For normalized fixations within the model's body and normalized fixations outside of the model's body there was no main-effect of group, no main-effect of condition, and group x condition interactions (all $p > .05$).

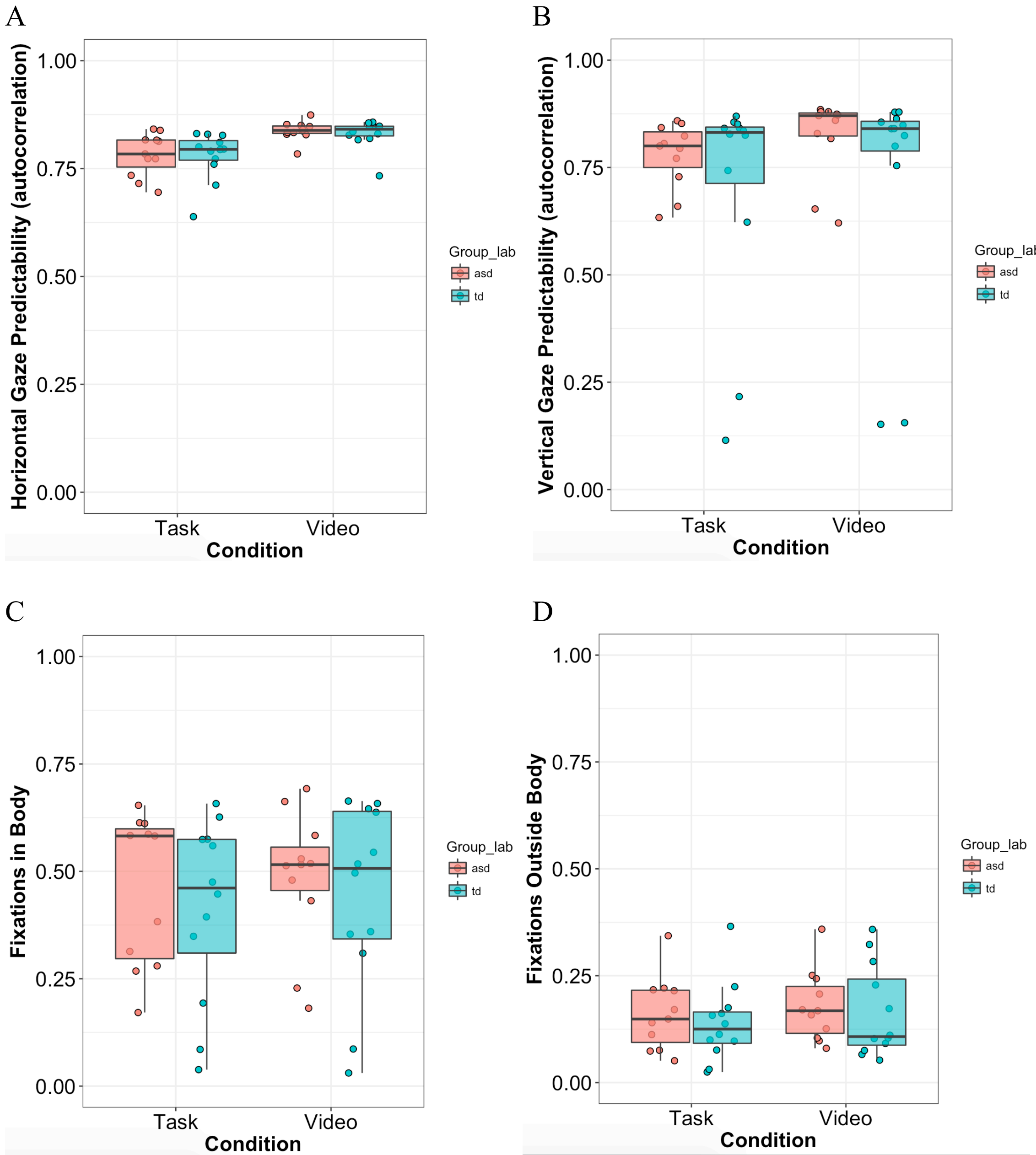


*Figure 2.6.* The boxplots display visual attention measures for each eye-tracking presentation condition by group. (A) Horizontal gaze predictability, (B) Vertical gaze predictability, (C) Mean Normalized Fixations within the model's body, and (D) Mean Normalized Fixations outside the model's body.

**Specific Aim 2: Predictors of visual attention measures.**

**Horizontal Gaze Predictability.** Model comparisons (see Table E.2) indicated the interaction model (m2) as the best fitting model to examine the impact of motor proficiency, motor skill knowledge, and inhibitory control on horizontal gaze predictability. Table 2.4 presents all statistical summary for horizontal gaze predictability. None of these covariates were significantly associated with horizontal gaze predictability ($p > 0.05$ for all). After accounting for these covariates, there was still a significant main-effect of condition ($t(23) = 7.03$, $p < 0.001$). However, there was no main-effect of group and no group x condition interaction. Thus, horizontal gaze predictability was generally higher in the video condition, than in the task-card condition.

Table 2.4

Model Statistics for Predictors of Horizontal Gaze Predictability

| | Estimate | Std. Error | *df* | *T* | *p* |
|---|---|---|---|---|---|
| Fixed Effects | | | | | |
| Intercept | 0.808 | 0.007 | 23 | 110.18 | < .001*** |
| BOT-2 Total Composite | -0.010 | 0.010 | 23 | -1.00 | 0.33 |
| Motor Skill Combined | 0.002 | 0.006 | 23 | 0.43 | 0.67 |
| Flanker Uncorrected Standard Score | 0.006 | 0.010 | 23 | 0.68 | 0.50 |
| Condition | 0.037 | 0.053 | 23 | 7.03 | < 0.001*** |
| Group | -0.0001 | 0.0155 | 23 | -0.04 | 0.97 |
| Group X Condition | 0.002 | 0.007 | 23 | 0.34 | 0.74 |

**Vertical Gaze Predictability.** Table 2.5 presents a summary of model m2 for vertical gaze predictability. None of these covariates were significantly associated with horizontal gaze predictability ($p > 0.05$ for all). After accounting for these covariates, there was still a significant main-effect of condition ($t(23) = 2.38$, $p = 0.03$). However, there was no main-effect of group and no group x condition interaction (*ps* > 0.05). Thus, horizontal gaze predictability was generally higher in the video condition, M = ##, than in the task-card condition, M = ##.

Table 2.5

Model Statistics for Predictors of Vertical Gaze Predictability

| | Estimate | Std. Error | *df* | *T* | *p* |
|---|---|---|---|---|---|
| Fixed Effects | | | | | |
| Intercept | 0.761 | 0.035 | 23 | 21.49 | < .001*** |
| BOT-2 Total Composite | 0.048 | 0.053 | 23 | 0.09 | 0.36 |
| Motor Skill Combined | -0.035 | 0.028 | 23 | -1.26 | 0.22 |
| Flanker Uncorrected Standard Score | 0.088 | 0.047 | 23 | 1.88 | 0.07 |
| Condition | 0.022 | 0.009 | 23 | 2.38 | 0.03* |
| Group | 0.129 | 0.075 | 23 | 1.72 | 0.10 |
| Group X Condition | 0.011 | 0.013 | 23 | 0.83 | 0.42 |

**Fixations Within the Model's Body**. The model fit for influence of predictors on percentage of fixations within the model's body did not improve with the addition of covariates or fixed effects of group and condition. For consistency, Table 2.6 presents a summary of m2 (even though m0 was the best fitting model), so that the coefficients for fixations within the body can be compared to other dependent measures. None of these covariates were significantly associated with horizontal gaze predictability ($p > 0.05$ for all). Furthermore, after accounting for these covariates, there was no main-effect of condition, main-effect of group, nor a group x condition interaction ($p > 0.05$).

Table 2.6

Model Statistics for Predictors of Percentage of Fixations Within Body AOI

| | Estimate | Std. Error | *df* | *T* | *p* |
|---|---|---|---|---|---|
| Fixed Effects | | | | | |
| Intercept | 0.454 | 0.035 | 23 | 13.06 | < 0.001*** |
| BOT-2 Total Composite | -0.026 | 0.051 | 23 | -0.51 | 0.61 |
| Motor Skill Combined | -0.037 | 0.027 | 23 | -1.38 | 0.21 |
| Flanker Uncorrected Standardized Score | 0.078 | 0.046 | 23 | 1.70 | 0.10 |
| Condition | 0.019 | 0.015 | 23 | 1.28 | 0.21 |
| Group | 0.018 | 0.074 | 23 | 0.24 | 0.81 |
| Group X Condition | -0.001 | 0.021 | 23 | -0.03 | 0.98 |

**Fixations Outside the Model's Body.** The model fit for influence of predictors on percentage of fixations outside the model's body did not improve with the addition of covariates or fixed effects of group and condition. For consistency, Table 2.6 presents a summary of m2 (even though m0 was the best fitting model), so that the coefficients for fixations outside the body can be compared to other dependent measures. None of these covariates were significantly associated with horizontal gaze predictability ($p > 0.05$ for all). After accounting for these covariates, there was no main-effect of condition, main-effect of group, and no group x condition interaction (*ps* > 0.05).

Table 2.7

Model Statistics for Predictors of Percentage of Fixations Outside the Body AOI

| | Estimate | Std. Error | *df* | *T* | *p* |
|---|---|---|---|---|---|
| Fixed Effects | | | | | |
| Intercept | 0.161 | 0.016 | 23 | 10.31 | < 0.001*** |
| BOT-2<br>Total Composite | 0.032 | 0.023 | 23 | 1.40 | 0.41 |
| Motor Skill Combined | -0.010 | 0.012 | 23 | -0.83 | 0.21 |
| Flanker Uncorrected Standardized Score | 0.018 | 0.021 | 23 | 0.86 | 0.39 |
| Condition | 0.015 | 0.011 | 23 | 1.40 | 0.18 |
| Group | 0.046 | 0.022 | 23 | 1.39 | 0.18 |
| Group X Condition | -0.004 | 0.015 | 23 | -0.25 | 0.81 |

**Specific Aim 3: Mediation of Visual Attention on Group Differences in Skill Performance**

Tables 2.8 present the statistical summary for the composite score for the TGMD for the 6 skills presented as either a video or task during the eye-tracking. Model 2 is a full interaction model with group, condition, and group x condition. To determine potential mediation effects of visual attention variables on group in Models 3 (with mean horizontal autocorrelation) and 4 (with mean normalized fixation in the body) were compared to the effect of group in Model 2. Note: Model 1 only controls for group.

The group effects on TGMD-3 performance did not change with the addition of the visual attention variables (Model 2: $\boldsymbol{\beta}$ = -1.32, SE= 0.18, $T$ = -7.13, $p < 0.001$ compared with Model 3: $\boldsymbol{\beta}$ = -1.34, SE = -0.19, $T$ = -7.02, p < 0.005 and Model 4: $\boldsymbol{\beta}$ = -1.31, SE = 0.18, $T$ = -7.09, p < 0.001). Moreover, there was no effect of either mean horizontal gaze predictability (autocorrelation) or mean normalized fixation in the body ($p > 0.05$ for both).

Table 2.8

Model Statistics for Mediations of Visual Attention on Composite TGMD-3 Performance

| | Estimate | Std. Error | *t* | *p* |
|---|---|---|---|---|
| Model 1 | | | | |
| Intercept | 5.86 | 0.13 | 44.91 | < 0.001*** |
| Group | -1.32 | 0.18 | -7.13 | <0.001*** |
| Model 2 | | | | |
| Intercept | 5.86 | 0.13 | 44.91 | < 0.001*** |
| Group | -1.32 | 0.18 | -7.13 | <0.001*** |
| Condition | -0.02 | 0.17 | -0.12 | 0.91 |
| Group x Condition | -0.22 | 0.24 | -0.93 | 0.36 |
| Model 3 | | | | |
| Intercept | 5.94 | 2.64 | 2.25 | 0.03* |
| Group | -1.34 | 0.19 | -7.02 | <0.001*** |
| Condition | -0.02 | 0.22 | -0.12 | 0.92 |
| Group X Condition | -0.23 | 0.25 | -0.92 | 0.36 |
| Horizontal Gaze Predictability | -0.12 | 3.27 | -0.04 | 0.97 |
| Model 4 | | | | |
| Intercept | 6.30 | 0.34 | 18.47 | < 0.001*** |
| Group | -1.31 | 0.18 | -7.09 | < 0.001*** |
| Condition | -0.01 | 0.18 | -0.05 | 0.96 |
| Group X Condition | -0.23 | 0.25 | -0.94 | 0.36 |
| Normalized Fixations - Body | -1.01 | 0.70 | -1.43 | 0.16 |

## Discussion

The present study investigated differences in visual attention in children with and without ASD during the presentation of two types of visual supports for motor skills. We also investigated the factors that might influence visual attention to motor skills such as motor proficiency, inhibitory control, motor skill knowledge, and motor skill performance.

We found that children with ASD performed significantly worse than their TD counterparts for nearly all performance measures (motor proficiency, inhibitory control, motor skill knowledge, and motor skill performance), with the exception of three measures (BOT-2 bilateral coordination) and TGMD-3 locomotor score. However, even these two measures were approached significance ($p = 0.07$ for both). These results are consistent with previous studies examining motor deficits (Fournier et al., 2010; Pan et al., 2014) and cognitive difficulties (Adams & Jarrold, 2012; Christ, Holt, White, & Green, 2006) in children with ASD. Specifically, Pan (2014) also reports significantly lower performance on the BOT-2 in adolescent males aged 10- 17 years with ASD compared to peers without ASD.

Results of the motor skill knowledge task were quite interesting as significant group differences were observed. Overall, participants with ASD were less accurate (match condition) and took longer to respond (both conditions). These differences could be due to slower reaction/response times previously reported (Fournier et al., 2010) as well as difficulties identifying movements (i.e., less familiarity with the movements). The results from the TGMD performance, would suggest that the latter may indeed play a role, as children with ASD performed more poorly than their typically-developing peers for the ball skill tasks (and slightly worse for the locomotor skill, although this did not reach significance).

### Specific Aim 1

We predicted that children with ASD would exhibit less predictable gaze patterns and produce fewer fixations to predetermined areas of interests within the visual support stimuli and that these differences would be larger for the video condition (Hypothesis 1.1). This hypothesis was not supported as there were no group or group x condition interactions observed for any of the visual attention variables. Previous research suggests that compared to typically developing individuals, individuals with ASD demonstrate preferential attention to non-biological stimuli (Bird et al., 2011; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009) and reduced attention to socially-relevant stimuli (Dalton et al., 2005; Klin, Jones, Schultz, & Volkmar, 2002; Pelphrey et al., 2002; Sasson et al., 2008; Sasson et al., 2011; Spezio, Adolphs, Hurley, & Piven, 2007). Interestingly, although the participants with ASD demonstrated reduced ability to resist distracting information during Flanker performance (significant group difference), they did not exhibit reduced attention to the model compared to the participants without ASD. A possible explanation is the simplicity of the eye-tracking stimuli. Due to the exploratory nature of this study, the images for the eye-tracking task were designed to address the question of whether or not children with ASD would focus on the person modeling the task. Accordingly, stimuli consisted only of the model and essential equipment (e.g., ball, bat and tee, etc.) against a high contrast background. Similar results were also reported by Au-Yeung et al. (2011). Group differences in eye movements were reported during complex tasks but not during simple tasks.

Interestingly, we found that both groups exhibited greater horizontal autocorrelations in the video condition compared to the task card condition. This is likely due to the dynamic nature of videos, which may act as an attractor of visual attention. In contrast, the static image does not provide such a guide/attractor of visual attention. The participant may view the static images in a more random pattern and may return gaze to a previously viewed area of the image, which is not possible or relevant in the video condition. Such a change in direction of gaze would result in lower autocorrelation values, but is not necessary indicative of inappropriate viewing behavior. For instance, the viewer could be returning attention to the previously viewed area to help detect differences between the two images needed to decifer salient information regarding the displayed movement.

Although our findings do not support group differences in fixations to AOIs, other research has found that when presented with an array of images of objects and social images that children with ASD explored fewer images in the array than did typically developing children. Yet, for images explored, children with ASD looked at the images longer and made more fixations than the typically developing children (Sasson et al., 2008). Longer view time and increased number of fixations suggest that children with ASD have a harder time detecting and interpreting salient information from static images. In the present study, fixations within the four static images for each skill were collasped into a single variable to examine the percentage of view time attending to relevent information. In future iterations, it may be of value to include examination of scanpaths as well as the number and duration of fixations within a given area to compare how these images are viewed and how much attention is given to the individual components of the task cards. Addition support for the inclusion of scanpath variables includes research demonstrating reduced accuracy and greater inter-trial variability in accuracy of saccadic movements in children with ASD (Johnson et al., 2012; Stanley-Cary, Rinehart, Tonge, White, & Fielding, 2011; Takarae, Minshew, Luna, & Sweeney, 2007).

Further manipulation of stimuli may be useful in future studies. For example, increasing the duration of presentation time, adding a slow-motion video condition, or allowing individuals to self-select when the next image is presented or to allow participants to repeat viewing may highlight differences in the time needed for sufficient exploration of stimuli. The inclusion of potentially distracting stimuli in the image may help to determine if individuals with ASD have difficulties identifying relevant aspects of the image.

**Specific Aim 2.**

We predicted that factors such as inhibitory control, motor proficiency, and motor skill knowledge would affect visual attention. The present results did not support this hypothesis. It is possible that inhibitory control, motor proficiency, and motor skill knowledge do indeed influence visual attention. However, there are several potential explanations for this result in the present study. It is possible that given the simplicity of the stimuli (i.e., there is no distracting stimuli in the image), there is a reduced need for inhibitory control during visual attention for these stimuli. Similarly, motor proficiency and motor skill knowledge may be more relevant to motor planning and execution of movements but not necessarily to attending to simple movement stimuli.

**Specific Aim 3.**

We hypothesized that the group differences in motor skill performance would be mediated by visual attention measures (i.e., horizontal gaze autocorrelations and percentage of fixations on the model). This hypothesis was not supported; group differences in motor skill performance remained significant after accounting for these visual attention measures. Since no group differences were observed for the visual attention measures, it was unlikely that any individuals variability in those measures would change the group effect in performance.

## Limitations and Future Directions

One limitation of the present study is sample size. Increased sample size may be needed to improve power of analyses, especially for examinations of predictors and mediators of relationships between study variables. Related to sample size is the selection of appropriate controls for the children with ASD. In the current study, children with ASD perform worse on nearly every behavioral measure. These significant delays and deficits in motor performance are consistent with those previously reported in children with ASD (Fournier et al., 2010). Therefore, a potentially meaningful alternative to using age-matched controls is to match the children with ASD with developmentally-matched or skill-matched controls (e.g., children that are younger in age but matched on motor skill). This would allow one to determine if differences in visual attention are due to ASD versus due to poor motor skills.

Another potential limitation in the current study is the simplified nature of the stimuli and exclusion of more difficult sports-specific skills that are expected to be beyond participants' current repertoire. Appropriate adjustment to eye-tracking stimuli and motor skill knowledge task content may increase sensitivity of these tasks to detect group differences.

Lastly, future investigations of visual attention to movement instructional supports could benefit from the addition of visual attention measures such as scan paths, fixation frequency, and fixation duration. These measures may provide more meaningful information regarding how children with and without ASD view instructional supports, especially task cards.

**Conclusion**

Visual supports have successfully improved performance in cognitive, language, social, and occupational tasks (Bellini & Akullian, 2007) and application to motor skill instruction and physical activity settings has been advocated (Breslin & Liu, 2015; Breslin & Rudisill, 2011; Case & Yun, 2015). Investigation of mechanisms responsible for effectiveness of visual supports in movement settings is sparse. The present study explored the role of visual attention to these supports. Current literature presents mixed results regarding impairments in visual attention. Inconsistencies between studies may be attributed to differences in study design, measures, and sample characteristics. Findings of the present study suggest that children with and without ASD direct visual attention to task card and video presentation of motor skill, as measured by percentage of fixations on the model and predictability of horizontal gaze, similarly. We were unable to determine the extent to which visual attention may be influenced by factors such as motor proficiency, motor skill knowledge, and inhibitory control; the present study suggests a lack of influence.  Additionally, the impact visual attention may have on differences in observed motor skill performance between children with and without ASD remains uncertain. Further work is needed to investigate these questions and examine successful implementation of visual supports for motor skill instruction.

## Conclusion

Visual supports are commonly used for individuals with autism spectrum disorder to improve communication and support appropriate behavior. Use of supports such as task cards and video modeling to improve motor skill instruction and assessment in individuals with ASD has received considerably less attention. The overarching focus of this dissertation was to better understand the potential effectiveness of these supports for motor skill instruction and examine the potential role of visual attention. Findings of Study 1 support the use of video modeling as an appropriate and successful tool to aid motor skill instruction in this population. The primary finding of Study 2 suggests that visual attention to these supports is similar in children with and without ASD. With respect to the parameters of this study, differences in inhibitory control, motor proficiency, or motor skill knowledge did not impact visual attention. Additionally, visual attention did not conclusively mediate the relationship between group and skill performance. Taken together, these results should be interpreted cautiously due to discussed limitations. Considerable work is needed to test the effectiveness of these supports in instructional climates and gain insights to mechanisms impacting successful implementation.

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## Appendix A

The Auburn University Institutional
Review Board has approved this
Document for use from
04/24/2017 to 12/11/2017
Protocol # 06-262 EP 0701

**Auburn University**
SCHOOL OF KINESIOLOGY

**INFORMED CONSENT FOR DETERMINING THE EFFECTIVENESS OF A MOTOR DEVELOPMENT PROGRAM**

We invite your child to participate a Motor Development Research Program. We are interested in determining the effects motor development programming has on the children's motor skill development and cognitive skills. The assessments measure actual motor skill performance (measured by the Test of Gross Motor Development), motor proficiency (measured by the Bruininks- Oseretsky Test of Motor Proficiency, and cognitive skills (measured through the completion of a series of reasoning tasks). Additionally, descriptive information, including height, weight, Body Mass Index, sex, race, and date of birth, and presence of any disabilities will be collected. The assessments will be used for future programming as it relates to Motor Development Programs as well as provide specific instructional information about the progress of your child. Following is an explanation of each assessment:

The *Test of Gross Motor Development* is a measure of fundamental motor skill competence. The 12-item test includes 6 locomotor skills (running, jumping, hopping, leaping, galloping, and sliding) and 6 object-control skills (rolling, throwing, catching, striking, bouncing, and kicking).

The *Bruininks-Oseretsky Test of Motor Proficiency* as an instrument used to measure children's gross and fine motor skills. Specifically the assessment measures: Fine Motor Precision - 7 items (e.g., cutting out a circle, connecting dots); Fine Motor Integration - 8 items (e.g., copying a star, copying a square); Manual Dexterity-5 items (e.g., transferring pennies, sorting cards, stringing blocks), Bilateral Coordination - 7 items (e.g., tapping foot and finger, jumping jacks); Balance-9 items (e.g., walking forward on a line, standing on one leg on a balance beam); Running Speed and Agility - 5 items (e.g., shuttle run, one-legged side hop); Upper-Limb Coordination - 7 items (e.g., throwing a ball at a target, catching a tossed ball); Strength - 5 items (e.g., standing long jump, sit-ups).

*Cognitive Skills* will be measured both before and following your child's participation in the movement/physical activity program and will be assessed through a series of developmentally appropriate cognitive assessments (i.e., Picture Deletion Task for Preschoolers (PDTP), Children's Continuous Performance Test (CCPT), Object and Action Picture Recall Task (OAPRT), Auditory Digit Span Test (ADST), Corsi Block Task (CST), On Task Behavior Observation, and Go/No Go Task (GNGT)). The assessment will assess your child's ability to recall shapes and pictures. We will also conduct a computer-based task to assess participants' knowledge and understanding of various motor skills. During this task participants will be shown 4 images of a person performing a motor skill and asked to identify the image that either matches or does not match the name of the skill present on the screen.

Parent/Guardian initials_________



301 Wire Road, Auburn, AL 36849-5323; Telephone 334-844-4483; Fax 334-844-1467
www.auburn.edu/kine

*Descriptive Information* including height, weight, Body Mass Index, sex, race, number of siblings, birth order, and date of birth will be gathered for your child. Height will be measured using a standard tape measure. Children will be asked to stand with their back against a wall and height will be measured to the nearest centimeter. Children will also stand on a standard scale to measure their weight to the nearest kilogram. Body Mass Index, a measure of overweight and obesity, will be calculated from the height and weight measures using the formula height divided by weight$^2$. Parents/guardians will be asked to report their child's sex, race, date of birth, and presence of any diagnosed disability.

There are no foreseeable risks or discomforts associated with completing the Test of Gross Motor Development, completing the Bruininks-Oseretsky Test of Motor Proficiency, and completing the cognitive tasks.

Please note that any child who expresses a desire to quit the assessments will be allowed to stop immediately. Participants will also be told that they can remain in the Motor Development Research Program without completing all the assessments. To preserve confidentiality, the children's performance and responses will be reported as group results only. I am informing you that any information obtained from the assessments may be used in any way thought best for education and publication. Unless otherwise notified by you, I plan to present the results of this program assessment at a scientific conference and publish the results in an appropriate journal. In any presentation or publication, the data will remain anonymous.

Your decision whether or not to allow your child to participate will not jeopardize his/her future relations with Auburn University or the School of Kinesiology. At the conclusion of the assessments, a summary of group results will be made available to all interested parents. Should you have any questions or desire further information, please contact: Dr. Mary Rudisill at (334) 844-1458 (phone) rudisme@auburn.edu (email). You will be provided a copy of this form to keep.

For more information regarding your rights as a research participant you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@aubum.edu

HAVING READ THE INFORMATION PROVIDED YOU MUST DECIDE WHETHER OR NOT TO ALLOW YOUR CHILD TO PARTICIPATE. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO ALLOW YOUR CHILD'S PARTICIPATION IN THE STUDY.

Child's Name________________________________________

Parent/Guardian Signature___________________________ Date ______

Investigator Signature______________________________ Date ______

SCHOOL OF KINESIOLOGY

AUBURN UNIVERSITY
COLLEGE OF EDUCATION

**(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)**

**PARENT PERMISSION/MINOR ASSENT (AGES 13+)**

**for a Research Study entitled**

**"Eye tracking in individuals with and without developmental disabilities"**

You are invited to participate in a research study to determine what children and teens with and without developmental disabilities pay attention to while watching videos or pictures of movement. The study is being conducted by Dr. Melissa Pangelinan (Assistant Professor), Jacqueline Megan Irwin (Graduate Student) and Brooke Converse (Lab Manager) the School of Kinesiology at Auburn University. You were selected as a possible participant because:

- Your child is between the ages of 6 and 17 years
- In addition your child:
  - Is able to understand instructions
  - Is able to tolerate wearing eye tracking glasses
  - Is able to watch videos or images on a computer screen for up to 10 minutes
  - Is able to control his/her behavior (i.e., no serious behavioral issues that affect his/her ability to follow instructions/complete tasks)

**What will be involved if you participate?** If you decide to have your child participate in this research study, we will record your child's eye movements during one sessions lasting about 1 hour. A practice eye-tracking session will be performed to allow your child to become familiar with task. During this practice session, your child will sit in front of a computer monitor, wear the eye-tracking glasses, and watch a short video of their choice (~ 5 minutes).

Your child will watch videos or pictures of movement skills on the computer monitor while wearing eye-tracking glasses. The movement skills are the same as in a common motor assessment and include: running, galloping, hopping, striking, kicking, and throwing. The video will start with a cross ("+") in the middle of the monitor for 2 second followed by a short video of a movement skill. This will repeat for each skill until the skills has been presented a total of 3 times. The video will take about 3 minutes.

Participant's Initials ______ 

Next, your child will look at pictures shown in a sequence from left to right across the computer monitor. First, a cross ("+") will appear for 2 seconds. Then, four pictures will be shown that highlight key components of the movement from start to finish. This will repeat for each skill until the skills have been presented a total of 3 times. This will take about 3 minutes.

During the study, videos may be taken of your child to ensure proper scoring of your child's performance.

**Are there any risks or discomforts?** Some participants with tactile sensitivity (e.g., children that don't like the feel of wearing glasses) may experience mild discomfort wearing the eye-tracking glasses. Breaks will be scheduled and encouraged to reduce any fatigue, boredom, or frustration during the study. However, all procedures are completely non-invasive and would be similar to wearing normal eyeglasses while watching a video or computer screen. In addition, there is a risk of a breach of confidentiality. However, all efforts will be taken to maintain confidentiality.

**Are there any benefits to yourself or others?** Your child's participation is completely voluntary. Although the study is not intended to provide a direct benefit to your child, the information gathered may help us better understanding visual attention in individuals with disabilities and how visual supports (like pictures and videos) may help motor skill learning. You and your child are free to ask questions or to withdraw from participation at any time without penalty. A signed copy of this consent form will be given to you.

**Will you receive compensation for participating?** All participants will receive an age-appropriate prize (valued at less than $5).

**If you change your mind about participating,** you and your child can withdraw at any time during the study. Your child's participation is completely voluntary. If you or your child choose to withdraw, all data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University or the School of Kinesiology.

**Your privacy will be protected.** All information collected in this study is strictly confidential, and your name or that of your child will not be identified at any time. The data collected will be grouped with data from other subjects for presentations at scientific conferences and publication in scientific journals. Data will be stored in a locked file cabinet in a locked room and/or on a password-protected computer. Only the investigator will have access to the data. Your or your child's information may be shared with representatives of Auburn University and government authorities if required by law.

Participant's Initials ______

**If you have questions about this study,** *please ask them now or* contact Megan Irwin at jmi0002@auburn.edu or Dr. Melissa Pangelinan at melissa.pangelinan@auburn.edu or by phone at 334-844-8055. A copy of this document will be given to you to keep.

**If you have questions about your rights as a research participant,** you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu.

**HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO PARTICIPATE.**

| | | |
|---|---|---|
| Child's Name | Child's Signature | Date |
| Participant's Name | Participant's Signature | Date |
| Investigator Obtaining Consent | Investigator's Signature | Date |

Participant's Initials ______

SCHOOL OF
KINESIOLOGY

AUBURN UNIVERSITY
COLLEGE OF EDUCATION

**(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)**

## MINOR ASSENT (AGES 8-12)

**for a Research Study entitled**

**"Eye tracking in individuals with and without developmental disabilities"**

You (*and your parents or guardian(s)*) are invited to be in a research study to help us understand what children look at when they watch videos or see pictures of people moving.

If you decide you want to be in this study, you will wear special glasses that help us know how your eyes are moving. You will watch videos and see pictures of people moving when you wear these glasses. The videos will take about 3 minutes and the pictures will take about 3 minutes.

Some of the time that you are wearing the special glasses and watching the videos or looking at pictures, we will have a movie camera on, taking a video of you. We need the video to study later, after you go home. We can only make the video if you and your parent(s) or guardian give us permission to do that.

You can stop at any time. Just tell your parents or Megan Irwin if you don't want wear the special glasses and watch the videos or look at pictures any more. No one will be angry with you if you stop.

Participant's Initials ______

After you finish, we will give you a small prize to show how much we appreciated your help.

If you have any questions about what you will do or what will happen, please ask your parents or guardian or ask Megan Irwin now. If you have questions while you are wearing the special glasses and watching videos or looking at pictures we want you to ask us.

If you have decided to help us, please sign and print your name on the line below.

| | | |
|---|---|---|
| Child's Signature | Printed Name | Date |
| Parent/Guardian's Signature | Printed Name | Date |

***(Parent/Guardian must also sign Parent/Guardian Permission form!)***

| | | |
|---|---|---|
| Investigator Obtaining Consent Signature | Printed Name | Date |

Participant's Initials ______ Page 2 of 2

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## VIDEO RELEASE – CHILD

During your child's participation in this research study, **"Eye tracking in individuals with and without developmental disabilities"**, your child will be videotaped. Your signature on the Informed Consent gives us permission to do so.

Your signature on this document gives us permission to use the videotape(s) for the additional purposes of publication, training, and presentation beyond the immediate needs of this study. These videotapes will not be destroyed at the end of this research but will be retained 3 years upon completion of the study

Your permission:

**I give my permission for videotapes produced in the study, "Eye tracking in individuals with and without developmental disabilities", which contain images of my child, to be used for the purposes listed above, and to also be retained for 3 years upon completion of the study.**

| | | |
|---|---|---|
| Child's Name | Child's Signature | Date |
| Participant's Name | Participant's Signature | Date |
| Investigator Obtaining Consent | Investigator's Signature | Date |

## Appendix B

## Demographic Surveys

**SUPPLEMENTAL INFORMATION**

1. Participant's name: ______________________________________________

2. Child's due date: ________________________________ 3. Child's birth date: ________

4. Birth Weight:______________________________________

5. Age in months sitting independently:_______________________

6. Age in months standing independently:_______________________

7. Age in months of walking (5 steps):_______________________

8. Have your child been diagnosed with autism (circle one)? Yes No

9. How much early intervention has the child received?
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

10. Does your child have any other disabilities (i.e. ADHD, asthma, etc.)?
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
__________________________

11. Medications the child is currently taking:
______________________________________________________________
______________________________________________________________

12. Child's race: African American _Hispanic Caucasian Asian American
____________________________ Other (please specify)

13. The number of siblings the child has and the child's birth order:
# of siblings:_ Bi1ih order:___________

15. Age of parents at the child's birth:
Mother:________
____________
Father:_____________________

16. Parent's highest level of education:

Mother: ___ ________________________________________

Father: __________________ ______________________

17. Estimated Annual Family Income (optional):____________ under $20,000
_ _ _ _ $20,000-40,000
____ $40,000-60,000
— — — — $60,000-80,000
— — — — $80,000-100,000
___________ over$100,000

Additional Information for Eye-tracking Study at AU PedMov Lab

1) At what age was your child diagnosed with autism/ autism spectrum disorder?
_______________________________________________________________

2) Who provided the diagnosis (e.g. family physician, school psychologist, neuropsychologist, etc)?
______________________________________________________________________

3) What criteria/formal assessment was used for the diagnosis (e.g. symptom checklist, ADOS-I, ADOS-II, CARS, ADIR-II, etc)?
______________________________________________________________________

4) Would you feel comfortable sharing assessment results? If yes, please provide information that information attached to this document or indicate how you would like to share it (email, fax, phone, etc).
______________________________________________________________________

5) Has your child been reevaluated since original diagnosis?
______________________________

6) If so, who provided the evaluation and which assessment(s) was used? Would you feel comfortable sharing the results?
______________________________________________________________________

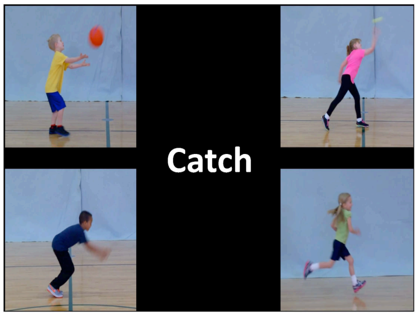
---

7) Does your child participant in any after-school physical activities or sports? If so, please describe.
______________________________________________________________________

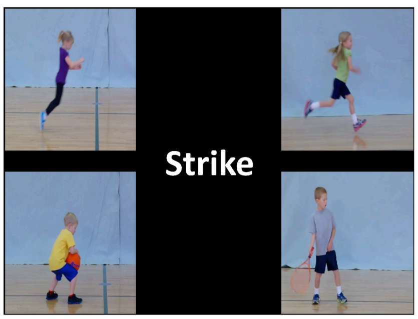
______________________________________________________________________

## Appendix C

**Slides for Motor Skill Knowledge Task – Matching Conditions**


Catch


Throw

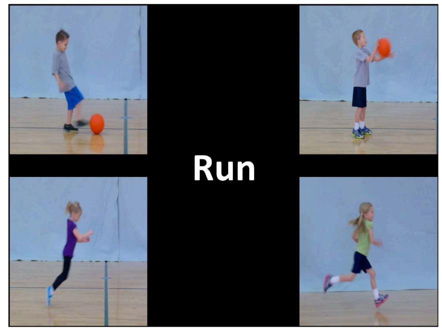

Strike


Jump

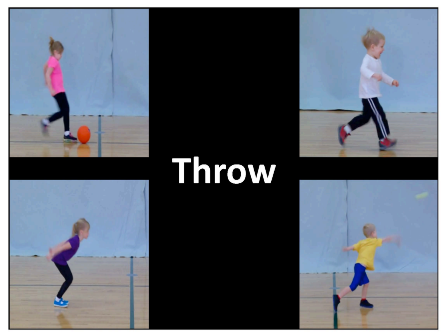

Run


Kick


Strike


Run


Jump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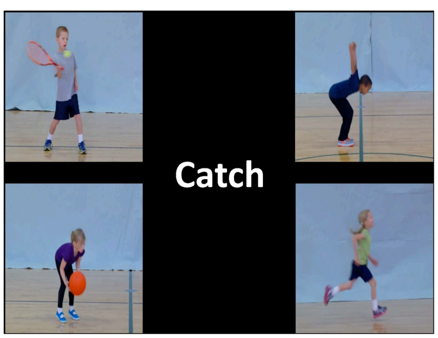
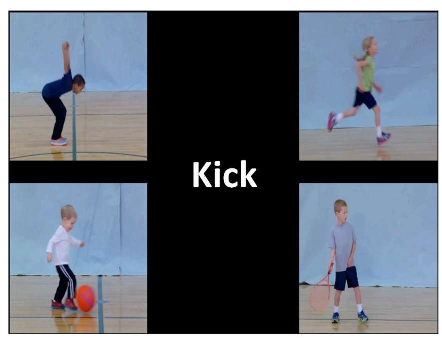
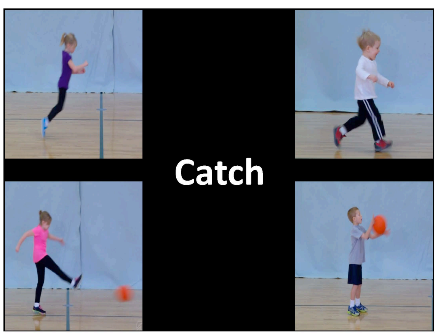
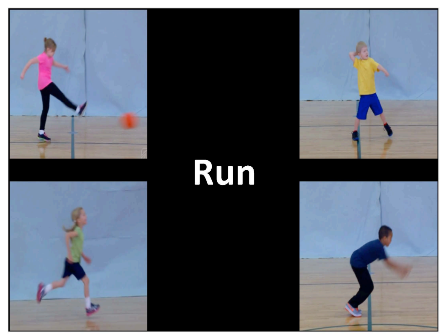

Catch

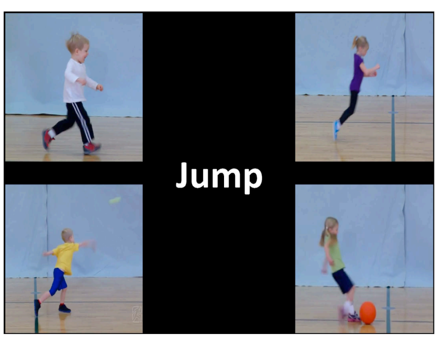

Kick


Strike


Throw


Catch

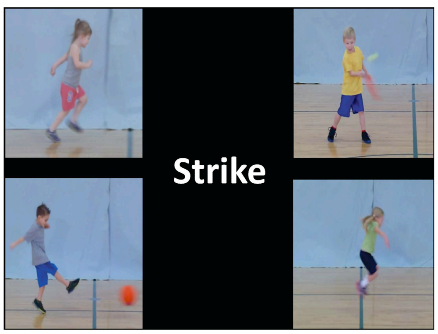

Run


Jump


Kick

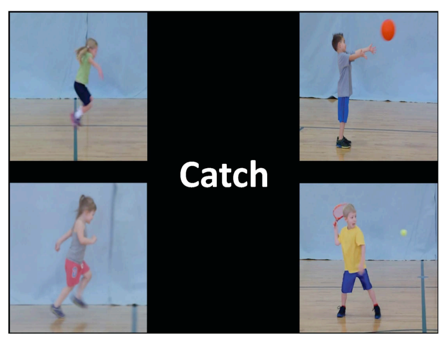

Run


Kick


Strike

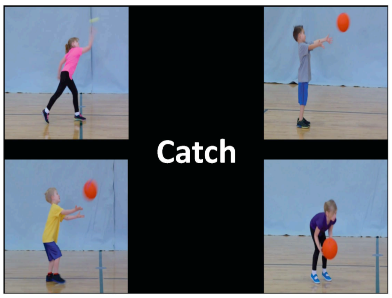

Throw


Jump


Catch

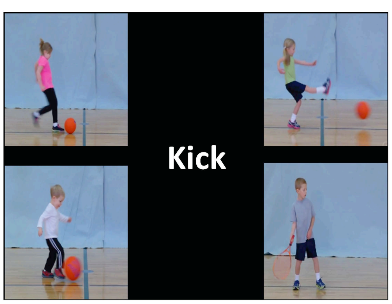
**Slides for Motor Skill Knowledge Task – Not-matching Conditions**

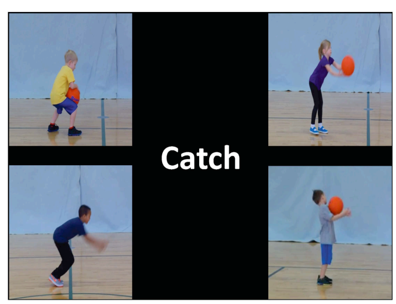


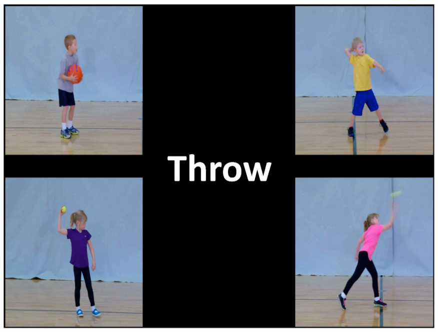


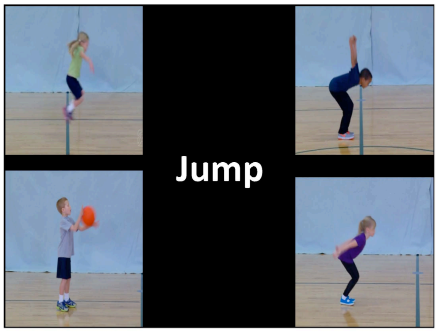


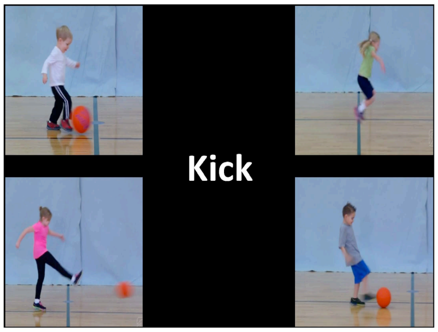


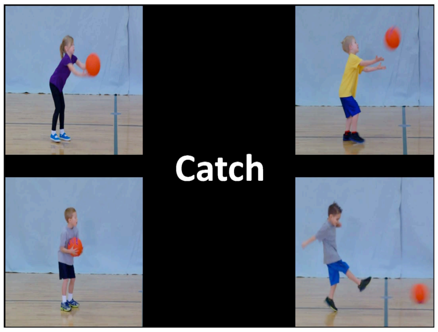



Throw

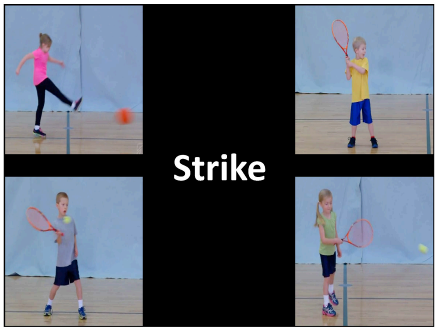

Jump


Kick


Catch


Jump


Throw

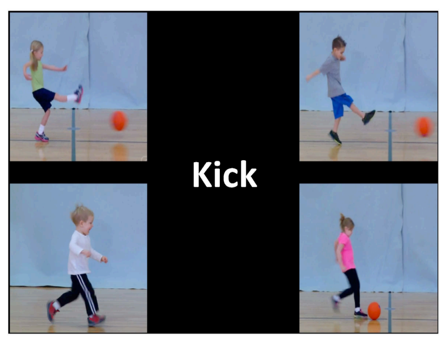

Strike

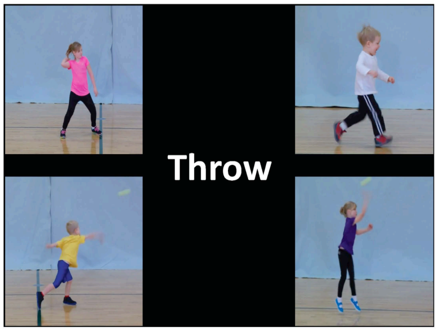

Run


Jump

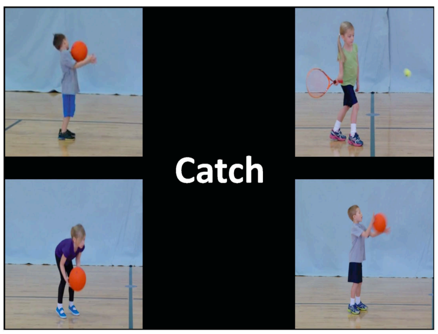

Strike


Run

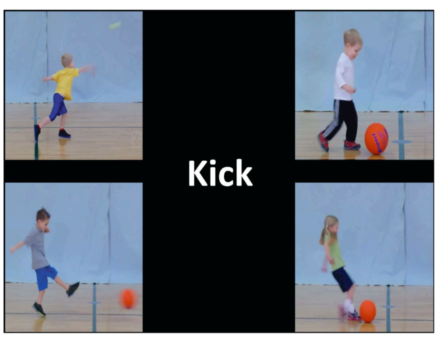

Kick

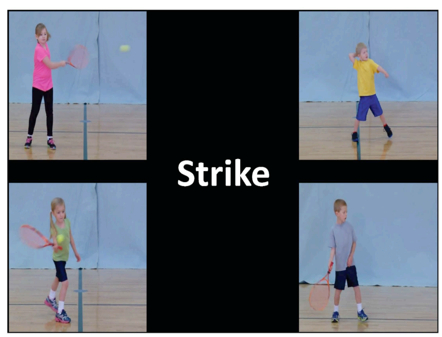

Throw


Jump


Catch


Run


Kick


Strike

## Appendix D

## Task Card Stimuli

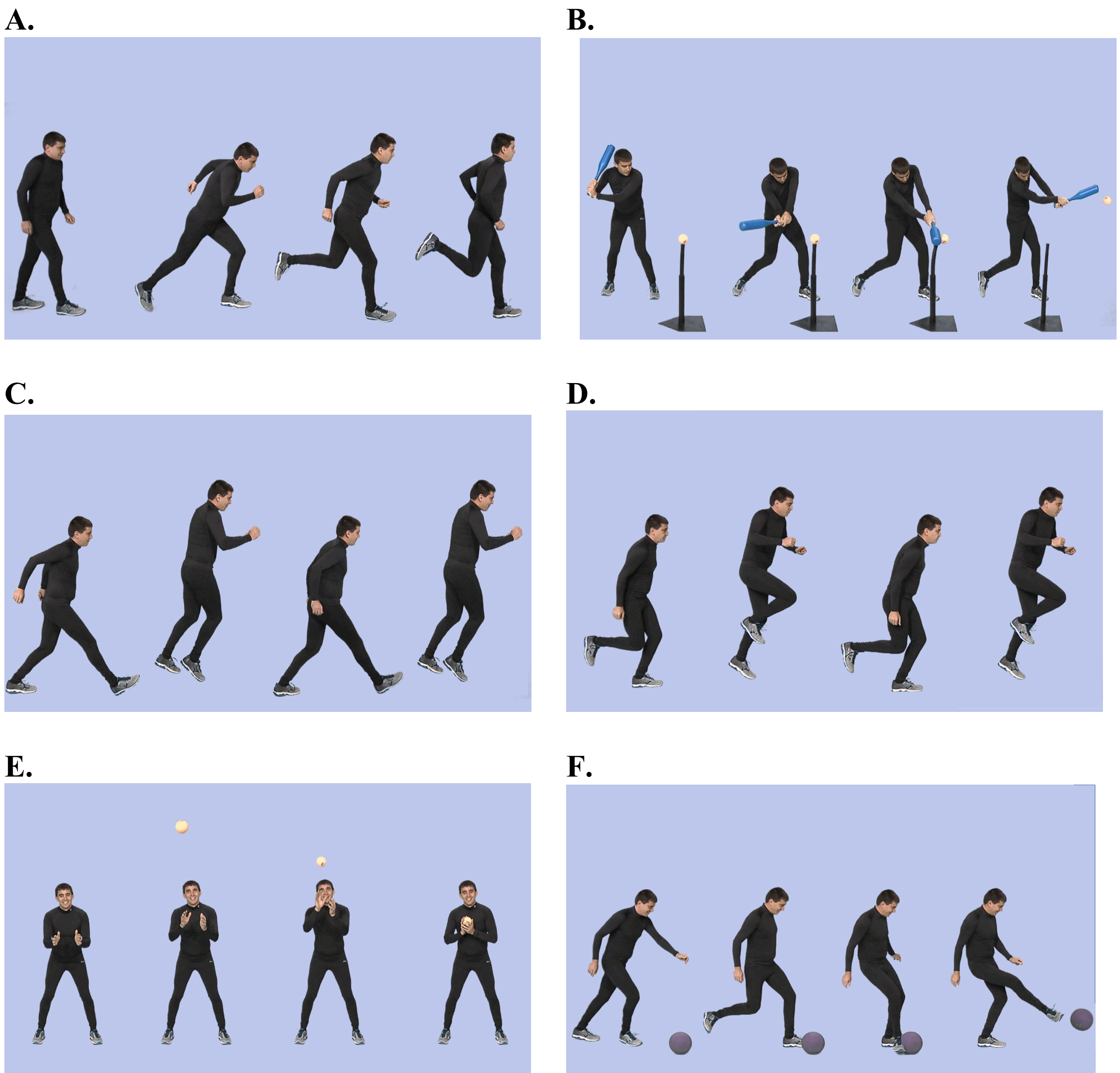



*Figure* B.1 Task card stimuli. Images (A) Run, (C) Gallop, and (E) Catch were used in task card 1 and (B) Strike, (D) Hop, and (F) Kick were used for task card 2.

# Appendix E

## Supplemental Results

Table E.1 Correlations among Predictors of Visual Attention

| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|
| 1. BOT-2 Total Composite Normalized | – | | | | | | | |
| 2. Median RT – NM Centered | -.18 | – | | | | | | |
| 3. Median RT- NM Normalized | -.18 | 1.00 | – | | | | | |
| 4. Accuracy – NM Centered | .45 | -.30 | -.30 | – | | | | |
| 5. Accuracy – NM Normalized | .45 | -.30 | –.30 | .1.00 | – | | | |
| 6. MSK Combined Normalized | .39 | -.80 | -.80 | .80 | .80 | – | | |
| 7. Flanker Uncorrected Std. Centered | .43 | -.36 | –.36 | .54 | .54 | .56 | – | |
| 8. Flanker Uncorrected Std. Normalized | .43 | –.36 | –.36 | .54 | .54 | .56 | 1.00 | – |

Median RT- NM = Median response time (ms) in non-matching condition, MSK Combined = motor skill knowledge combined score

Table E.2 Model Comparison for Predictors for Visual Attention

| Model | df | AIC | BIC | Deviance | $\chi^2$ | $\chi^2$ df | p |
|---|---|---|---|---|---|---|---|
| Horizontal Gaze Autocorrelation | | | | | | | |
| Mod0 | 3 | -142.10 | -136.62 | -148.10 | | | |
| Mod | 6 | -137.96 | -126.99 | -149.96 | 1.85 | 3 | .60 |
| XC1b | 9 | -158.35 | -141.89 | -176.35 | 26.39 | 3 | < .001 |
| Fixations on Model | | | | | | | |
| MNB0 | 3 | -46.83 | -41.35 | -52.83 | | | |
| MNB1a | 6 | -44.14 | -33.17 | -56.14 | 3.30 | 3 | .34 |
| MNB1b | 9 | -39.79 | -23.33 | -57.79 | 1.65 | 3 | .64 |