A mixed-methods analysis of the effects of a fundamental motor skills intervention for children with autism spectrum disorder

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by

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ABSTRACT

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder characterized by deficits in social communication and pervasive repetitive behaviors (American Psychiatric Association [APA], 2013). Further, ASD is one of the fastest rising childhood developmental disorders, affecting 1 in 68 children (Christensen et al., 2016). In addition to the hallmark charactizations of this condition is a growing body of research (Lloyd, MacDonald, & Lord, 2013; Liu, Hamilton, Davis, ElGarhy, 2014; Staples & Reid, 2010) that suggests that individuals with ASD also demonstrate delays in the development of gross motor skills. Despite mounting evidence of delay, few interventions have targeted gross motor skills as an outcome (Staples, MacDonald, Zimmer, 2012). Three recent studies (Bremer, Crozier, & Lloyd, 2016; Bremer & Lloyd, 2014; Ketcheson, Hauck, & Ulrich, 2016), amoung others, demonstrate the increasing awareness to this issue; however, continued theory-based research is needed to builded an effective motor intervention for children with ASD.

The purpose of this parallel, convergent mixed methods design study was to test the validity and effectiveness of a fundamental motor skill (FMS) intervention for children with ASD that uses dynamic systems theory (DST; Newell, 1986). The intervention was based on intentional manipulations of task constraints, hereafter referred to as *task modifications*, to build FMS. This study incorporated both quantitative and qualitative data to understand not only how the task modifications work to influence the motor performance of children with and without ASD, but how potential changes in motor performance, or the perception of, was understood by parents. Furthermore, this study sought to understand how the intervention effected the daily lives of the individual and their family.

Results revealed that a motor intervention based on dynamic systems theory may: (a) significantly improve gross motor performance of children; (b) provide an effective means to build motor skills in children with ASD; and (c) allow for a high level of engagement and successful practice. Furthermore, parent interviews suggest that there are number of barriers to physical activity, as well as many benefits. Futher, results suggest that the home environment may play a role in the gain made during a school based intervention; acting as an environmental constraint. Lastly, when looking at changes in motor performance compared to themes discussed by parents, data suggest that motor skills may play a role as a mediating factor in a child's physical activity level. Additionally, the results suggest that direct changes from increases in motor performance may have delayed indirect changes in other developmental skill and in the child's life.

While data suggest significant improvements, a small sample size and the heterogeneity of ASD limit the overall generalizability of the intervention. Further research is necessary to fully understand the potential of an intervention based on task modifications. Moreover, while significant findings bolster the effectiveness of this intervention, 6 weeks proved not to be long enough to create lasting improvements in the motor skills of children with ASD. Future research should increase the frequency and dosage of the overall intervention while incorporating the parents and families of children with ASD to ensure the overall success and potential impact on other aspects of a child's life.

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APPROVAL OF THE DISSERTATION

This dissertation, "A mixed-methods analysis of the effects of a fundamental motor skills intervention for children with autism spectrum disorder", has been approved by the Graduate Faculty of the Curry School of Education in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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DEDICATION

To my amazing wife, Daniella, for without you or your support, this would never have been possible.

… and …

To all the families of living within the autism spectrum, you are pillars of strength. I hope my work helps in some small way.

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CHAPTER 1

Introduction

Autism spectrum disorder (ASD) is classified in *The Diagnostic and Statistics Manual of Mental Disorders* (5th ed.; *DSM-5*; American Psychiatric Association [APA], 2013) by two defining traits: (1) severe deficits in social communicative behaviors (SCD), and (2) highly restrictive, repetitive behaviors (RRB). Per the *DSM-5* (APA, 2013), these deficits must be persistent and present since birth. Much of the previous research on ASD has focused on these two key areas, and for good reason, as deficits in these areas can severely limit daily function. However, a growing body of research over the past decade has focused on the motor development of children with ASD (Staples, MacDonald, & Zimmer, 2012). This body of research has started to paint a clear picture of a delay or deficit in the motor development of children with this disability (Liu, Hamilton, Davis, & ElGarhy, 2014; Lloyd, MacDonald, & Lord, 2013; Staples & Reid, 2010). Interestingly, the notion that children with ASD may display problems with coordination or use different movement patterns than children without ASD is not a new concept. Concerns with the motor ability of children with ASD have been present since the earliest reports of ASD research. Kanner (1943), in an analysis of several boys with "autism characteristics," suggested that the children appeared "clumsy" in gross motor movement and lacked motor control (p. 248). A year later, Hans Asperger (1944; Asperger & Frith, 1991), independent of Kanner, described participants as "clumsy" and "gauche" (p. 90). The World Health Organization (WHO, 1993) stated in *The International Classification of Diseases*, 10th Edition (ICD-10), which is similar to the *DSM-5*, that clumsiness appears to be a common feature of ASD, but is not required or essential for diagnosis. In a more recent study, Ghaziuddin and Butler (1998) found that all 45 of their participants with pervasive developmental disorders (PDD) demonstrated issues of motor coordination, with the highest rate of "clumsiness" in children diagnosed with autism.

Currently, there is a limited understanding of whether motor impairments are derived as a cause of the disability or due to a combination of other hallmark ASD factors, such as limited communication and restricted behaviors/interests. However, it has become clear that children with ASD often have motor delays and display different motor patterns than peers without ASD (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). Continuing the work of Ghaziuddin and Butler (1998), Berkeley, Zittel, Pitney, and Nichols (2001) analyzed the motor characteristics of 15 children with ASD, compared them to age-matched norms for the Test of Gross Motor Development (TGMD; Ulrich, 1985), and found that nearly all were below average, with the majority falling in the "poor" or "very poor" normative ranges of the TGMD. While this is a prominent study, it is not without its limitations regarding interpretations. First, the TGMD was not normed with children with ASD in mind; therefore, it may not be valid to consider normative data in a one-to-one comparison. Further, Berkeley et al. reported that during locomotor testing, participants seemed to focus more on the product of the movement (e. g., A to B) than on the process (i.e., how to do it). This subtle inconsistency in interpretation limits the reliability of the assessment and makes comparison to normative data tenuous, at best.

Recent studies have focused on the motor abilities of toddlers at risk for ASD (Liu, 2012; Lloyd et al., 2013; Matson, Mahan, Fodstad, Hess, & Neal, 2010; Ozonoff et al., 2008). Early identification and intervention are popular, although not revolutionary, topics (Ulrich, 2010) and have been identified as beneficial to the overall development of children with ASD (Bradshaw, Steiner, Gengoux, & Koegel, 2014; Eldevik et al., 2009; Estes, 2015). This research into the early identification of and intervention with children with ASD has drawn more attention to the motor-skills development of children with ASD (Lloyd et al., 2013) and led to the recommendation that motor-skill deficits be included in the diagnosis process (Flanagan, Landa, Bhat, & Bauman, 2012; Liu, 2012; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Researchers argue that motor skills are much more easily assessed by parents and are often noticeable before deficits in social behavior can be determined. It is important to note that it is not clear whether motor deficits demonstrated by children with ASD are attributable to some underlying motor deficit associated with ASD or to communication (e.g. not sure what do do) or behavioral issues (e.g., unmotivated to try one’s best; Ozonoff et al., 2008). It is evident, however, that gross motor differences exist in toddlers at risk for ASD (Liu, 2012; Lloyd et al., 2013), and the deficits only appear to become greater over time (Fournier et al., 2010; Staples & Reid, 2010). Recent research has identified deficits in motor ability that persist into adolescence (Green et al., 2009; Whyatt & Craig, 2012), and are evident when comparing children with ASD to age-matched children without ASD (Liu et al., 2014; Liu & Breslin, 2013a; Pan, Tsai, & Chu, 2009) or even developmentally matched peers (Staples & Reid, 2010).

It has also been suggested that there is a link between the development of motor skills and acquisition of social skills (MacDonald, Lord, & Ulrich, 2013b), as well as adaptive behavior development (MacDonald, Lord, & Ulrich, 2013a). More specifically, children with more severe ASD, based on calibrated autism-severity scores (i.e., the amount of stereotypic behaviors displayed) appear to have greater motor deficits than children with less severe ASD symptoms (MacDonald, Lord, & Ulrich, 2014). Autism-severity scores are derived from the raw scores of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore & Risi, 1999), which represents the core deficits specific to the social communication skills and behaviors found in ASD (MacDonald, Lord, & Ulrich, 2013b). Raw scores are derived from algorithms with strong sensitivity and specificity (Gotham, Pickles, & Lord, 2009; Gotham, Risi, Pickles, & Lord, 2007), and appear to occur independent of cognitive function (Gotham et al., 2009). In other words, an individual with a high autism-severity (i.e., numerous stereotypic autistic behaviors) will not necessarily have a low IQ or visa versa. MacDonald and colleagues (2014) compared gross and fine motor skills to autism-severity scores and found that young children (12-33 months) with higher scores had both lower fine and gross motor skills. This suggests that the more severe a child's autism (as noted by increased presence of ASD characteristics), the lower his/her fine and gross motor skills are likely to be. MacDonald et al. (2013b) also found that object control skills, as measured by the TGMD-2 (Ulrich, 2000), were predictive of calibrated autism severity. Comparitively, Colombo-Dougovito and Reeves (2017), in analyzing how diagnosis differentiates the motor and social skills of individuals with ASD, found that there was little difference between more and less severe labels of ASD. However, they noted that gross motor skills were delayed when compared to normative samples in addition to delayed social skills; positing that while there is little difference between individuals with ASD, data demonstrated that gross motor performance is still delayed. Results from these three studies add to mounting evidence that motor skills may act as a type of behavioral cusp for the development of a variety of skills in children with ASD.

Other studies found a relationship between language and cognitive development and motor development. For example, a study by Bedford, Pickles, and Lord (2015) suggests that early development of gross motor skills (e.g. walking) may affect early language development. This study followed 209 children (158 with initial ASD or PDD-NOS diagnosis) at 2, 3, 5, and 9 years of age, and found that early delays in motor skill development (i.e., delayed walking) was associated with slower language development in children with ASD (Bedford et al., 2015). Moreover, cognitive and motor skill performance has been recognized as influential in the development of children with ASD (Helt et al., 2008; Landa, Gross, Stuart, & Bauman, 2012; Sultera, Pandey, Esser, & Rosenthal, 2007). However, little research has been done that focuses on motor skills. Even when research in occupational therapy is included, many interventions mainly address play-based activities and rarely consider the direct development of motor skills (Case-Smith & Arbesman, 2008). In a recent review of 23 articles analyzing the effect of exercise in individuals for ASD, Dillon, Adams, Goudy, Bittner, and McNamara (2017) suggest there is positive evidence for the use of exercise as an evidence-based practice; yet, the evidence is limited (i.e. only one well designed study) and further research is warrented. Although play-based activities and exercise have some components of movement, they are focused more on social interaction or health-based outcomes, rather than functional motor skills (FMS).

FMS (e.g., locomotor and object-control skills) are considered by many to be the essential building blocks for more complex motor movement (Clark & Metcalfe, 2002). Ultimately, the development of these skills enables the individual to be more successful—and therefore more confident—in future physical activity (Stodden et al., 2008). Some researchers assert that successful FMS abilities can lead to higher motor competency, which in turn could increase the likelihood of participating in physical activity in later years (Stodden et al., 2008; Stodden, Gao, Goodway, & Langendorfer, 2014). An increase in the rate of physical activity for children with ASD has been suggested to have a positive effect on the occurrence of stereotypic behavior (Bremer, Crozier, & Lloyd, 2016; Lang et al., 2010). However, prerequisite motor skills are necessary to properly perform an activity (Larouche, Boyer, Tremblay, & Longmuir, 2014; Williams et al., 2008); they also increase the likelihood of remaining physically active in the future (Barnett, van Burden, Morgan, Brooks, & Beard, 2009). In a study by MacDonald, Esposito, and Ulrich (2011), the authors found that the physical activity of individuals with ASD decreases with age, which mirrors similar results from previous studies (Pan & Frey, 2006).

If motor competence has as much of an effect on individuals with ASD as it does in other populations (Stodden et al., 2008), it is essential that the FMS necessary for inclusion in motor activities are strengthened in children with ASD (Barela, 2013); this appears to be the best strategy for increasing the likelihood that these individuals will remain physically active across the lifespan. Although early descriptive studies have detailed the motor deficits of children with ASD, the focus of most interventions for this population has been social skills development; very few motor skill interventions have been implemented (MacDonald et al., 2012; 2014). Improved FMS in early development could provide children with the foundational skills necessary for better outcomes later in life (MacDonald et al., 2014).

Lack of Motor Intervention for ASD

Although numerous interventions have been developed to address various aspects of the characteristics of ASD (McDonald & Machalicek, 2013; Wong et al., 2013), few address the development of FMS in children with ASD; instead, the majority address the core stereotypic characteristics of ASD. This lack of attention to FMS is critical, given recent findings that link gross motor skill development and social and language development in children with ASD. With the importance of FMS for lifespan motor development (Clark & Metcalfe, 2002) and the implications for lifetime physical activity (Stodden et al., 2008; 2014), it is vital that FMS be enhanced in this population as the best strategy for maintaining a healthy level of physical activity. With an already high prevalence of overweight (14.8%) and obesity (23.2%) in children with ASD (Broder-Fingert, Brazauskas, Lindgren, Iannuzzi, & Van Cleave, 2014), lifelong physical activity will play a central role in maintaining a healthy quality of life for these individuals (Raz-Silbiger et al., 2015).

A literature review, not surprisingly, revealed only a handful of gross motor interventions for improving FMS in children with ASD. Two of the more recent studies (Bremer & Lloyd, 2016; Bremer, Balogh, & Lloyd, 2014) demonstrate an increasing awareness of the needs of children with ASD in relation to motor development. For example, Bremer and colleagues (2014), in a small sample (*n* = 9) pilot study of 4-year-old children with ASD, demonstrated an FMS intervention's positive effect on gross motor skills, as well as improvements in adaptive behavior and social skills. This intervention consisted of 12 hours of direct instruction given over either 6 weeks (2 hours per week) or 12 weeks (1 hour per week). The intervention covered all FMS (e.g., running, hopping, leaping, throwing, catching, etc.) and was delivered either 1-on-1 or 1-on-2, following a similar format each week: warm-up, review of previous skill, direct instruction on new skill, practice of new skill, obstacle course, free play, and clean up (Bremer et al., 2014). This intervention mimicked the flow of a typical physical education (PE) or adapted physical education (APE) class. Furthermore, although the intervention demonstrated a positive influence on the development of FMS in young children with ASD, little information was provided as to the prompts and instruction for each skill except that the delivery method was direct instruction.

Continuing in a similar format, Bremer and Lloyd (2016) applied a similar strategy in a school-based setting for five children with ASD and ASD-like symptoms (3-7 years of age). Again, the intervention was provided in PE/APE-like format: warm-up, review of previous skill, instruction on and practice of new skill, obstacle course, and clean up, and concluded with an opportunity to play with a ride-on bike as a reward. An instructional example was provided that detailed the use of visuals, environmental cues, verbal cues, and physical prompting. Given in two 6-week blocks consisting of 13.5 hours of 1-on-1 instruction, Bremer and Lloyd identified improvements in many individual items, as well as overall improvement in locomotor skills for 4 of the participants and in object control skills for 3 of the participants. In addition to the quantitative data collected, the authors interviewed the special education teacher who assisted with the instruction. Interview data were transcribed and thematically coded. The teacher was positive about the experience overall, but commented:

> There wasn't a lot of focus … [there was] a lot of anxiety, so things were done very quickly with a lot of physical prompting to get them to do what I wanted them to do. Or if they threw the ball, it was like an aimless [throw] it wasn't directed. (p. 79)

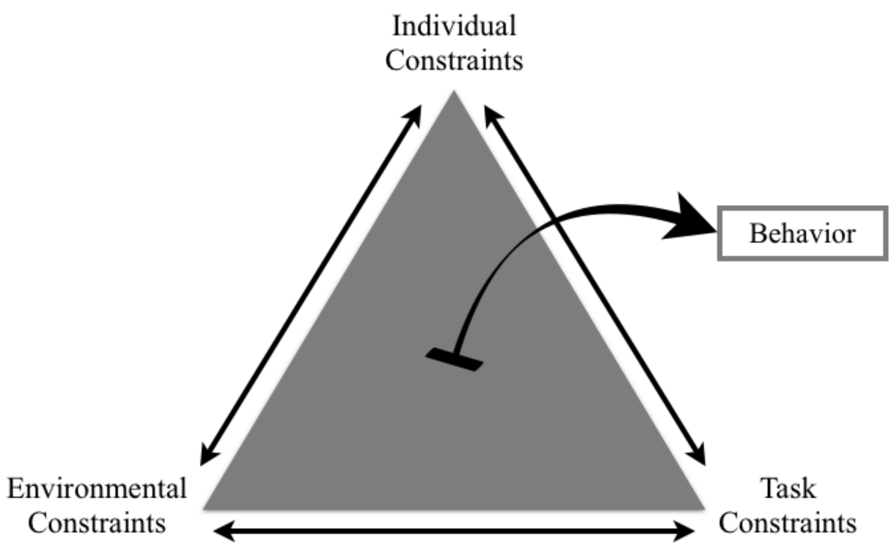
Perhaps, due the various limitations individuals with ASD face, direct instruction with physical prompting may not be the most appropriate type of instruction for a motor intervention.

Dynamic Systems Theory

Dynamic systems theory (DST; Newell, 1986; Newell & Jordan, 2007) may provide the framework for creating a set of instructions that does not require constant verbal or physical prompting, thus reducing the likelihood of anxiety and stereotypic behaviors due to frustration. The concept of dynamic systems is popular across a multitude of fields, including, but not limited to, mathematics, physics, astronomy, chemistry, meteorology, biology, cognition, neurology, and the social sciences (Thelen & Ulrich, 1991), as a means to explain the production of behavior within connected systems. Most recently, this concept— labeled a *constraint-led approach*—has emerged in physical and occupational therapy as a means of isolating certain movements to reduce specific impairments. DST posits that a behavior occurs as the confluence of interactions between the characteristics of the individual, the environment, and the task (Figure 1);

these are commonly referred to as *constraints*. Often perceived as a negative term, synonymous with restraints, within DST constraints are simply viewed as the circumstances that influence behavior patterns—in this case, motor movement (Gagen & Getchell, 2006).

Figure 1: Newell's Model of a Dynamic System



(Newell, 1986)

Many developmental specialists who study motor behavior use this framework to explain the complex coordination of influences on movement. The term *individual* is more common in recent literature than Newell's term, *organismic* (1986), mostly to relate the theory to human movement rather than Newell's general biomechanical definition. Individual constraints are often considered to be the structural (weight, height, etc.) and functional (motivation, attention, etc.) characteristics unique to the individual (Haywood & Getchell, 2005). In contrast, *environmental constraints* refer to everything that exists outside the individual, such as temperature, time of day, space (e.g., inside or outside), or the surface of the floor/ground (Langley, 2001). Hutzler (2007) takes environmental constraints a step further, by including social (e.g., peer, parent, and professional attitudes and support) and physical barriers (i.e., accessibility).

Lastly, *task constraints* encompass everything involved in the action itself. These could include the directions for the task (e.g., keeping personal space), movement goals (e.g., doing something quickly or slowly), or the equipment being used (Gagen & Getchell, 2006). DST offers enhanced understanding of the complexities of human movement, since throughout the lifespan new behaviors emerge, evolve, and on occasion dissolve (Clark & Phillips, 1993), but most importantly are difficult to manifest the exact same way twice (Renshaw, Chow, Davids, & Hammond, 2010).

In DST, the spontaneous pattern formation that emerges from the interactions of constraints is referred to as *self-organization* (Davids, Araújo, Vilar, Renshaw, & Pinder, 2013; Kamm, Thelen, & Jensen, 1990; Thelen, 1995), which is the body's ability to find a stable pattern of movement based on the influence of constraints (Renshaw et al., 2010). These stable states are often referred to as *attractor states* (Thelen, 1995; Thelen & Ulrich, 1991). An attractor state refers to the most preferable pattern based on a set of constraints (Šerbetar, 2014; Thelen, 1995).

Newell (1986) suggested that "extreme manipulation" is needed to further test the notions of the self-organization of coordination. Newell and Jordan (2007) provide ample support for understanding behavior and movement through DST, as well as the ability to influence movement through the manipulation of constraints. However, they suggest that research that purposefully manipulates constraints to elicit changes in behavior will be required to fully understand DST. In response to their assertion, the author conducted a literature search of how DST has been manipulated and tested in relation to motor skills,[1] and identified a small collection ($N = 18$) of studies that manipulated or employed some form of constraints to affect movement patterns. Many of the reviewed studies manipulated task and environmental constraints, which demonstrated a positive effect on individuals' overall movement patterns. Only one study (Vernadakis, Papastergiou, Zetou, & Antoniou, 2015) used DST to create specific task modifications for activities based on participants' current performance levels[2]. Taken together, these studies confirm the potential of specific constraint manipulations to improve overall motor patterns.

Implications for Individuals with Autism Spectrum Disorder

The individual influence of each constraint within a DST framework offers insight into motor development in the general population, but is also particularly informative about the movement patterns of individuals with disabilities. Instead of looking at disability as a deficit that needs to be overcome, DST would suggest that disability is simply a constraint that influences the person's movement (Getchell & Gagen, 2006). By adjusting the view of disability, building motor skills becomes less about overcoming barriers and more focused on adapting constraints to encourage more efficient movement patterns. By understanding how one constraint influences another to allow for movement to emerge—i.e., by adjusting or modifying tasks or the environment—a practitioner or researcher is able to create a situation in which more appropriate motor movement can occur (Gagen & Getchell, 2004).

This intentional manipulation of constraints may offer significant benefits for the treatment of ASD. As motor development research is relatively new in this field, it

[1] See Chapter 2 for a full review of DST interventions.
[2] See Chapter 2 for a full description of Vernadakis et al.'s (2015) study.

generally lacks depth (Staples et al., 2012). Much of the research has addressed the general delays displayed by children with ASD[3]; however, such impairments do not appear to be universal (Dewey, Cantell, & Crawford, 2007). Lacking in the research on motor development in children with ASD is an effective method for improving motor abilities. As much of the research on ASD has focused on reducing communication deficits and repetitive behaviors (McDonald & Machalicek, 2013; Wong et al., 2013), little work has been done on motor skills beyond making modifications based on previous evidence-based practices (Colombo-Dougovito, 2015; Ketcheson, Hauck, & Ulrich, 2016) or to better include children in activity (Healy, 2014), or to improve performance on motor assessments (Breslin & Rudisill, 2011; 2013). A dedicated intervention based on a sound theory is needed to strengthen motor skills in children with ASD, which in turn could increase the likelihood of sustained physical activity over time (Stodden et al., 2014).

DST may offer valuable insight into how an intervention could be designed and constraints modified to make meaningful changes in an individual's motor abilities. Although DST's efficacy has not been formally tested, there are a number of examples of how constraints can be used to shape behavior (Farrow & Reid, 2010; Renshaw et al., 2010; Ulrich, Ulrich, Collier, & Cole, 1995) and be designed around specific adjustments to tasks to improve performance (Vernadakis et al., 2015). By intentionally modifying the constraints of a task or environment, an intervention based in DST could move past what typically limits instruction for children with ASD.

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[3] See Fournier, Hass, Naik, Lodha, & Cauraugh (2010) for an overview.

Purpose

Taking into consideration the limited research on motor interventions for children with ASD, as well as the issues faced by the types of instruction commonly used with this population, the purpose of this dissertation is to test the validity and effectiveness of a motor intervention for children with ASD that uses dynamic systems theory. The intervention was based on intentional manipulation of task constraints, hereafter referred to as *task modifications*, to build FMS. Through this study, the author sought to expand the understanding of how changes in motor skills affect other aspects of a child's life, namely adaptive behavior, social skills, and family relationships. It was hypothesized that through specific, direct task modifications, individuals with ASD would demonstrate an improvement in motor-skill performance. Furthermore, increases in gross motor skills, or the impression thereof, would a direct impact on other facets of an individual's life.

Research Questions

This study sought to answer four directed research questions using both quantitative and qualitative methods:

RQ1: Do task modifications, based on the principles of dynamic systems theory, increase motor performance?

Sub-RQ1: Are positive effects from the motor intervention demonstrated in individuals with ASD?

RQ2: What influence do changes in FMS have on the adaptive behavioral skills or social skills of individuals with ASD?

RQ3: How do parents' perceptions of their child's physical ability change as a result of participation in a motor intervention?

RQ4: What effect, if any, do changes in FMS have on other aspects of a child's life?

Statement of Significance

This research seeks to present a mode of intervention that can improve the motor abilities of children with ASD. As only one of four known studies to focus on this aspect of ASD, this study has great potential to help lay the foundation for future research on motor interventions for children with ASD. Previous studies (Bremer et al., 2014; Bremer & Lloyd, 2016) have focused on direct instruction-based interventions, which may not be the best mode of instruction for individuals with ASD. This study goes further than previous studies to achieve in-depth understanding of the effects of a specific task-prompt style to improve motor skills based on a well-founded theory, DST (Newell, 1986). As with prior studies, an additional goal was to contribute to the literature on how changes in motor skills positively or negatively affect adaptive behaviors and social skills. Finally, this study pushed the boundaries further than previous studies to understand how motor intervention influences other aspects of a person's life by also considering the parents' perspectives.

Independent and Dependent Variables

One independent and eight dependent variables were evaluated during the dissertation study. The variables are as follows:

Independent Variable

1. Grouping criteria (i.e., ASD group, age matched, and developmentally matched)

Dependent Variables

1. Rate of change in gross motor skills (as measured by priori criteria; see Appendix A)
2. Gross motor performance (as measured by TGMD-3).
3. Adaptive behavior score (as measured by VABS-3).
4. Social skills score (as measured by VABS-3).
5. Number of trials per session.
6. Number of successful trials.
7. Time-on-task per session.
8. Understanding of skill.

Delimitations

This study is delimited as follows:

1. The participants in the ASD group were recruited from a school for individuals with autism in Central Virginia.
2. The participants in the age-matched and developmentally matched groups were recruited from private elementary and preschools in Central Virginia.
3. Participants in the ASD and age-matched groups were between 5 and 11 years of age.
4. Participants in the developmentally matched group were required to have a level of gross-motor-skill impairment similar to that of the ASD group, which suggests that some of the children included may not have been developmentally ready for certain skills.
5. The diagnosis of participants with ASD was confirmed by SCQ scores.

6. All participants demonstrated an ability to understand prompts (provided either verbally or visually) and remained engaged throughout the session with little distraction.
7. Sessions were conducted in either a gymnasium, multi-purpose room, or outside.
8. Sessions were conducted 1-on-1 by either the author or a trained instructor.
9. Modifications to tasks were determined prior to the intervention.
10. Modifications of instruction (e.g., verbal and visual prompts) was individualized for each participant as necessary.
11. This study focused on understanding whether this method is effective as an intervention; future studies will seek to understand the efficacy of such an intervention.

Limitations

The following limitations and assumptions may have affected study outcomes:

1. Participants in the ASD group exhibited a variety of characteristics related to ASD that cause variance among the sample that was difficult to control for.
2. Participants in the ASD group used a variety of reward and prompt procedures, specific to his/her education plan and individual to him/herself, which may have limited the practice time and on-task time of certain sessions.
3. The study did not control for participants' prior experience of FMS.

4. Sample size was small due to the difficulty of recruiting participants with ASD; each of the additional groups was recruited to match the number of participants in the ASD group.
5. IQ of participants was not accounted for. It has been suggested that an IQ above 70 limited influences of potential cognitive impairment; however, this was not accessible or feasible to measure for this study. Further, by including participants with potentially lower IQs, this study was more likely to capture a more representative sample of children with ASD.
6. The socioeconomic status (SES) or home situation of the parents was not be accounted for.
7. It was assumed that the gross motor measurements (i.e., using SC and TGMD-3) are accurate measurements of overall gross motor ability, as well as locomotor skills and ball control skills.
8. Incremental growth between skill criteria was assumed to be similar from point to point; unfortunately, each skill criterion change is not uniform, and could include multiple incremental changes that are not captured between criterion points.

Definition of Terms and Abbreviations

1. Adaptive behaviors: The collection of conceptual, social, and practical skills that all people learn to function efficiently in their daily lives.
2. Age-matched (AM) peers: Participants matched to the ASD group by chronological age.
3. Attractor state: A pattern of behavior that is highly preferable due to the constraints at hand.
4. Autism: Original term for describi ng individuals with characteristic deficits in social communication and repetitive/restrictive behaviors. Now grouped under the term *Autism Spectrum Disorder.*
5. Autism Spectrum Disorders (ASD): Umbrella term used in the most recent edition of *The Diagnostic and Statistics Manual* (*DSM-5*) to describe a set of complex, heterogeneous conditions characterized by deficits in social communication, as well as restricted and repetitive patterns of behavior.
6. Ball-control skills: Term introduced in the updated TGMD to replace Object-control Skills; see below.
7. Calibrated autism severity: A quantitative score produced by the ADOS-2; the higher the score, the more stereotypic behaviors present.
8. Constraint: A neutral term in dynamic systems theory that influences a given behavior pattern.
9. Developmentally-matched (DM) peers: Participants matched to the ASD participants by standard deviations from the mean; this group's mean age will be roughly half of the ASD group's mean age.

10. Environmental Constraint: Anything within the individual’s environment, such as gravity, light, temperature, floor surface, or barriers.
11. Fundamental motor skills (FMS): Foundational skills necessary for more complex movement; divided into body-management (e.g., balance, awareness), locomotor, and object-control skills.
12. Individual Constraint: And individual’s height, weight, strength, balance, coordination, emotional mood, or motivation.
13. Locomotor skills: Basic movement that produces locomotion, such as running, galloping, skipping, leaping, jumping, sliding, and hopping.
14. Object-control skills: Propulsive or receptive skills that involve the manipulation of an object, such as throwing, catching, kicking, striking, and dribbling.
15. Rate-limiter: A characteristic that is hindering the performance of a new pattern of movement.
16. Task Constraint: Any constraint (i.e., individual, task, or environmental) having to do with the task at hand.
17. Task Modification: Purposeful adaptation of a task to manipulate a task constraint faced by an individual.
18. Time on Task: The amount of time a child is engaged during the lesson, whether with the instructor, activity, or during break.

CHAPTER 2

Review of Literature

Several topics discussed in the previous chapter warrant a deeper analysis to better understand the motor characteristics of children with ASD: (1) motor competence in general populations and its potential effect on physical activity, (2) motor characteristics of children with ASD, (3) rates of obesity and physical activity of children with ASD, (4) current motor interventions for children with ASD, and (5) recent use of dynamic systems theory for interventions. The purpose of this review is, first, to identify how motor competence affects physical activity in populations without disabilities, as well as how motor skills can mediate this relationship. Second, the review will provide an overview of current research on the gross motor characteristics of individuals with ASD, followed by consideration of the state of obesity and physical activity within this population. Third, the review will describe current motor intervention research, and specifically, research conducted in populations of individuals with ASD. Lastly, this review will discuss how dynamic systems theory (DST; Newell, 1986) could provide a solid theoretical foundation for building an effective intervention designed to strengthen the FMS of individuals with ASD.

Motor Competence

Movement is essential to overall human development (Wagner, Haibach, & Lieberman, 2013). It allows us to experience the world, as well as understand our place in it. It is present in every facet of our lives, yet it is often neglected after infancy in terms of its relevance to overall development. However, the motor behaviors that are developed as we age can have great consequences on our overall health and can affect both the amount and types of physical activity we participate in throughout the lifespan (Barnett, van Beurden, Morgan, Brooks, & Beard, 2009; Lloyd, Saunders, Bremer, & Tremblay, 2014). Fundamental motor skills (FMS), such as locomotor (e.g., running, skipping, etc.) and manipulative (e.g., kicking, throwing, etc.) skills, are often considered to be the building blocks of later motor-skills acquisition and the development of more complex, sport-specific movement (Clark, 2007; Clark & Metcalfe, 2002; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). If motor skills are not developed at a young age, children and adolescents will have a difficult time learning more complex skills and may not continue to participate in certain physical activities (Barela, 2013). Without the proper development of the FMS early in life, the chances of maintaining the benefits of daily physical activity can be limited.

Role of Motor Competency

Often, motor skills are discussed in terms of *motor competence*; for example, the proficiency one performs FMS (e.g., locomotor and manipulative skills; Stodden et al., 2008). In their dynamic association model, Stodden et al. (2008) suggest that the lower an individual's competence is perceived to be, the less physical activity he or she will perform. This relationship becomes more evident as people age, demonstrating a positive association of perceived motor competence and rate of physical activity (Haga, Gísladóttír, & Sigmundsson, 2015). In young children, the relationship is not as clearly predictive, because children's perception of motor competence is fluid (Harter, 1999) and often inflated (Goodway & Rudisill, 1997; Harter, 1999). A young child's inflated perceived competence can be a benefit when developing FMS, as they are not as easily discouraged from participation based on actual motor competence (Stodden et al., 2008). However, this perceived motor competence is tied inevitably to perceived attempts at mastery of the task; individuals need to perform the task adequately, and often enough, to keep positive about their performance. Recent research (Bardid et al., 2013; Stodden et al., 2014) suggests that the development of FMS at a young age is linked to physical activity levels later in life.

Although longitudinal research is limited in this area, most studies compare childhood to adolescence; little has been done to compare childhood motor competence to adult physical activity. A 20-year follow-up study by Lloyd et al. (2014) of preschool children's actual motor performance and adult levels of physical activity found no significant differences between adults who, as children, were considered either high or low in motor proficiency (measured by the Test of Gross Motor Development [TGMD]; Ulrich, 1985). The authors note several limitations to their analysis—namely, limited sample size in the second data collection, $N = 17$, and a limited number of male participants—which could mean that the group is not a fair representation of the original sample. Further, the follow-up study employed self-reported measures of physical activity and sedentary behavior, instead of actual measures of motor performance, which may have introduced an element of bias; individuals who were in the low-proficiency group originally may have misrepresented their actual activity levels. Interestingly, the study did find gender differences in physical-activity levels at the follow-up, with women from the higher-proficiency group, as measured at age 6, having less time spent in sedentary behaviors, which is consistent with other research in this area (Bardid et al., 2013, Colley et al., 2011a; 2011b; Thomas & French, 1985).

In a robust systematic review, Cattuzzo et al. (2016) analyzed 44 studies to examine the relationship between motor competence and physical activity, as well as other components of health-related physical fitness (e.g., body mass and cardiorespiratory fitness). This analysis provided strong evidence for an inverse relationship between motor competence and body weight, as well as a positive relationship with cardiorespiratory fitness and musculoskeletal fitness. As with the obesity and physical-activity rates of children with ASD, in general populations, body weight and obesity seemingly play an important mitigating role in an individual’s motor competence. It is unclear whether one causes another; however, it is far more likely that the relationship is bidirectional, as Stodden et al. (2008) suggest. As body mass increases, success in motor activities declines, causing a decrease in motor competence and, ultimately, lower rates of physical activity. Similarly, the relationship can go in the other direction, with lower motor competence decreasing an individual’s physical activity and, in turn, leading to increases in body mass. Regarding Cattuzzo et al.’s review, the 44 studies were mostly cross-sectional (82%), with sample sizes ranging from 18 to 7,175, and focused on childhood, adolescence, or both; no adults participated in any of the reviewed studies.

As with the results of Lloyd et al.'s (2014) study, Cattuzzo et al.'s (2016) findings reveal a critical gap the literature. The development of motor skills—and, by association, motor competence—is often attributed to increased lifetime physical activity. Yet, little evidence supports this claim. Further, confounding evidence is the variability in the assessment of motor competence. In the review by Cattuzzo et al., 26 of the 44 studies used a product-oriented assessment, such as the Köperkoordination-Test für Kinder, Bruininks–Oseretsky Test of Motor Proficiency, or the Movement Assessment Battery for Children. The remaining 18 studies employed a process-oriented assessment, such as the TGMD or the Peabody Developmental Scales.

In another systematic review, Logan, Webster, Getchell, Pfeiffer, and Robinson (2015) analyzed 13 studies of FMS competence and physical activity published between 2001 and 2013 that included 10,534 participants across three countries (Australia, n = 8; United States, n = 4; Estonia, n = 1). Twelve of the 13 studies revealed at least one positive relationship between FMS competence and physical activity; however, correlations ranged from r = .16 to r = .55. This variability could be attributable to the variety of measures used to assess FMS and physical activity. Cuttuzzo et al. (2016) suggest that certain motor-competence measures (i.e., product-oriented assessments) may overlap with elements of physical-fitness measures, and note that measures such as the tennis ball/medicine ball throw, standing long jump, and grip strength have been used interchangeably to measure both physical fitness and motor competence.

Performance and Ability

The research in this area outlines a distinct issue in the motor-research domain, which is the assumption that what is measured (e.g., motor performance) is a true representation of ability (e.g., motor ability or behavior). Concepts from motor learning and motor development are often confused, and terms such as *movement* and *motor* are used interchangeably; frequently, they are misused to describe how motor skills are developed (Burton & Miller, 1998; Staples et al., 2012). Clark (1994) described *motor development* as the changes in *movement behaviors* over a lifespan, as well as the processes that underlie these changes. Ideally, therefore, by measuring movement behaviors, researchers can theoretically understand and infer an individual's motor development.

It is not, however, that simple. To understand how an individual develops, one must understand the difference between movement and motor. Movement refers to the observable act of moving (Staples et al., 2012) or the performance of a motor task. Motor, on the other hand, refers to the underlying processes of a movement skill (Staples et al., 2012); in other words, the unobservable changes that occur within the body. As a result, motor ability is difficult to measure directly and can only be inferred through *motor performance*. However, it is too often assumed that each measure of motor performance is a reliable and valid inference of a motor behavior or ability. As demonstrated in the previous section, similar assessments are often used, interchangeably, to measure different constructs of motor ability. Yet, comprehension of these key differences is essential to assess and understand a person's development.

Recent years have seen an increase in research that suggests a link between gross motor movement and its influence on the potential cognitive abilities that underlie academic learning (Piek, Dawson, Smith, & Gasson, 2008; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011), which renders accurate assessment of a person's motor development essential. Once an individual's present level of motor performance is understood, potential interventions can be devised to best improve his or her skills. As the processes of motor ability are derived from motor performance, the measure of performance skills must be reliable and valid. Making the connection between motor performance and motor ability is difficult in general populations; this difficulty is exacerbated when considering populations with disabilities, especially individuals with ASD.

Motor Competence and ASD

As will be discussed later in the chapter, individuals with ASD have potentially higher rates of obesity (Broder-Fingert et al., 2014; Egan, Dreyer, Odar, Beckwith, & Garrison, 2013; Hill, Zuckerman, & Fombonne, 2015; Zuckerman, Hill, Guion, Voltolina, & Fombonne, 2014) and lower rates of physical activity (Sowa & Meulenbroek, 2011; Srinivasan, Pescatello, & Bhat, 2014). As is the case in populations without disabilities, it is difficult to ascertain in the literature whether one condition is an outcome of the other or if there is a reciprocal relationship. Stodden et al.'s (2008) dynamic association model suggests that this relationship is bidirectional and that motor competence mitigates the relationship. Therefore, the demonstrated delays and deficits in motor skills of individuals with ASD[4] would suggest the presence of a lower level of motor competence in this population; however, the literature does not include studies of this concept in the ASD population. A possible decrease in motor competence, in addition to social barriers (Memari et al., 2012) and decreased motivation (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Koegel & Mentis, 1985), may play a role in the

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[4] For extent of motor impairment, see "Motor Characteristics," below.

elevated rates of obesity and decreased physical activity. If motor competence, ultimately, influences physical activity and, in turn, an individual's weight, it is important that children with ASD can execute motor skills effectively and remain physically active across the lifespan.

Motor Characteristics of ASD

As described briefly above, individuals with ASD have demonstrated impairments in motor ability compared to their peers without disabilities (Liu et al., 2014; Staples & Reid, 2010), yet the magnitude and root of these impairments are a mystery (Staples et al., 2012). At present, the literature is inconclusive as to whether motor impairments are inherent to ASD, and should therefore be included in the diagnostic criteria (Liu, 2012; Teitelbaum et al., 2004). In a pinnacle review of the motor coordination of individuals with ASD, Fournier et al. (2010) provide strong evidence of a profound deficit in motor function, regardless of ASD severity, when compared to peers. Yet, the magnitude of the deficit is unclear, due to the heterogeneity of individuals with ASD, and findings are limited due to small sample sizes. In addition to the potential limitations, publication bias must be taken into consideration when evaluating studies in aggregate. When no negative cases arise in a review, one of two scenarios could be present: (1) the phenomenon is occurring, as confirmed by overwhelming evidence, or (2) only studies that report significant findings have been published, thereby providing a skewed view of the overall phenomenon. Fournier et al. considered these possibilities, and employed three methods to test for potential bias; their results suggest minimal likelihood of publication bias. This further strengthens the evidence for a demonstrated deficit of motor ability in individuals with ASD. Unfortunately, due to the small sample sizes and heterogeneity of ASD among the studies, a definitive deficit level is difficult to identify. Yet, clearly, individuals with ASD develop gross motor skills and coordination differently—often, more slowly or delayed—from peers without ASD.

Moreover, recent studies have implied that motor impairments in ASD affect other aspects of the child's development; namely, language development (Bedford et al., 2015), social skills (Bhat, Landa, & Galloway, 2011; MacDonald et al., 2013b), and adaptive behavior (MacDonald, Lord, & Ulrich, 2013a). Previous studies do not go so far as to suggest that motor skills are essential for the development of these other skills, but refer to a relationship within the individual and a connectedness between the processes necessary to complete each skill. In a review of 209 toddlers (≤ 36 months at onset of study; 158 with ASD or PDD-NOS and 51 with general developmental delays), Bedford et al. (2015) analyzed receptive and expressive language in comparison to early motor skills, as measured by the Mullen Scales of Early Learning (MSEL). The authors employed a longitudinal design; their results suggest that age at reported onset of walking predict later receptive and expressive language development. When controlling for nonverbal IQ and reported severity of ASD symptoms, these results became nonsignificant; however, gross motor skills did predict later receptive and expressive language development in older children (2 to 9 years). Bedford et al.'s findings demonstrate that the severity of ASD symptoms has a great effect on the overall development of individuals in this population. Yet, they also suggest that motor-skill development plays an important role in development of the whole individual. While early motor skills did not predict early language development, early gross motor ability was predictive of later language development—this is, by strengthening motor skills early in a child's development, children with ASD may develop the unseen but prerequisite skills necessary for future development.

Infants and Toddlers (Birth to 3 years)

With the drive for early intervention (Lord et al., 2006) and the potential mitigating effects of early motor development (Bedford et al., 2015; MacDonald et al., 2013b), reaching children with ASD early with interventions is imperative. Until recently, with the advent of more robust screening measures such as the ADOS (Lord et al., 2000) and awareness, diagnosing ASD at very young ages has been difficult. While many children, on average, are diagnosed with ASD around 3.1 years of age, for many others this may not happen until they start school a few years later (Mandell, Novak, & Zubritsky, 2005), making early intervention difficult. Understanding of the motor characteristics of infants and toddlers has been limited, but recent studies (Liu, 2012; Lloyd et al., 2013; Matson et al., 2010) have demonstrated that motor skills of children with ASD are severely delayed.

In an exploratory analysis of 44 children with ASD (32 males, 12 females), Liu (2012) demonstrated a delay in 26 motor milestones (e.g., sitting with support, crawling, etc.), with 11 being statistically different from normative data for children who were developing typically. These results offer an extremely useful account of the motor characteristics of children with ASD, and support previous accounts of delayed motor milestones (Ming, Brimacombe, & Wagner, 2007). Moreover, Liu et al.'s findings provide evidence that motor-skill deficits may be present in children with ASD long before SCD present themselves, which leads the authors to suggest that motor skills should be included in the diagnostic assessment. Although motor deficits may be present early in young children with ASD, it is difficult to determine whether the deficits are indeed an indicative part of the disability. Deficits at young ages may be attributable to the limited ability to jointly attend to tasks or imitate actions seen in many individuals with ASD (APA, 2013).

Two factors limit Liu et al.’s analysis and hinder interpretation of the magnitude of deficits: (1) children’s motor milestones were reported via parent questionnaire, and (2) the authors did not include a control group of children without ASD. In the first instance, parent recollections can be unreliable when identifying specific months in which a milestone occurred. Although the authors state that some parents referred to home videos, medical records, or baby books, many did not. In the second instance, without including a reference group of similarly aged children it is hard to know whether this sample of children matured differently from children in similar circumstances but without ASD. Additionally, Liu et al.’s assertion that motor impairments should be included in ASD diagnosis at young ages may cause children whom do not have ASD, yet have a motor delay, to be misdiagnosed. Without the ability to access SCD, as language does not occur until 18 to 24 months, using motor skills as the diagnostic criteria would be only suggestive. Screening for motor impairments at a young age may be an effective way to track children who may present later with ASD; however, it should not be a defining characteristic, as similar disorders may demonstrate a similar delay in motor-milestone achievement.

Lloyd et al. (2013) provide strong additional evidence for delayed motor skills in young children with ASD. They collected data on 162 participants between the ages of 12 and 36 months from a large research database; participants had no known genetic disorders besides ASD at entry into the study. Fifty-eight participants were measured a second time 12 months later, on average, which provided a longitudinal analysis of skill development. Employing a direct measure for motor ability (MSEL), results suggest that all participants were below the expected scores for chronological age. Moreover, gross motor development slowed significantly as the children aged. In addition to demonstrating deficits in motor abilities and the increasing gap as children age, Lloyd et al. used nonverbal problem-solving skills as a covariate within their analysis to account for the potential of unrecognized intellectual disabilities (ID) to bias the results. Since significant deficits still occurred despite controlling for potential identifiers of ID, this would suggest that cognitive ability is not responsible for the motor delays and support the theory that motor deficits in children with ASD are not a secondary problem but, rather, are inherent to the condition (Lloyd et al., 2013; Ozonoff et al., 2008).

Early Childhood, Adolescence, and Young Adulthood (4-21)

Unfortunately, the outlook for motor delays and deficits in children with ASD do not improve as they mature into adolescence and young adulthood (see Fournier et al., 2010). In most studies, delays and deficits are present in childhood (Liu & Breslin, 2013a; Whyatt & Craig, 2012) through adolescence (Green et al., 2009; Jasiewicz et al., 2006) and young adulthood (Abu-Dahab, Skidmore, Holm, Rogers, & Minshew, 2012). There are no known studies of the motor characteristics of adults with ASD; this will warrant future research as the large population of children with ASD ages and requires additional services (Turcotte, Mathew, Shea, Brusilovskiy, & Nonemacher, 2016). Furthermore, deficits in early childhood through adolescence are present in individuals with ASD compared to peers without ASD (Liu et al., 2014) and developmentally matched peers (Staples & Reid, 2010). Even so, delays and deficits may not be universal across the spectrum (Dewey et al., 2007).

In a recent analysis of 21 children with ASD (*M* age = 7.57 years) and 21 age-matched typically developing children (*M* age = 7.38), Liu et al. (2014) found that the overall gross motor scores of children with ASD were significantly different (p = .002) from those of their peers without ASD. Furthermore, effect sizes, as determined by Cohen's *d*, were large on the locomotor subtest (ES = 1.12), object-control subtest (ES = 1.07), and overall gross motor quotient (ES = 1.00). This provides important information about how impaired children with ASD are compared to their peers in terms of motor-skill ability; however, several aspects of the study raise concerns about interpreting the results.

As with many studies of individuals with ASD, the sample size is small, and therefore findings are difficult to generalize to the broader population. Second, MacDonald et al. (2014) suggest that the severity of the symptoms (i.e., SCD and RRB) of ASD affects the individual's gross motor abilities (i.e., the more severe the symptoms, the lower the gross motor score). Liu et al. (2014) did not consider this possibility in their analysis; perhaps participants in their sample demonstrated more severe symptoms than similar aged peers with ASD, and therefore results would differ significantly in individuals with fewer ASD-specific symptoms.

Second, the literature recognizes the difficulty individuals with ASD have with imitating and following verbal directions. Liu and Breslin (2011, 2013) provide strong evidence for the use of visuals in improving performance on standardized assessments by children with ASD, because visual information is more likely to be accessed. Liu et al.

(2014) state that "each child received verbal descriptions and demonstrations prior to the gross motor skill performance" and that "participants were also provided additional directions if they did not seem to understand the first time" (p. 2). It is difficult to ascertain from these statements how much assistance participants with ASD were given during the assessment. It is assumed during motor assessments that children's motor ability is captured, and by providing verbal directions and a visual demonstration that the participant understands what is expected. By not including an explanation of the measures taken, the results may be biased due to participants with ASD having a limited understanding of what was being asked of them.

Staples and Reid (2010) further provide evidence that suggests a deficit in motor skills among children and adolescents with ASD. Twenty-five children with ASD (M_{age} = 11.15 years; 21 males, 4 females) were compared to three separate comparison groups without disabilities, each individually matched on either (a) chronological age, (b) movement skill performance, or (c) mental age. Overall, Staples and Reid took a considerable amount of care in ensuring (1) that the sample population of children with ASD was on the spectrum by using the ADOS and (2) that the comparison groups were "typically" developing, with no documented disabilities or movement issues, by checking with the participant's physical educator and reviewing school records. This analysis was one of the first to move beyond comparing children with ASD to typical age or normative data. By taking extra steps to confirm diagnoses in each of the sample groups, interpretations from the analysis have much greater impact and validity.

Using the locomotor and object-control raw scores from the TGMD-2 (Ulrich, 2000), Staples and Reid (2010) showed a significant difference between children with

ASD and the chronological age-matched ($p < .01$) and mental age-matched ($p < .01$) groups. There was no significant difference between the children with ASD and developmentally matched group ($M_{age} = 5.87$) on locomotor ($p = .72$) or object-control ($p = .81$) skills; this suggests that children with ASD, on average, perform motor skills at a level about half their age. Staples and Reid state that all the participants with ASD could perform each of the skills of the TGMD-2; however, all participants demonstrated difficulty in coordinating movements, especially between sides of the body or arms and legs. This suggests that children with ASD are significantly delayed in their motor skills, but not qualify categorically as having a deficit.

Furthermore, Staples and Reid suggest that difficulties in tasks, especially in object-control tasks, could stem from limited ability to practice and that accompanying visual cues might be helpful, which has been corroborated by Breslin and Rudisill (2011, 2013) and Liu and Breslin (2013b) as an effective method for improving performance. As with all research on children with ASD, Staples and Reid were limited by sample size in the generalizability of their interpretations; however, by using three comparison groups, the results are much more easily interpreted by providing a basis for the difference. Unlike Liu et al. (2014), Staples and Reid describe how the test was administered. Again, researchers did not use visuals to guide administration; however, they described the procedure to allow future researchers to replicate it. Lastly, Staples and Reid recognized that a ceiling effect was occuring in about 20% of the chronologically aged group and a flooring effect in about 16% of the participants with ASD. This would not change the significant difference between these groups, yet it does suggest that the overall magnitude of differences between these groups may not have been fully captured.

Obesity and Physical Activity in ASD

With a demonstrated delay in motor development, in addition to hallmark deficits (i.e., SCB and RRB), an individual with ASD may have a greater risk for developing obesity compared to individuals without ASD. Despite a high prevalence (1 in 68; Christensen et al., 2016), only limited research has focused on understanding how this population is affected by obesity (Egan et al., 2013). This is surprising, considering the concerns about overweight and obesity in the general population. Further, while obesity may not be a direct predictor of physical activity in children with motor difficulty (Joshi et al., 2015), the motor-planning and motor skills of children are affected by additional weight when higher task constraints are placed on them, regardless of additional disability (Gill & Hung, 2014). Since obesity has been shown to be detrimental to overall health (Deckelbaum & Williams, 2001), especially as we age (Masters et al., 2013), and physical activity has a mitigating effect (U.S. Dept. of Health and Human Services, 1996), it is important to understand what the literature suggests for individuals with ASD. As mentioned previously, the research in this area is scarce in light of its presence in the national news (Hill et al., 2015); however, in the following sections I will discuss what current research suggests are (1) the incident rates of obesity for individuals with ASD, (2) the physical activity of individuals with ASD, and (3) the benefits that can be gained from physical activity.

Incidence of Obesity

Commonly measured by body mass index (BMI), determinations of overweight (OWT) and obesity (OBS) are measured by the individual's percentile rank according to normative data. A ranking of ≥ 85 or ≥ 95 will place an individual in the overweight or

Table 1: Summary of Obesity Prevalence Estimates in ASD

Study	Age	ASD, *n*	ASD Diagnosis	Wt/Height	OWT%	OBY%
Broder-Fingert et al. (2014)	2 – 20	2976	ICD-9	Measured	37.5	23.8
Chen et al. (2010)	10 – 17	247	Parent-report (telephone interview)	Parent report	—	23.4
Curtin et al. (2005)	3 – 18	140	Retrospective chart review	Measured	35.7	19.0
Curtin et al. (2010)	3 – 17	454	Parent-report (telephone interview)	Parent report	—	30.4
Egan et al. (2013)	2 – 5	273	Retrospective chart review	Measured	33.0	17.6
Evans et al. (2012)	3 – 11	53	Confirmed with ADI-R	Measured	—	17.0
Ho et al (1997)	School age	54	—	—	—	42.6
Hyman et al. (2012)	2 – 11	362	*DSM-IV*; Confirmed with ADOS	Measured	—	8.3
Memari et al. (2012)	7 – 14	113	*DSM-IV-TR*; Confirmed with ADI-R	Measured	40.7	27.4
Phillips et al. (2014)	12 – 17	93	Parent-report (in-person interview)	Parent report	52.7	31.8
Rimmer et al. (2010)	12 – 18	461	Parent-report (Web-based survey)	Parent report	42.5	24.6
Whiteley et al. (2004)	2 – 12	50	Prev. clinical diagnosis, confirmed with ADI-R	Parent report	42.0	10.0
Xiong et al. (2009)	2 – 11	429	Parent-report, confirmed with CARS	Measured	33.6	18.4
Zuckerman et al. (2014)	2 – 18	276	*DSM-IV-TR*, ADOS	Measured	35.1	17.0

Note: ADI-R, Autism Diagnostic Interview–Revised; CARS = Childhood Autism Rating Scale; *DSM-IV-TR = Diagnostic and Statistical Manual of Mental Disorders*, Fourth Edition, Text Revision; ICD-9 = International Classification of Disease, Ninth Revision. Modified from Hill, A. P., Zuckerman, K. E., & Fombonne, E. (2015).

obese category, respectfully. The most recent prevalence statistics from the CDC, based on data from 2011 and 2012, estimate that 31.8% of children aged 2 to 19 were overweight and 16.9% were obese (Ogden, Carroll, Kit, & Flegal, 2014). According to Hill et al. (2015), the prevalence estimates of overweight and obesity within ASD populations varies greatly (see Table 1). When considering the prevalence statistics in relation to the national data, the rates for overweight and obesity are similar. However, in some studies, overweight and obesity have been found to be much greater than national data on the general populations (Phillips et al., 2014; Rimmer, Yamaki, Lowry, Wang, & Vogel, 2010; Whiteley, Dodou, Todd, & Shattock, 2004). When considering the variance in rates of overweight and obesity in the context of the great heterogeneity among ASD populations, it is difficult to reach a conclusion about the most accurate account. However, when looking closer at studies by Phillips et al. (2014), Rimmer et al. (2010), and Whiteley et al. (2004), among others, rates were based on smaller samples, and data were collected by parental report. Because of these limitations, the authors' interpretations of results may be biased.

When looking to studies with much larger sample sizes (Broder-Fingert et al., 2014; Egan et al., 2013; Hill et al., 2015; Zuckerman et al., 2014), prevalence rates more closely resemble those from the national statistics of the general population, but are still elevated. Hill et al. (2015), in their analysis of 5,053 participants (ages 2-20) from the Autism Speaks Autism Treatment Network (ATN) for the period 2008-2013 at 19 sites across the United States and Canada found that 33.6% of children were overweight and 18% were obese. Broder-Fingert and colleagues (2014) conducted a similar large-scale review by comparing 2,976 children with autism or Asperger syndrome (2,075 with autism, 901 with Asperger syndrome; ages 2-20) in the Partners HealthCare System Research Patient Database Repository (RPDR) to a control group from the same database and found that children with Asperger syndrome and autism had significantly higher odds of being overweight or obese. Specifically, of the children with autism and Asperger syndrome, 23.2% and 25.3% were obese, respectively. Both Hill et al. and Broder-Fingert et al. stratified their data by age bands to understand the differences as children age. In comparison to age-matched controls, Broder-Fingert et al. found that individuals with ASD were at higher risk across each of the ages and that unhealthy weight gain occurred early. This was similarly demonstrated by Hill et al.'s analysis of each of the age bands, yet they found significance in only two age bands. The younger (2-5) and adolescent (12-17) groups were significantly elevated compared to the general population from the NHANES dataset (Ogden et al., 2014).

In a smaller retrospective analysis of 273 participants ($M_{\text{age}} = 3.89$, SD = 0.91), Egan and colleagues (2013) found rates for overweight to be 15.38% and obesity to be 17.58%. Interestingly, the authors also found that adaptive function in the domains of communication, daily living, social skills, and motor skills had little impact on overweight status, leading them to suggest that barriers to healthy living are the result of impairments associated directly with ASD (e.g., SCD and RRB; Egan et al., 2013). When these results are combined with the demonstrated deficits found in studies discussed above, it is difficult to assume that motor skills play no role in the rate of overweight and obesity in ASD populations. Egan et al.'s the motor-skill scores were based on the Vineland Adaptive Behavior Scales (VABS; Carter et al., 1998). The VABS is a validated and reliable assessment often used in research, including past motor research with ASD

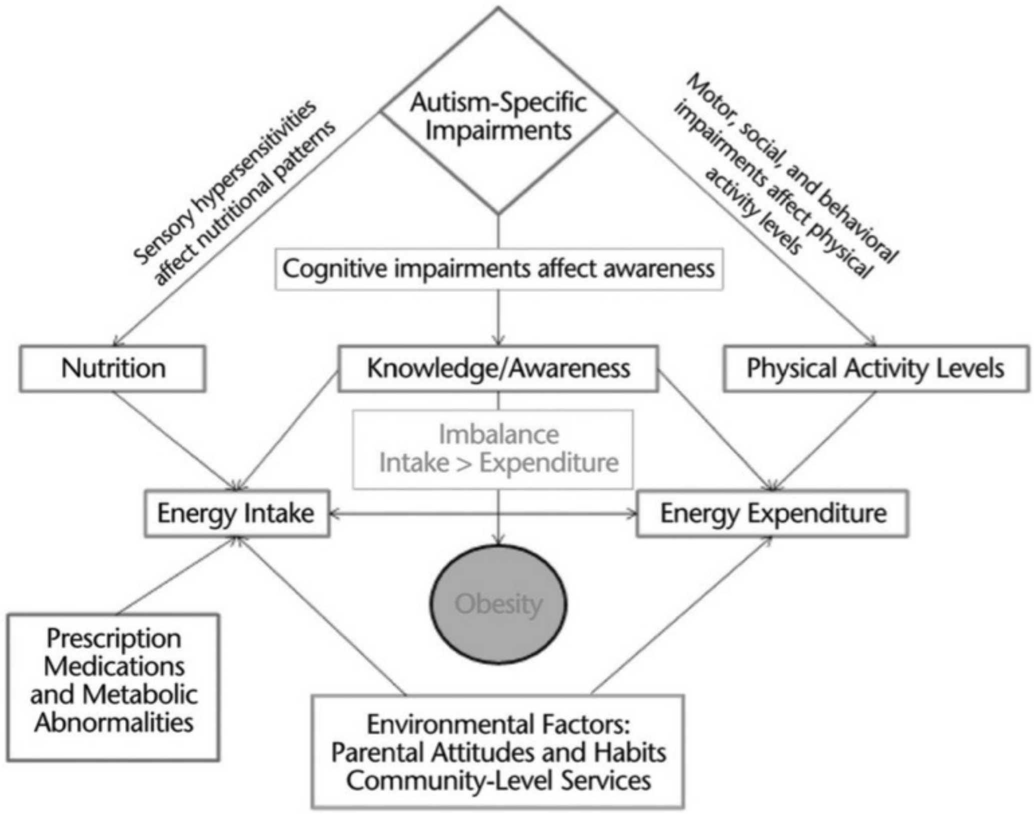
(Green et al., 2009, 2002); however, it uses parental report for each of the subtests, instead of a direct measure of the child. While parental report is beneficial for large-scale research, it often does not give the most accurate picture of a child's ability. Therefore, any dismissal of motor skills' effects on overweight and obesity should be interpreted with caution.

Current explanations for the driving forces behind the increased rates of overweight and obesity are plentiful, but lack substantial evidence (Broder-Fingert et al., 2014). Recent suggestions for differences are a potential genetic susceptibility, differences in dietary intake, lower rates of physical activity, limited social opportunities, pharmaceutical factors, or some combination (Broder-Fingert et al., 2014; Hill et al., 2015; Zuckerman et al., 2014). Although the risk factors for unhealthy weight may be similar to those for the general population (Zuckerman et al., 2014), they may be exacerbated by the unique characteristics of those with ASD. For example, children with ASD often display diminished motivation for activity and are often rewarded with food as a motivator to complete tasks. This decreased activity and increased food intake may explain some of the elevated overweight and obesity prevelance among this population. However, due to the large heterogeneity among individuals with ASD, those who display higher rates of RRB may mitigate some of the effects of the increased food intake.

Physical Activity and the Potential Benefits

Srinivasan, Pescatello, & Bhat (2014) present a model of contributing factors for obesity in children and adolescence with ASD that takes into consideration not only the child's physical activity and nutrition, but social factors from parents and the community, prescriptions, and individual "impairments" as well. The model suggests that each of the factors plays an equal role in the individual's weight status, with physical activity being central to balancing energy intake and expenditure (see Figure 2).

Figure 2: Model of Contributing Factors for Obesity in ASD



(From Srinivasan, Pescatello, & Bhat, 2014)

Overall, however, evidence suggests that individual with ASD are not likely to engage in high levels of physical activity (Pan & Frey, 2006), and rates are likely to decline as the child ages (MacDonald et al., 2011; Memari et al., 2012). Again, small sample sizes and the ASD population's heterogeneity limit much of the research on ASD. In two recent reviews of the effects and benefits of physical activity for individuals with ASD (Sorensen & Zarrett, 2014; Sowa & Meulenbroek, 2011), sample sizes ranged from 1 to 30, with 70% between 3 and 20. Sowa and Meulenbroek (2011) provide further positive evidence for the use of exercise-based interventions to assist with motor and social deficits in individuals with ASD; the small sample size, however, limits the findings' generalizability. Furthermore, due to the great variance among individuals with ASD, the suggested effects of exercise and physical activity on ASD are limited. Nevertheless, when looking at the research in this area, evidence for increasing the physical activity of individuals with ASD is overwhelmingly positive.

Bremer, Crozier, and Lloyd (2016), in a recent review of 13 studies, focused on the impact of exercise interventions on behavioral outcomes for children and youth (≤ 16 y/o) with ASD. Bremer et al. reported that a total of 11 behavioral outcomes were assessed across the 13 studies, and outcomes were divided into three broad categories: stereotypic behaviors (i.e., SCD and RRB), cognitional and attention (i.e., on-task behavior, academic responding, and work performance), and social-emotional behavior (i.e., adaptive skills, social skills, and problem behaviors). Overall, the interventions included suggest that exercise can be an effective method to address behavioral issues in children with ASD, but the variance between studies on frequency, intensity, type, and dosage made avenues for future research or practical implications difficult to identify. Furthermore, the variation in what constituted "exercise" provides little guidance.

This diversity was further demonstrated in the meta-analysis by Sowa and Meulenbroek (2011). Overall, in a limited number of studies (n = 16), Sowa and Meulenbroek suggest that exercise-based interventions have a positive effect on both, the motor and social skills of individuals with ASD. Even so, the variability between studies, again, makes practical suggestions difficult. Individual interventions, compared to group interventions, seemed to provide a greater benefit for individuals with ASD, but, similar to the conclusions of Bremer et al. (2016), the variability among participants in each of the studies Sowa and Meulenbroek reviewed provides little in terms of generalizability and must be interpreted on an individual level based on severity of ASD. Lang et al. (2010) provide further positive evidence for the inclusion of physical exercise as an intervention for individuals with ASD, but, once again, the studies reviewed are limited by small sample sizes and variation among participants. Nevertheless, evidence from the studies suggests that increased physical exercise may decrease undesirable behaviors in children with ASD.

Continuing in this trend, a review by Strahan and Elder (2013) of interventions for obesity in adolescents with ASD suggests that physical activity can be a powerful way to induce weight loss; however, limited motor ability and low muscle tone often reduces the amount of exercise an individual with ASD can perform. Todd and Reid (2006) demonstrated that in three young adults with autism, it was possible to increase the rates of physical activity (i.e., walking, jogging, and snowshowing) in individuals with ASD by using self-monitoring and using food as reward. However, due to limited motor skills, overall success may have been limited. Decreased success due to limited motor skills and motor coordination prevents individuals from participating in more advanced skill activity (Memari et al., 2012). Furthermore, walking and jogging may not provide the necessary energy expenditure to overcome the added caloric intake due to the edible rewards. Obviously, the motivation provided by the food offers short-term access to increased physical activity, but this increase may be slowed by limited motor ability. By providing individuals with ASD the FMS required for physical activity, perhaps food rewards will be used less due to increasingly successful performance.

Motor Intervention[5]

In response to the demonstrated deficits in motor ability in the ASD population across the lifespan—as well as the increased obesity rates and decreased physical activity—it is essential that motor interventions be developed to address these deficits. To inform motor interventions in ASD, it is important to understand what has been done in other populations. Recent systematic reviews and meta-analyses have been done on FMS interventions with children and youth (Logan, Webster, Getchell, Pfeiffer, & Robinson, 2015; Lubans et al., 2010; Morgan et al., 2013) and with individuals with developmental delays (Kirk & Rhodes, 2011) and severe/profound intellectual disabilities (Houwen, van der Putten, & Vlaskamp, 2014). Motor interventions have also been designed based on behavior analytics (Alstot, Kang, & Alstot, 2013), which is a common intervention strategy for addressing the needs of ASD. In the next sections, an overview of the recent analyses of motor interventions targeting FMS will be discussed, followed by motor interventions directed at individuals with ASD.

Interventions and FMS for General Populations

Major findings of reviews and meta-analyses of general motor interventions are summarized in Table 2. When looking at results in aggregate, evidence for the use of motor interventions to improve FMS is strong. Each of the studies analyzed, regardless of population, demonstrated positive support for the interventions' ability to improve FMS. Each of the meta-analyses (Alstot et al., 2013; Logan, Robinson, Wilson, & Lucas, 2011; Morgan et al., 2013) reported moderate to large effect sizes, demonstrating a relatively large difference between pre- and post-test measures of motor performance. Further,

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[5] At submission of this disseration, a manuscript titled, "The state of fundamental motor interventions for children with autism spectrum disorder.", was in preparation.

Logan and colleagues (2011) reported no relationship between effect size and duration of the intervention, which suggests that the intervention's length may have little effect on overall outcomes.

This is further demonstrated when considering children with developmental delays (Kirk & Rhodes, 2011), which are often due to limited opportunities or exposure, or an underlying issue with coordination. Kirk and Rhodes (2011) found that 81% of studies of children with developmental delays found significant improvements in motor skills through a motor intervention. Further, locomotor skills demonstrated the largest improvements. This is evidenced, as well, in the work of Goodway, Crowe, and Ward (2003) on FMS interventions that target disadvantaged youth. The study demonstrates that FMS do not "emerge," but must be taught. Through intervention, even children with delays or deficits can show great improvement. When taking this information into consideration for motor interventions for children with ASD, it is important to understand the derivation of their deficits or delays. Many children with ASD show a deficit in gross motor skills (Fournier et al., 2010), but deficits are not universally reported (Dewey et al., 2007). Demonstrated deficits could be caused by an underlying constraint of the disability or lack of exposure to skills and limited access to the information. Regardless of underlying condition, however, there is a need for an early, well-controlled, motor-skill intervention for young children with ASD (MacDonald et al., 2014).

Table 2: Major Findings on General Motor Interventions

Study	Major Findings
Alstot, Kang, & Alstot (2013)	Use of behavioral principles (Applied Behavior Analysis) has a large, positive effect on the acquisition of sport-specific motor skills. Analysis included participants from elementary to college age. No further information was included about participants.
Houwen, van der Putten, & Vlaskamp (2014)	Despite limitations from cognitive impairment, individuals with severe or profound intellectual disabilities can benefit from interventions designed to improve motor skills. Sample sizes were relatively small, and little information was given about the impact on cognitive or social outcomes.
Kirk & Rhodes (2011)	81% (9 of 11) studies identified significant improvements in motor skills following an intervention, with locomotor skills showing the largest improvement. Findings are congruent with previous studies of motor interventions in groups from low-SES backgrounds.
Logan, Robinson, Wilson, & Lucas (2011)	Motor-skill interventions are an effective strategy to improve FMS in children; overall, studies demonstrated a moderate effect size. A nonsignificant relationship was found between effect size of pre- to post-improvement of FMS and the duration of the intervention (in minutes).
Lubans, Morgan, Cliff, Barnett, & Okely (2011)	Found strong evidence for a positive association between FMS competency and physical activity in children and adolescents, as well as a positive relationship between FMS competency and cardiorespiratory fitness and an inverse association between FMS competency and weight status. Suggested further longitudinal research is needed to reach more concrete conclusions.
Morgan et al. (2013)	Of 22 eligible studies, 19 provided unique interventions for 1 or more FMS. Meta-analysis revealed statistically significant effects for overall gross, locomotor, and object-control skills proficiency. Most interventions were delivered primarily by the physical education teacher in a school setting.

Current Research on Motor Interventions for ASD

To understand the motor interventions available for ASD, recent studies that sought to improve the motor abilities of individuals with ASD were reviewed. Studies that focused on the effects of instructional methods (i.e., visuals[6]) on short-term improvements in outcome measures were excluded from this review. While these studies could arguably be considered interventions to improve motor performance, the goal of this review was to evaluate interventions aimed at improving motor abilities rather than oneoff performance measures. See Figure 3 for the flow of the literature review.

Overall, the seven included studies reported positive effects from their respective motor interventions (Table 4); however, each intervention differed in its method of delivery and assumption of gross motor ability (see Table 3). The limited motor-intervention research on children with ASD suggests that although deficits are present, it is nevertheless possible to alter the trajectory of a child's motor development. Of the studies identified, the majority (83%) used a very small sample sizes, ($n \leq 8$), as is common with much of the research in the field of ASD. One study (Wuang, Wang, Huang, & Su, 2010) used a relatively large sample (60), which is unusual for studies of children with ASD. As expected, most participants were male; of the studies that reported gender, 21% (17/80) of participants were female and 79% (63/80) were male. This is in line with the reported ratio of ASD prevalence in males to females of 4.3:1 (Fombonne, 2005).

[6] See Breslin & Rudisill, 2011, 2013; Liu & Breslin, 2013b

Figure 3: Flow of literature review for motor intervention in ASD

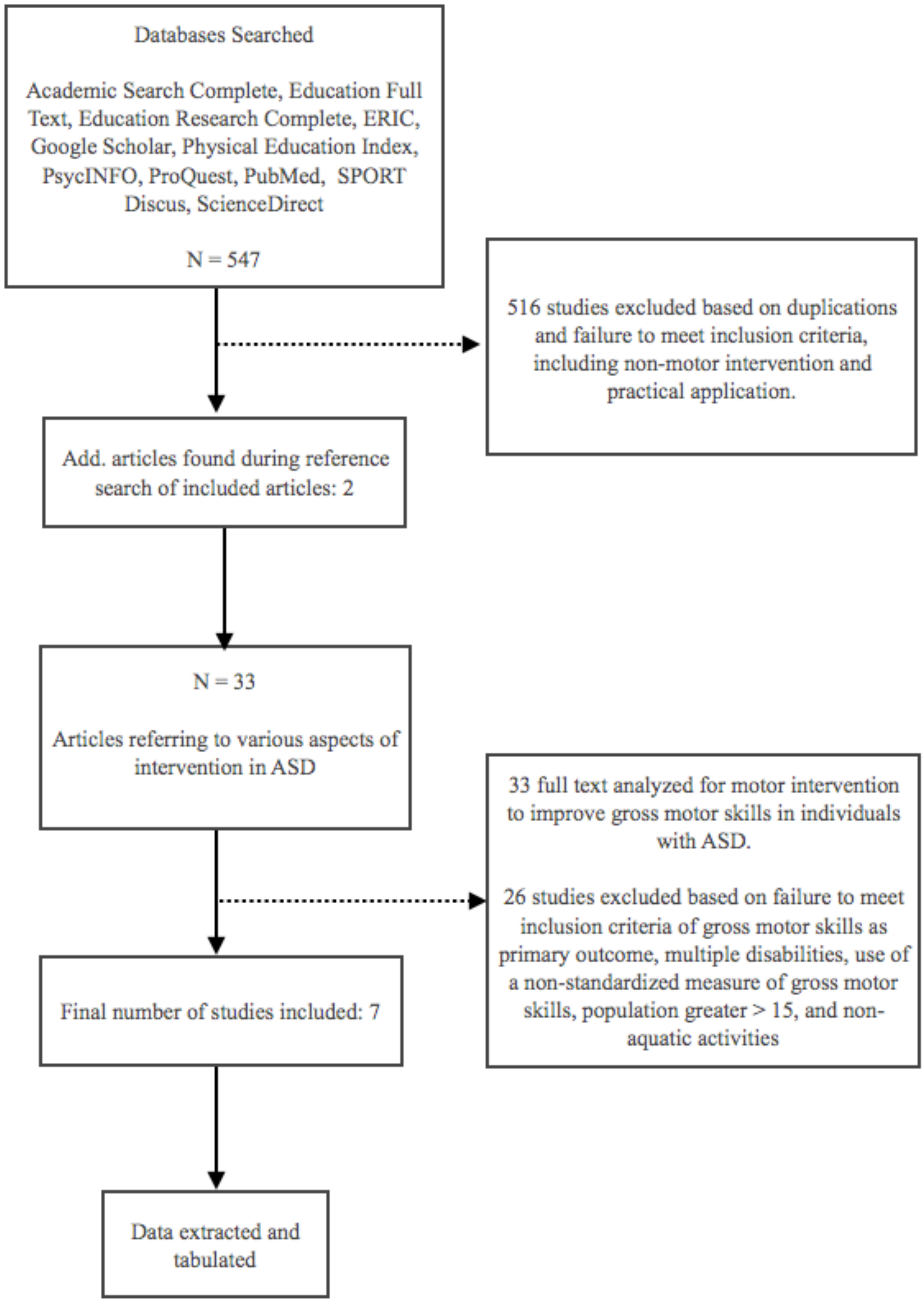

Table 3: Overall Study Characteristics for ASD Interventions

Study	Participants (*N*, age, gender)	Diagnosis	Research Design	Intervention (Intensity and Dosage)	Gross Motor Measure	Sampling Strategy	Theory
Bremer, Balogh, & Lloyd (2014)	8, 7 boys, 1 girl, 4 y/o	Autism Spectrum Disorder	Experimental, Wait-list Control	<u>Group 1</u>: 1/w for 60 min/ for 12 weeks <u>Group 2</u>: 2/w for 60 min/ for 6 weeks	PDMS-2* MABC-2**	Purposive	None specified
Bremer & Lloyd, 2016	5, 4 boys, 1 girl 3-7 y/o	4 ASD, 1 ASD-like behaviors	Multiple Methods	2/w for 45 min/ for 12 weeks.	TGMD^	Convenience	None specified
DeBolt, Clinton, & Ball (2010)	3 children, gender n/a 6 – 10 y/o	Autism	Case Study	1/w for 90 min/ for 10 mo.	TGMD^	Convenience	None specified
Duronjić & Válková (2010)	5, 4 boys, 1 girl, age 62-81 mo	Autism Spectrum Disorder	Case Study, Observation	2/w for 60 min/ for 8 weeks	MABC**	Purposive	None specified
Hawkins, Ryan, Cory, & Donaldson (2014)	1 boy, 1 girl, 11 y/o & 7 y/o, respectively	ASD (boy) & PDD-NOS (girl)	Multiple Baseline	3/w for 30 min/ for 5 weeks	BOT2^^	Purposive	None specified
Ketcheson, Hauck, & Ulrich (2016)	20, 15 boys, 5 girls, 4-6 y/o	Autism Spectrum Disorder	Experimental	5/w for 4 hr/ for 8 weeks	TGMD	Purposive	None specified
Wuang, Wang, Huang, & Su (2010)	60, 47 boys, 13 girls 6 – 8 y/o	Autism	Experimental, Wait-list Control	2/w for 1 hr/ for 40 total sessions	BOTMP^^	Purposive	None specified

Note: * = Peabody Developmental Motor Scales, 2nd edition; ** = Movement Assessment Battery for Children, 2nd edition; ^ = Test of Gross Motor Development, 1st or 2nd edition; ^^ = Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition.

Table 4: Major Findings of ASD Interventions

Study	**Major Findings**
Bremer, Balogh, & Lloyd (2014)	Intervention focused on developing FMS significantly improved motor skills, but did not show an effect on adaptive behavior or social skills. No significant differences between the two intensities of interventions.
Bremer & Lloyd (2016)	Results demonstrated a slight improvement on individual items of the TGMD-2, as well as overall improvement in locomotor skills for 4 of the participants and object-control skills for 3 of the participants. Qualitative responses from the APE teacher suggest an increase in confidence when instructing individuals with ASD in the physical education setting.
DeBolt, Clinton, & Ball (2010)	Improvements were greater than what would have occurred with age. A community-based APE program can be beneficial for building FMS in children with ASD.
Duronjić & Válková (2010)	Preschool children with autism can improve motor and social skills if involved in physical activity at least twice per week.
Hawkins, Ryan, Cory, & Donaldson (2014)	Equine-assisted therapy can provide moderate to large short-term gains in gross motor skills (specifically, body coordination, strength, and agility).
Ketcheson, Hauck, & Ulrich (2016)	Classroom Pivitol Response Teaching (CPRT) provides a suitable framework for providing instruction to children with ASD in order to build gross motor skills. Further, CPRT provides opportunity to increase social interaction.
Wuang, Wang, Huang, & Su (2010)	Significant improvement in gross motor function in 20-week simulated horseback-riding intervention, as well as sustained effect for potentially 20+ weeks post-intervention. Positive alternative for actual horseback riding.

As expected with small sample sizes, the research designs were predominantly case studies (33%) or single subject (16%). Bremer and colleagues (2014) employed a wait-list control design; however, with only 8 participants, the possibilities for inferential statistics was severely limited. Wuang et al. (2010) used a larger sample size and, like Bremer et al., a wait-list control. Due to the larger sample size, Wuang et al. could use inferential statistics to gain further insight into the intervention's effects. In Bremer and Lloyd's (2016) multiple-method study, the authors collected both quantitative and qualitative data; however, data types were separately analyzed, interpreted, and discussed. Also, due to a limited sample size, Bremer and Lloyd's quantitative data were limited to visual analysis. Qualitative data were used to discuss the intervention's potential external effects on the perceptions of teachers who instruct individuals with ASD. Qualitative data analysis suggests that instructors would be more confident in working with individuals with ASD by using a school-based intervention.

Several outcomes have emerged from reviewing the limited literature in this area to guide future research and motor intervention. First, motor intervention, seemingly in any form, can have a significant effect on the development of motor skills in children with ASD. Second, the intensity and duration of the intervention does not seem to influence the overall effectiveness of the intervention itself. Lastly, while all the studies included occurred in the last seven years, the limited number of interventions and the lack of a theoretical foundation is a concern. Therefore, suggestions are offered for designing future motor interventions for children with ASD.

Four of the studies (Bremer et al., 2014; Bremer & Lloyd, 2016; DeBolt, Clinton, & Ball, 2010; Ketcheson et al., 2016) focus on FMS in children with ASD, while the remaining studies focus on general gross motor skill development through physical-activity practice (Duronjić & Válková, 2010), equine therapy (Hawkins, Ryan, Cory, & Donaldson, 2014), or simulated equine therapy (Wuang et al., 2010). In the latter studies (Hawkins et al., 2014; Wuang et al., 2010), the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP; Bruinicks, 1978) was utilized as the gross motor assessment. The BOTMP assesses the assumed underlying processes that enable FMS (Staples et al., 2012). The BOTMP has been demonstrated to be valid and reliable (Bruininks, 1978), yet its construct validity has been questioned; Wiart & Darrah (2001) suggest that the assessment measures to do not map onto the defined constructs (e.g., gross and fine motor skills) very effectively. Ultimately, the focus of these studies, while demonstrating good evidence for the use of equine therapy, have little benefit in terms of gross motor skills. Since the motor deficits often described in children with ASD frequently refer to FMS, an intervention that provides only minimal benefit in that area will not be overly useful for this population in this regard.

While Hawkins et al. (2014) provide little evidence for future interventions, theirs is one of two studies—Ketcheson, et al. is the other—to confirm the diagnoses of the children with ASD who were included in the study. As there is such variety among diagnoses and the children comprise a constellation of behavioral possibilities (Bernier & Gerdts, 2010, p. 179), it is vital that studies include a diagnosis or severity measure. Including this information not only provides assurance that the children studied most likely have ASD, but also offers a basis for comparison to other participants in the study and to other studies of children with ASD. By knowing the characteristics of the sample, readers and future researchers can relate that information to children they are working with. For example, if an intervention is found to work with children who display mild ASD behaviors, it is likely that that intervention will be beneficial to children displaying similar characteristics. It is unlikely, however, that the same intervention will be beneficial for children who display severe characteristics of ASD without additional modifications or adjustments to the protocol.

The study by Duronjić and Válková (2010) provides slightly better insight into what is needed for future interventions; however, it ultimately falls short in providing the necessary detail for replication. In this study, researchers used 18 exercise “lectures” spread over an 8-week period, but included scant information about what each lecture consisted of. As a result, little insight about future interventions can be gained, beyond the benefits of providing opportunities to engage in physical activity. It is likely that simple exposure will be beneficial for many children with ASD; however, children with ASD often lack motivation for many physical activities. Without understanding how to engage students or modify content, there is little chance of replicating these results.

Further, Duronjić and Válková used the Movement Assessment Battery for Children (MABC; Henderson et al., 2007) to measure gross motor changes. While the raw scores of the MABC are often employed in research on children with ASD to compare sample groups, Duronjić and Válková use the normative data from the MABC to analyze the change over the course of the intervention. Further, the authors use a combination of case study and observation to analyze changes in motor skills from the intervention. This holistic approach can provide detailed information and insight when used with small samples (Creswell, 2007); however, Duronjić and Válková provide little depth regarding either quantitative or qualitative findings. Without more extensive analysis, little transference can occur and the findings' implications are limited.

The study by DeBolt et al. (2010), which also contains limited information, focuses on an APE intervention for FMS in children with ASD. While this study takes a step in the right direction by focusing on FMS directly and using a common measure for FMS (TGMD-2; Ulrich, 2000), it again falls short in providing the quality necessary to build future motor interventions. Like Duronjić and Válková (2010), DeBolt et al. offer little detail about the intervention itself, stating only that it was a community-based APE program that matched a participant with a disability to a "nondisabled university student". Also, the authors used a case study design, and collected little data beyond pre- and post-assessment reports. As with Duronjić and Válková and Hawkins et al. (2014), DeBolt et al. used normative data to demonstrate change. Based on the reported raw scores, participants showed very little improvement over the course of 10 months. For example, one participant moved from the "poor" to "below average" percentile rank in normative data, but only raised his/her raw score from 16 to 18. For the TGMD, that is the equivalent of gaining one component of one skill. For a 10-month intervention, this does not seem significant; the authors, however, considered it "outstanding improvements" (p. 26). Strengthening the skills of a child with a disability often takes much longer than doing the same with a child without a disability, and improvement in a few components can significantly improve motor development overall. Nevertheless, building one component of one skill in 10 months of instruction does not appear to be overly effective.

Bremer et al.'s (2014) pilot study, in addition to providing strong support for FMS motor interventions for children with ASD, offers solid insight into what is needed for future motor interventions. The authors studied participants in a one-on-one or one-on-two intervention focused on core FMS, such as running, hopping, throwing, catching, etc., to test the effectiveness of an FMS intervention and compare two intervention intensities (1/w for 12 weeks vs. 2/w for 6 weeks; each session 60 min). Further, each session focused on one core skill while reviewing previous skills. Directions were given in short, direct sentences, with multiple demonstrations. Bremer et al. found a significant effect for the motor intervention, but little effect for treatment intensity; suggesting that an intervention of any length can be beneficial. The study also provides a solid foundation for future interventions and offers important suggestions for further research. As with all but one of the studies, a small sample size limits generalizability and statistical interpretations; however, Bremer et al. acknowledge this limitation and suggest that future studies increase the sample size and length of intervention (> 18 weeks) to gain better insight into the intervention's effects, not only on FMS, but also on social skills and adaptive behavior. Finally, a control group receiving neither intervention would have provided better insight into the effect of treatment intensity, but the constraints of a pilot study and small numbers limited design possibilities.

In a recent pilot study, Bremer and Lloyd (2016) looked at the effects of a school-based FMS intervention for children with ASD. Over the course of 12 weeks, participants were given 13.5 hours of instruction on 12 FMS (e.g., jumping, galloping, throwing, kicking, etc.) and balance. The intervention was performed 3 times each week for 45 minutes, which allowed approximately one week of instruction for each of the 12 skills.

Instruction was given to the whole group, but each child received one-on-one instruction from one of the authors, a special physical educator, or a graduate student. Like the study by Bremer et al. discussed study previously, Bremer and Lloyd's intervention provided a warm-up, review of previous skill, introduction of new skill, skill practice, skill activity, obstacle course, clean up, and bike activity. The obstacle course focused on components of the practiced skill for that session, while the bike activity was used as a motivational tool. Due to the limited sample size, no inferential statistics were obtained. Visual analysis demonstrated improvement in many areas across the individual skill items, but it is unknown whether skill development was due to the motor intervention, the opportunity to practice test items, or simple maturation, as there was no control group. Further, while there is merit to providing instruction within the constraints of the classroom setting, devoting one week to each skill may not provide enough instruction to sustain growth in motor abilities. It is likely that the training sessions offered guidance to participants and familiarized them with the skill they were being asked to perform. As there was no follow-up, however, it is impossible to determine whether the effects of the intervention were sustained or merely temporary.

Ketcheson et al. (2016), in their use of Classroom Pivotal Response Teaching (CPRT), provide a unique framework for motor interventions that was not present in the aforementioned studies. CPRT, unlike direct instruction, is considered an evidenced-based practice (EBP) for children with ASD (Wong et al., 2013). Furthermore, Ketcheson et al. provided instruction at a higher frequency and dosage than each of the previously discussed studies (i.e. 4 hours per day, 5 days per week, for 8 weeks). During data collection, participants were provided instruction 1-on-1 following the 8 key components of the CPRT program; components are listed as antecedent (student attention, clear and appropriate language, easy and difficult task, shared control, and multiple cues) and consequence strategies (direct reinforcement, contingent consequence, and reinforcement of attempts; Ketcheson, et al., 2016). As with previous interventions, Ketcheson et al. found significant increases between pre- and post- measures; demonstrating further evidence to the benefit of motor programs are for children with ASD. The dosage and intensity, however, of this intervention may make transference to other situations potentially problematic.

While Bremer et al. (2014), Bremer and Lloyd (2016), Ketcheson et al. (2016), and—despite limitations and lower quality—the other studies reviewed support the effectiveness of motor interventions to build motor skills in children with ASD, only limited information is available about what should be done or how interventions should be delivered. Bremer et al. provide some insight into instructions and content, but information is limited. Studies by Bremer et al. and Bremer and Lloyd do provide evidence that “single-step instructions, progressive skill acquisition, and visual prompts” (Bremer et al., 2014, p. 68) can be effective in relaying information to children with ASD to assist with motor skills. Ketcheson et al. suggest that “direct and intensive instruction on targeted motor skills delivered within an evidence-based framework” may result in positive outcomes (p. 11). Research into the effect of visuals (Breslin & Rudisill, 2011, 2013; Liu & Breslin, 2013b) on performance of motor tasks has demonstrated the potential importance of ensuring that the most effective instructional methods are used with children with ASD. Although research on evidence-based practices in other domains has demonstrated the positive effects of visual communication with children with ASD

(Wong et al., 2013), Bremer and Lloyd and Ketcheson et al. were the only studies that mentioned the use of visuals during the intervention and describes the method. This is a huge limiting factor for future interventions. If the method for delivering the intervention is not effective, the impact of the intervention itself will be limited. This trend is also demonstrated overall in FMS interventions for general populations (Logan et al., 2011, 2015; Morgan et al., 2013). Even when demonstrating overall positive potential, without including how the intervention was done, it is unlikely that the study outcomes could be replicated.

Children with ASD have been shown to develop motor skills differently than peers (Liu et al., 2014), which many consider a deficit (Bhat et al., 2011; Lloyd et al., 2013; Ozonoff et al., 2008) and a defining feature of ASD (Liu, 2012; Teitelbaum et al., 1998). While the cause of these delays is still up for debate (Staples et al., 2012), it is clear that the motor skills of these children lag behind their peers (Fournier et al., 2010). Motor interventions may provide opportunities to build skills and change the trajectories of development to match the rate of their peers. While most motor interventions in general have provided a positive outlook on the overall effects on the development of skills (see Tables 2 and 4), little information is provided regarding practical strategies for future development and practical application of interventions (Morgan et al., 2013).

In this review, several studies that focused on the development of motor skills in children with ASD were described in detail; however, only three (Bremer et al., 2014; Bremer & Lloyd, 2016; Ketcheson et al., 2016) provide strong evidence for future inquiry. This area is in critical need of quality, theory-driven research that will provide evidence-based practices aimed at building the FMS of children with ASD.

Dynamic Systems Theory and Motor Intervention[7]

In response to the limited theory-driven motor intervention research in ASD, the following section provides a background on the theory that provided the basis for this dissertation study. Dynamic systems theory (DST; Newell, 1986) suggests that a behavior (i.e., movement) is due to the influence of individual, environmental, and task constraints[8]. It must, again, be emphasized that the term "constraint," when used within this theory, is not a negative term, but simply a neutral term to describe something that either prevents or encourages certain patterns of movement. Therefore, constraints, whether individual, environmental, or task-related, self-organize within the body to allow certain patterns of behavior to emerge (Figure 1). According to the theory, if one constraint is altered or changed, the others will reorganize to produce a new pattern of movement. Theoretically, if one manipulates a certain constraint purposefully, one could influence an individual's pattern of movement (Newell & Jordan, 2007).

Moreover, DST provides a different lens with which to view a disability. Instead of considering a disability to be a barrier or deficit that must be overcome, DST treats disability as an individual constraint. In other words, the disability itself, while hindering certain aspects of movement, may also influence certain patterns of movement—and to accommodate a specific individual constraint, environmental or task constraints can be adjusted to influence a new pattern of movement.

In this section, first the background of motor development will be briefly discussed to situate DST within the broader spectrum of motor development. Next, DST

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[7] This section was published in the International Journal on Disability and Human Development; DOI: 10.1515/ijdhd-2016-0015

[8] Definitions of task, individual, and environmental constraints can be found under "Definition of Terms and Abbreviations" in Chapter 1.

will be contrasted to other popular theories of motor development. Finally, current research will be discussed demonstrating how DST has been addressed in the literature over the past 40 years and its implications for the development of motor interventions.

Brief Background of Motor Development

The coordination of the human body to produce movement is a complex, systematic process (Kamm et al., 1990) that goes largely unnoticed by the individual performing the movement. The phenomenon refers to the underlying processes of an individual's motor ability; often the emergence, change, and growth of those abilities are considered to be motor development (Gabbard, 2008). The dynamics of motor development in individuals are not understood in depth, relatively speaking, in the context of research on human behavior. However, its roots are deep within larger fields of developmental research, some of which go as far back as the late 1700s (Payne & Isaacs, 2005), including work by Darwin (1877) and Shinn (1900). Early work in motor development was conducted, primarily, by child psychologists in an attempt to comprehend the "nature versus nurture" phenomenon (Roberton, 1989). By the mid-20th century, motor development researchers seemed to have learned everything there was to know about motor behavior, and by the 1960s researchers had moved away from the biology of how motor movement occurred toward more psychological aspects of cognition, language, and social development (Thelen, 1995). Nearly 30 years later, researchers reinvigorated motor development research, questioning the traditional views of how motor skills are be attained and developed throughout the lifespan (Gabbard & Krebs, 2012).

Clark and Whitall (1989) suggest four divisions in the foci and theories that underlie theories about motor development: the Precursor Period (1789-1928), the Maturation Period (1928-1946), the Normative/Descriptive Period (1946-1970), and the Process-Oriented Period (1970-present). In the most recent period, the Process-Oriented Period, focus has shifted from a predominant interest in *what* an individual can do to *how* an individual can do it. Early thinking in this period concentrated on information-processing theory, which, stemming from maturational theory, suggests that the human brain functions similarly to a computer, in that movement processes are called up by the brain for the body to perform (Stelmach, 1978). Once an individual learns the process of a movement, that information is stored for recall when needed. Realistically, this discrete, linear development of the brain does not fully cover the complexity that is human movement (Kamm et al., 1990; Thelen & Ulrich, 1991). Thelen and Ulrich (1991) question the neuro-maturational explanations of causation and argue that the central problem with this perspective is that it limits the scope of how movement is derived through behaviors that arise from the interaction of many underlying subsystems and processes.

While each discipline of thought has contributed multiple theories that offer unique and crucial insight, they often focus on a single aspect of development and occasionally parallel one another (Lewis, 2000). This emergence of frequently incompatible theories is as daunting to many developmental specialists as it is to the practitioners attempting to use them, largely, due to the few shared similarities (Lewis, 2000). An alternative theoretical explanation offers a multifaceted approach to motor development and is described by a variety of terms, including *coordinative structure* *theory*, *dynamical perspective*, *dynamical systems*, *dynamical pattern theory, ecological approach*, and *constraint-based/led approach* (Clark & Phillips, 1993), but is most commonly known as dynamic systems theory.

Maturation and Information-Processing Theories

Early maturational beliefs about development (Gesell, 1929; McGraw, 1943) played a vital role in developmental research and gave way to the formation of standard stages for development that are often still in use today. These explanations were founded on the belief that motor skills emerge from the developing nervous system, and that changes were built into natural growing patterns (Hadders-Algra, 2010). Maturational researchers provided a guide for developing many standard assessments of the development of motor behaviors (Payne & Isaacs, 2005). However, the idea that movement simply occurs once the individual has matured does not fully explain the variations in movement between individuals or even within an individual. Further, it does not explain why some movement stages are not demonstrated in some individuals' development (e.g., an infant who skips the creeping stage and moves directly from crawling to cruising or to walking). This limited explanation of the "how" has led researchers to begin considering that certain aspects of development differ for each individual and that movement does not simply appear—i.e., that it is at some point learned (Goodway, Crowe, & Ward, 2003).

During the 1970s, Stelmach (1978) proposed the information-processing theory of motor development. This theory compared movement's occurrence to that of a computer running a program. The computer inherently does not know the program, but once "learned" can recall that program when needed (Stelmach, 1982). Therefore, when an individual encounters a situation, the brain processes the situation, recognizes what is needed, and recalls a response to the situation (Stelmach, 1982). However, what this theory fails to fully explain is how the body reacts to new situations or a rapid change in events. Schema theory (Schmidt, 1975) attempts to fill in some of the voids in information-processing theory by proposing that much like the motor programs created and stored for information processing, the brain creates a program (i.e., schema) for each new situation the individual encounters for a particular skill. By providing opportunities to practice in different situations, the brain learns each of the new schemas and therefore will be far more likely to be able to recall a given schema quickly when needed. While widely accepted in the motor-learning domain and the underlying force behind variable practice, schema theory does not fully explain the spontaneous shift in motor patterns or the sudden emergence of a motor behavior.

DST changes the concept of movement from that of a program to be run or performed to that of an emergent behavior based on coordination of various degrees of freedom. By accounting for influences from the constraints operating within the individual, the environment, and the task itself, the body can coordinate movement. If the brain were left to control each of the degrees of freedom, humans would be limited to a single movement or task at a time. For example, consider shifting from walking on a concrete surface to walking on an icy surface. If the brain were the sole provider of information for movement, by the time the brain recognized what was occurring, the individual would have already fallen to the ground. In contrast, DST posits that most action occurs within the central nervous system, and, based on the influences from constraints, explores all possible possibilities and settles on the most effective (i.e., the attractor state; Hadders-Algra, 2010). Thus, when the individual steps onto an icy patch, this new constraint alters the other constraints, and the individual shifts accordingly to remain at equilibrium (e.g., standing upright and moving forward).

The variability faced by the system (i.e., the individual) provides further opportunities to improve methods of movement (Hadders-Algra, 2010; Ulrich, 2010). Further, each biological system tends to maintain a complex equilibrium (Moreno & Ordoño, 2015); therefore, when a single constraint is different, the body spontaneously self-organizes to maintain homeostasis (Clark & Phillips, 1993; Kamm et al., 1990; Thelen, 1995). Additionally, no one subsystem of constraints is dominant or contains all the elements for the skill (Kamm et al., 1990). Therefore, by changing one or more of the parameters of movement for an individual, DST predicts that subsequent adaptation of the remaining constraints will be adjusted and result in a change in behavior (Clark & Phillips, 1993; Šerbetar, 2014). This provides a potentially more in-depth mode of modifying movement than previous theories. Researchers and practitioners can evaluate the whole situation to better understand what is acting as a limiter within the movement and analyze what needs to be addressed through intervention.

Dynamic System Theory's Influence

To best understand how DST has been used to understand the complexities of human movement, I reviewed the literature to identify how, specifically, Newell's model had been incorporated into research. I recognize the limitations of incorporating only one theory and excluding similar theories, such as Gibson's ecological theory (1979) or Schmit's schema theory (1975). Gibson's ecological model is commonly used in motor-learning research, and provides strong evidence for analyzing the environment and perception of an individual's motor skills. Schmit's schema theory is also widely used, and is accepted as a model of skill development. However, these theories are primarily interested in discrete task learning and not on development over the lifespan. DST describes how the influence of constraints allows for a motor behavior to emerge on a discrete skill basis, but it also describes development as a nonlinear process that occurs longitudinally. Therefore, I focused on DST exclusively.

I also recognize that this list may not encompass all the research that uses constraints to develop motor skills; much of the research in this area is likely to include some form of task, environment, or individual manipulation or modification. However, such studies may not fully elucidate where the cause of those modifications or base them in DST. I excluded Wicke and Jensen's (2002) study, for example, because it did not use Newell's DST. Instead, the authors describe dynamic systems from the viewpoints of researchers who adopt a dynamic-systems approach, but because these are secondhand accounts of dynamic systems, it is difficult to ascertain the authors' understanding of and adherence to Newell's model of DST. The idea of dynamic systems stems from the early work of Bernstein (1967), who described the nonlinear dynamics of movement. Kugler, Kelso, and Turvey (1980) furthered this work to formulate the modern trajectory of understanding movement coordination. From this initial study, different lines of research have adopted a variety of viewpoints on this relationship, with Newell's model as one of them. In DST, according to Newell (1986), there is an equal and interdependent relationship between each of the constraints that spontaneously organizes in the form of a behavior; not all theorists who study in the dynamics of coordination agree with this assertion. In conducting this review, the author was interested in how researchers have used Newell's theory to inform the overall approach to this study.

In the following paragraphs, the main findings from 18 studies will be discussed, followed by specific examples and themes found in the literature, to understand how DST has been used to inform understanding of movement and how constraints have been manipulated to influence movement. To access the literature regarding DST, I (1) conducted a database search based on key words, and (2) analyzed all the articles that cited Newell's DST in connection to human motor movement. For the flow of the analysis, see Figure 4; see Tables 5 and 6 for an overview of the findings and major findings, respectively.

Beyond the variation in sample size and purpose, the included studies suggest that the foundations of DST are present in the production of movement and give evidence for its use in improving motor skills and development (see Table 6). Studying a sample of 12 infants with Down Syndrome (aged 9.5 to 18.5 months), Ulrich and colleagues (1998) manipulated the surfaces of a treadmill and could manipulate the infant's walking patterns. By using different surfaces, such as a carpeted treadmill with the infants in socks that had Velcro on the bottom or a knobby surface and bare feet, researchers found that they could influence the child's walking pattern. For example, in the Velcro situation, infants increased their alternating steps and demonstrated a fuller step. Conversely, on the knobby surface, the steps taken were much shorter and closer together. By modifying the surface, the authors could have a direct influence on the pattern of individuals, suggesting that task manipulation can be used to improve motor patterns. This evidence is further strengthened by Vernadikis et al.'s (2015) intervention study, which used task

Figure 4: Flow of literature review for DST studies

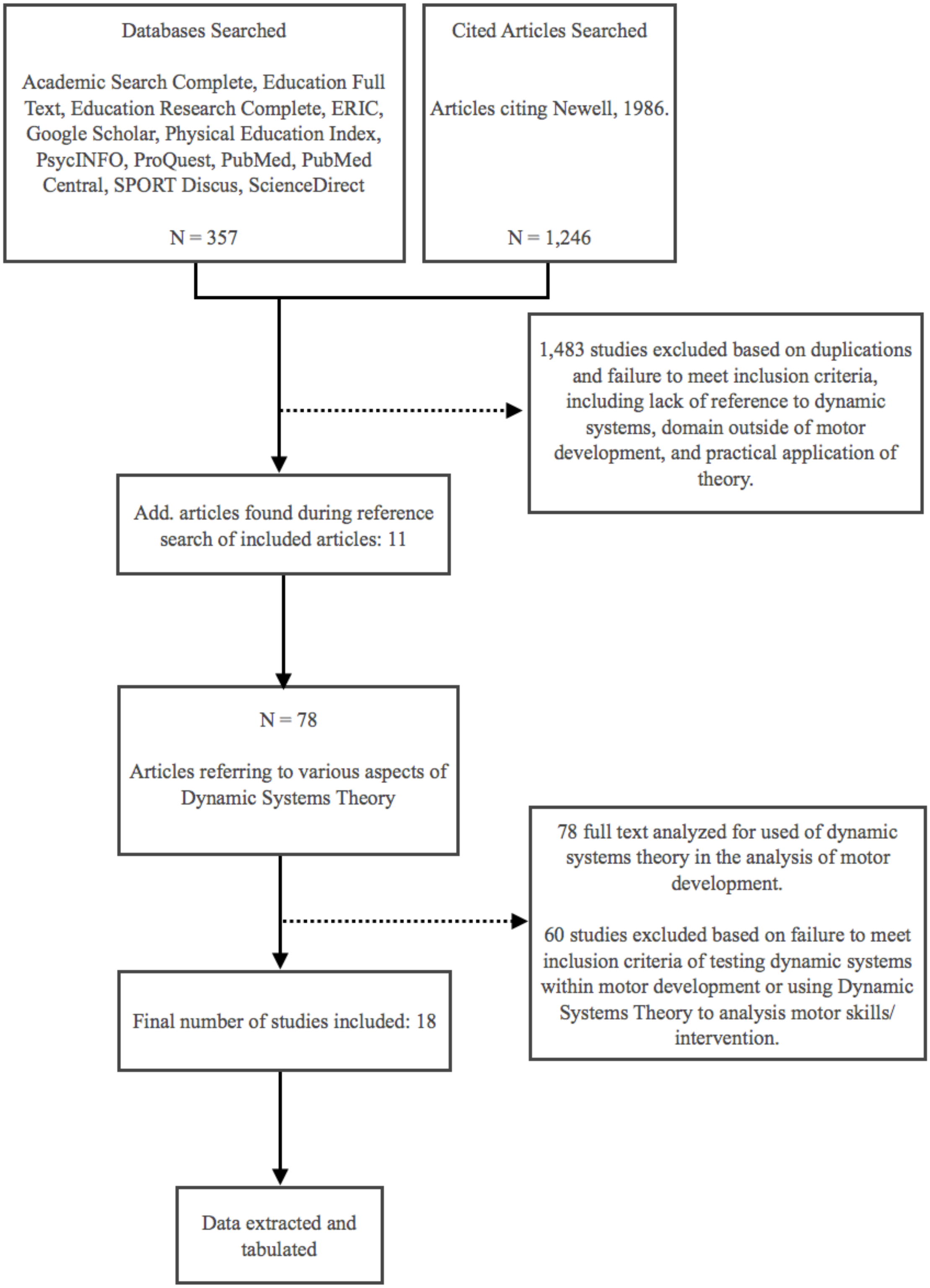


Table 5: Overall Study Characteristics for DST Interventions

Study	Participants	Characteristics	Measure	Dependent Variable	Aspect of DST Analyzed	Design
Abney, Warlaumont, Haussman, Ross, & Wallot (2014)	1 infant, 51 – 305 days old	N/A	Accelerometer, Voice Recordings, Parent Diary and Questionnaire	Changes in limb and vocal activity patterns over time	Individual Constraints	Case Study
Astill (2007)	20 children, 6 girls, 14 boys *M* age = 8.6 *SD* = 1.0	10 with developmental coordination disorder (DCD), 10 without	Catching performance	Number of catches, inter/intralimb correlation	Task Constraints	Experimental
Bennett, Button, Kingsbury, & Davids (1999)	24 children, 12 boys, 12 girls *M* age = 9.65 yrs *SD* = 0.23	Normally sighted, otherwise typically developing, poor catching performance	Catching performance transfer after practice w/ or w/o restricted vision	Catching score (0-5), number of catches, number of misses	Task Constraints	Experimental
Clemente, Couceiro, Martins, Dias, & Mendes (2012)	11 male soccer players. *M* age = 17.91 *SD* = 1.04	Experience in years: *M* = 8.60 *SD* = 1.52	Time within a 1 m^2 within a 20 x 20 matrix	Player trajectories, distance traveled, time of attack	Task Constraints	Experimental

Study	**Participants**	**Characteristics**	**Measure**	**Dependent Variable**	**Aspect of DST Analyzed**	**Design**
Farrow & Reid (2010)	23 primary school children. *M* age = 8.0 *SD* = 0.4	Limited or no tennis playing experience	Likert scale (1-7) on quality of components of rally performance	Rallying performance, hitting opportunity, success, & engagement	Task Constraints	Experimental
Langendorfer (1990)	Two separate groups: 34 young adults (17 m & 17 f), ages 19-25 & 43 children (23 m & 20 f), ages 9-10	"Nonhandicapped"	Throwing performance	Throwing accuracy only, accuracy & force, and force only	Task Constraints	Experimental
Langendorfer & Robertson (2002)	39 children (22 boys and 17 girls) filmed at 5.7 yr, 6 yr, 7 yr, 8 yr, and 13 yr	N/A	Velocimeter (ball velocity), Developmental components	Pattern of trunk, humerous, & forearm development over time	Individual Constraints	Longitudinal

Study	Participants	Characteristics	Measure	Dependent Variable	Aspect of DST Analyzed	Design
Liu, Meyer-Kress, & Newell (2006)	#1: 8 young adults (no age or gender) #2: 11 young adults	N/A Healthy	Rotational speed of a roller ball (hand accelerometer data)	Rate per second	Environmental constraint	Exploratory
Maida & Mccune (1996)	6 babies (4 boys and 2 girls split evenly between 2 groups)	3 sighted, no other handicap, 3 congenitally blind (either totally or had minimal light perception	Movement frequency counts at 5 sec	Motor skills prerequisite to crawling	Individual constraints	Exploratory
Ohgi, Loo, Morita, & Mizuike (2007)	6 (3 m and 3 f), 1-month old babies	Japanese, healthy	Accelerometer	Limb acceleration (activity)	Spontaneous Movements	Descriptive
Renshaw, Oldham, Davids, & Golds, (2007)	4 right handed batsmen (*M* age = 21, *SD* = 1)	High intermediate skill level	Time, measurements based on changes in location determined by body markers	Timing of swing relative to two conditions	Task Constraints	Experimental

Study	Participants	Characteristics	Measure	Dependent Variable	Aspect of DST Analyzed	Design
Stergiou, Jensen, Bates, Scholten, & Tzetis (2001)	10 (7 m & 3 f) runners (*M* age = 25.9, *SD* = N/A)	Healthy, running minimum 10 mi/week	Force plate, body markers placed on lower extremity	Change in jumping form based on height of obstacle	Task Constraints	Experimental
Sweeting & Rink (1999)	116 kindergarten and 2nd-grade students	N/A	Distance	Standing Long Jump Product Score	Environmental Constraints	Experimental
Ulrich, Ulrich, & Angulo-Kinzler (1998)	12 infants (*M* age = 13.2 mo., *SD* = 2.3)	Down Syndrome, sitting independently	Coded steps (alternating, single, parallel, and double)	Steps taken and quality of steps based on context	Task Constraints	Experimental
Ulrich, Ulrich, Collier, & Cole (1995)	9 infants (6 f & 3 m), age 8 to 11 mo.	Down Syndrome	Coded Steps (Similar to above)	Number of alternating steps	Individual Constraints	Longitudinal

Study	Participants	Characteristics	Measure	Dependent Variable	Aspect of DST Analyzed	Design
Vernadakis, Papastergiou, Zetou, & Antoniou (2015)	66 elementary students, age 6 to 7 (36 m and 30 f)	1^{st} and 2^{nd} grade in Greece, no disabilities	TGMD-2 PACES	Increase of FMS	Task Constraints	Experimental
Volman, Wijnroks, & Vermeer (2002)	12 children between ages 8 and 14.	Congenital spastic hemiparesis (Mild or Moderate)	Movement time, PV, time to PV, percent reach to PV, Movement units	Goal-directed reaching movements	Task Constraints	Experimental
Wu, Lin, Lin, Chang, & Chen (2005)	15 adults (7 men, 8 women) *M* age = 23.6 *SD* = 3.9	Healthy, right-handed	Movement time, PV, percent reach PV	Reaching movements	Task Constraints	Experimental

Note: TGMD-2 = Test of Gross Motor Development, 2^{nd} edition; PACES = Physical Activity Enjoyment Scale; PV = Peak velocity.

Table 6: Major Findings of DST Intervention

Study	Major Findings
Abney, Warlaumont, Haussman, Ross, & Wallot (2014)	Changes in vocalization were preceded by a period of higher variability. Limb activity increases; leg activity becomes more stable and repetitive with age, while arm patterns demonstrated an inverse relationship.
Astill (2007)	Changed in the task (i.e., ball thrown at midline, right, or left) changed the outcome for children with DCD. Children were much more likely to be successful—not only in catching the ball, but coordinating his/her limbs to catch—when the ball was thrown toward the midline or right side.
Bennett, Button, Kingsbury, & Davids (1999)	Participants demonstrated an increase in number of catches and decrease in number of misses, regardless of group. Practice performance varied the greatest under the various visual manipulations.
Clemente, Couceiro, Martins, Dias, & Mendes (2012)	The type of tasks (i.e., risk, neutral, or conservative) influenced the movement and time taken for the attacker. Attackers in a risk situation (e.g., team losing with time running out) drove the ball toward the goal and took a shot much quicker than attackers in other situations.
Farrow & Reid (2010)	A scaled court enhanced performance, regardless of scaled ball size. Participants using the standardized adult conditions demonstrated decreased hitting opportunities, as well as lower success and engagement.
Langendorfer (1990)	Some throwers demonstrated different patterns to achieve different throwing goals. Males' patterns showed greater change under different conditions. Age played very little role in the change of patterns.

Study	Major Findings
Langendorfer & Robertson (2002)	Participants demonstrated commonalities in both order of developmental levels and common pathways of development; however, there were individual differences, which were attributed to the interaction of constraints relevant to specific patterns.
Liu, Meyer-Kress, & Newell (2006)	Three levels of learners emerged; the most successful level of learning resulted in an S-shaped behavioral outcome, showing a sudden jump in performance. Another group demonstrated a much more level learning pattern, and one group showed no performance increase. Different patterns of change depended on the task dynamics and the learner.
Maida & McCune (1996)	Individual differences were found in development patterns in many of the categories, but an underlying sequence of varying lengths was identified prior to advancement.
Ohgi, Loo, Morita, & Mizuike (2007)	Motor development in infants occurs through processes of self-orientation, suggesting a nonlinear system in contrast to the traditional view of infant behavior as simple reflexes; infants' spontaneous movements are influenced by constraints capable of triggering voluntary skilled movement.
Renshaw, Oldham, Davids, & Golds, (2007)	Swing patterns changed significantly between different environmental constraints.
Stergiou, Jensen, Bates, Scholten, & Tzetis (2001)	The height of an obstacle caused a change in patterns of behavior; however, the variability of the system remained constant. This means that although the pattern changed, the internal factors adjusted to maintain as little deviation as possible from a typical pattern.
Sweeting & Rink (1999)	Environmental instructions did improve performance, suggesting that the use of environmental tasks to elicit performance is a viable instructional approach, but should not be used exclusively or indiscriminately.

Study	Major Findings
Ulrich, Ulrich, & Angulo-Kinzler (1998)	Step patterns varied depending on the task constraint. Informs how future interventions could influence stepping behavior through manipulating the task.
Ulrich, Ulrich, Collier, & Cole (1995)	Infants with DS were able to perform alternated walking steps when supported, long before walking voluntarily. Lower body fat, scaled-up strength, and ability to move forward act as control parameters for alternating walking.
Vernadakis, Papastergiou, Zetou, & Antoniou (2015)	Task modification is a useful tool for building object-control skills. Exergaming provides a more enjoyable method of improving skills, with similar gains to a typical face-to-face administration.
Volman, Wijnroks, & Vermeer (2002)	Applying a functional task context elicited positive changes in controlling reaching movements of the affected arm of children with spastic hemiparesis. Treatment of children with spastic hemiparesis should focus on practicing functionally relevant skills (actions) instead of nonfunctional movements.
Wu, Lin, Lin, Chang, & Chen (2005)	Task conditions (e.g., size and location) have an effect on movement time, peak velocity, and percentage of time to peak velocity. An individual’s accuracy may also be affected by the individual’s constraints—i.e., not only by the object’s size or location.

manipulation to improve motor skills. While the authors' goal was to understand the effects of exergaming versus a standard face-to-face intervention, they also offer strong evidence for the use of task manipulation to influence and improve children's motor skills. Although evidence is limited in the overall literature, the two studies positive support for the use of task manipulation in motor intervention. Other studies I reviewed further support the notion that task manipulations are the most common constraint employed to enact change (Newell & Jordan, 2007), as over 50% of them assessed or used task constraints. Most commonly, studies manipulated equipment to modify a task (Farrow & Reid, 2010; Langendorfer, 1990; Stergiou, Jensen, Bates, Scholten, & Tzetzis, 2001; Ulrich et al., 1998); however, changes in the task instruction could also be useful (Clemente, Couceiro, Martins, Dias, & Mendes, 2012).

Individual constraints (4 of 18 studies) were included to understand how movement is produced and, often, the development of early motor patterns in infants. As this is a difficult area to manipulate for an individual, it is not surprising to see that this type of manipulation is rarely used. Ulrich and colleague (1995) manipulated the individual constraints of infants with Down Syndrome by holding infants up while they "walked" on a treadmill, which caused them to adopt an effective, alternating walking pattern long before they performed independent walking. This demonstrates that a combination of individual constraints, such as strength, can act as a rate limiter (Thelen, 1995) that prevents independent walking from occurring. Infants in this study were not able to produce a walking pattern until their leg strength, and likely balance as well, was scaled up to allow for independent walking. However, when the individual constraint of balance was manipulated, the new walking pattern emerged. Manipulation of individual constraints can be straightforward in infants, but scaling this for an older population is slightly more difficult. A task analysis may provide insight into this issue[9], because it breaks down the skills being studied from simple to complex and includes everything needed to perform the skill. This could reveal, for instance, that an individual is limited by strength when performing a basketball shot. A researcher or practitioner could then scale up the individual's strength to allow a more mature pattern to emerge.

Lastly, environmental constraints were manipulated in the fewest studies reviewed. This result is surprising, given the popularity of structured teaching and the environment's influence, which has been demonstrated in psychology. However, the environment is typically considered when addressing behaviors such as on-task/off-task or time-on-task. It could be that the focus is so often on the task or the individual that the environment is assumed to have little effect or to be "controlled." However, in Newell's model, each area of constraint plays an equally vital role in the emergence of behavior. Any change in the environment could result in a varied motor pattern. This area warrants further study to understand how an individual's pattern of movement is changed based on the environment. As this review excluded Gibson's ecological theory (1979), which predominately focuses on the influence of the environment, the lack of studies using DST focusing on the environment could attribute to this. It is likely researchers studying that area would gravitate toward Gibson's theory over Newell's, as Newell is more concerned with all elements around the individual and Gibson focuses on the individual and environment. However, with that said, Sweeting and Rink (1999) demonstrated an improvement in jumping performance by using an environmental-constraint teaching

[9] See Balan and Davis, 1993; Burton and Davis, 1996; or Herkowitz, 1978

model; however, the authors suggest that it be used in conjunction with other teaching strategies and not as a standalone method.

About one third of the studies (5 of 18) reviewed involved infants. As motor development begins in infancy, it is logical that a considerable amount of research would focus on these key developmental years. Additionally, infant development has been thought to be predominantly reflex driven and to occur in stages, mostly due to earlier work by maturational researchers (Gesell, 1929; McGill, 1943). Few studies have involved older subjects. Maturational research gave rise to the understanding that individuals develop throughout the lifespan, and within each stage there are important skills to learn and develop (Clark, 1995; Payne & Isaacs, 2005). However, many skills thought to occur due to maturation do not simply appear, but instead require instruction (Clark & Metcalfe, 2002).

Further, the variability between when individuals develop and how proficient they become at a skill does not fit in a maturational model. With infants, the studies I reviewed suggest that motor behaviors appear in a nonlinear fashion (Ohgi, Loo, Morita, & Mizuike, 2007), with spontaneous movement becoming more stable and repetitive in the lower extremities and increasingly variable in the upper extremities (Abney et al., 2014). These findings suggest that development is less reflexive during the early years and is driven by outside forces. The only anomaly I found in the infant studies I reviewed was Maida and McCune's (1996) study of patterns of movement in infants. However, when analyzing this study in more depth, it became clear that the authors used DST in the study design, but analyzed the data using a maturational framework to confirm the presence of stages of development. As several of the studies in this review have demonstrated, constraints continue to exert influence as individuals age (Langendorfer, 1990), and can have different effects on the emergence of movement patterns during the development process (Langendorfer & Roberton, 2002).

One of the biggest surprises in the reviewed studies was the lack of intervention research that used DST as a framework, as numerous studies demonstrate the theory's relevance to development and the need for more research ((Brymer & Renshaw, 2010; Coker, 2014). One study (Vernadakis et al., 2015) focused on the improvement of motor skills instead of simply aiming to understand the constraints' influence on motor performance. Several studies (Astill, 2007; Langendorfer, 1990; Langendorfer & Roberton, 2002; Liu, Mayer-Kress, & Newell, 2006; Renshaw, Oldham, Davids, & Golds, 2007; Sweeting & Rink, 1999; Ulrich et al., 1998) focused on the influence of the constraint that resulted in an altered performance. These were not considered to be dedicated interventions, as the authors were not focused on improving skills but rather on the influence of constraints; improvement happened because of their manipulation and not due to predetermined influence. For example, Ulrich et al.'s (1998) study of the walking patterns of infants with Down Syndrome suggests that motor behavior can be influenced to improve the outcomes of an intervention.

In another study, Renshaw et al. (2007) analyzed the swing patterns and timing of young adult cricket players when they were swinging at a ball bowled either from a machine or by a person (i.e., an environmental constraint). Findings suggest that the timing was faster when a machine was pitching. This demonstrates the principle of spontaneous self-organization of a behavior based on the influence of an environmental cue, even when the overall situation is similar. The study does not, however, constitute a dedicated intervention designed to develop longlasting changes in motor behavior. Only one study, by Vernadakis and colleagues (2015), focused on an intervention with the aim of improving a motor skill—in this case, object control (e.g., kicking, throwing, etc.)—by using DST as a framework. The study serves as an important example of the benefit in employing DST in an intervention.

To study the effects of an exergaming routine against a traditional activity (TA) group, Vernadakis et al. (2015) developed two 8-week interventions. Both groups received the intervention twice per week for 30 minutes per session. No rationale was given for the length or timeframe; however, when looking at the intervention, it follows a typical physical education unit based on time per week and length. Within each intervention, critical elements of correct movement were imbedded into each lesson and a task analysis was conducted to inform the development of skills from simple to complex. Four lessons were developed for each intervention prior to beginning, but the rest were left open to allow for the flexibility to adjust to participant needs as skills emerged. In both interventions, the tasks were manipulated to encourage proper patterns of movement; in the TA group, equipment was also modified to further encourage new, appropriate patterns of movement. Ultimately, the authors' goal was to compare the potential validity of an exergaming motor intervention to that of a TA intervention to support the use of such an intervention. Perhaps unintentionally, Vernadakis et al. provided strong evidence for the use of DST, as both interventions (exergaming and TA) demonstrated a significant improvement from a pre- to a post-test, when compared to a control group ($F_{(4, 63)}$= 19.17*, p* < 0.001, partial η^2 = 0.394. Further, pre-tests resulted in a nonsignificant difference between groups, but both groups did show a delay in motor skills. This demonstrated that through DST, individuals with a motor delay can show significant improvement over a short amount of time.

Vernadakis et al.'s (2015) findings further support the use of dynamic systems in a motor intervention to increase motor skills; however, the authors also detail some of the potential issues in replicating this result. The study design used a trained motor-skills instructor to deliver instruction, as well as a task analysis to break the skill into a logical sequence. Further, instruction was developed as the participants progressed, which is an important aspect of this intervention. The instructors using this intervention must be able to visually assess and judge when to adjust the skill to fit the needs of the participant. As the types of modifications were not described, it is difficult to understand the detailed adjustments the instructor—or the exergame, for that matter—made.

With that being said, the study by Vernadakis et al. (2015) is an encouraging outcome that is overdue and necessary to fully understand DST, as well as its effects on motor behavior (Newell & Jordan, 2007). The study is an important step in building more effective motor interventions for individuals with motor delays. Since DST holds that the influence of constraints allows behaviors to emerge from the central nervous system (Clark, 1999; Newell, 1986; Thelen, 1995), this type of intervention could potentially be highly beneficial for individuals with cognitive delays, motor planning issues, or a pervasive developmental disorders. It has recently been demonstrated that a delay occurs in the motor development of children with ASD (Fournier et al., 2010; Liu et al., 2014; Pan et al., 2009). DST may provide the framework for the manipulation of constraints in order to move past deficits in communication and social behavior, as the constraints influence behavior outside of the brain's control and beyond the influence of instruction

(Thelen, 1989). As Ulrich et al. (1998) demonstrated with infants with Down Syndrome walking with different constraints on a treadmill, the type of constraint can spontaneously influence the change in motor pattern. Furthermore, Astill (2007), working with children with developmental coordination disorder (DCD), demonstrated how certain task constraints influence movement in children with coordination issues. By controlling for where and how a tennis ball was delivered, researchers revealed an effect on overall performance; this suggests that to improve success and performance, instructors should take task constraints into consideration. If the constraint has enough influence and the correct influence, interventions have the possibility to influence a positive change in behavior.

Implications for ASD

Despite a limited number of empirical studies that use Newell's model as a framework for intervention, a number of articles have referenced DST as a potentially promising theory to guide intervention (Brymer & Renshaw, 2010; Coker, 2014). In this review, only one intervention article was identified; the rest mainly validated the idea of how constraints influence motor behavior. The single intervention study was published recently (Vernadakis et al., 2015) and suggests a possible increase in interest in motor development and the potential effects of DST. Despite the lack of research that formally includes Newell's DST model (1986), many articles provide suggestions about how constraints can be used to modify performance (Coker, 2014) in a variety of populations, including patients recovering from strokes (Sabari, Kane, Flanagan, & Steinberg, 2001) and children with autism (Pope, Liu, Breslin, & Getchell, 2012), and on skills ranging from swimming (Seifert et al., 2014) to language development (Spoelman & Verspoor, 2010).

DST provides a practical view of how behavior occurs without attributing the occurrence to any one subsystem, but rather is an active and fluid interaction between multiple elements. This interaction best explains the nuances of behavior caused by individual variability. As far as motor movement is concerned, it is evident that this behavior occurs through the influences of more than just a predesigned “program.” Individual motor movement and development can be and is affected by the constraints present at the time. This interaction of constraints can be of potential benefit to researchers and practitioners looking to improve motor skills. As shown in several studies (Langendorfer, 1990; Renshaw et al., 2010; Stergiou et al., 2001; Ulrich et al., 1998), a manipulation of just one constraint can cause a spontaneous reorganization of the other constraints to produce a new behavior. If done purposefully, the manipulation of constraints can provide a powerful intervention to influence motor movement for the better (Vernadakis et al., 2015).

This type of intervention can be extremely beneficial for children with ASD—or any disability, for that matter—as the modified constraint manipulates the behavior without a necessary influence from the individual. As children with ASD often display motor impairments, it is imperative that a motor intervention be developed to counteract this delayed development, as it could have repercussions for individuals with ASD in the future (MacDonald, Esposito, & Ulrich, 2011). As the hallmark of ASD is a deficit in social communication (Staples et al., 2012), typical instruction and modeling have little effect on the motor output of these individuals. DST provides a framework for influencing behavior beyond verbal instruction or physical interaction. By manipulating how the individual performs a task or the environment it is performed in, practitioners and researchers can influence motor output and, in turn, work to build an intervention of modifications that results in a more efficient and mature movement pattern.

CHAPTER 3

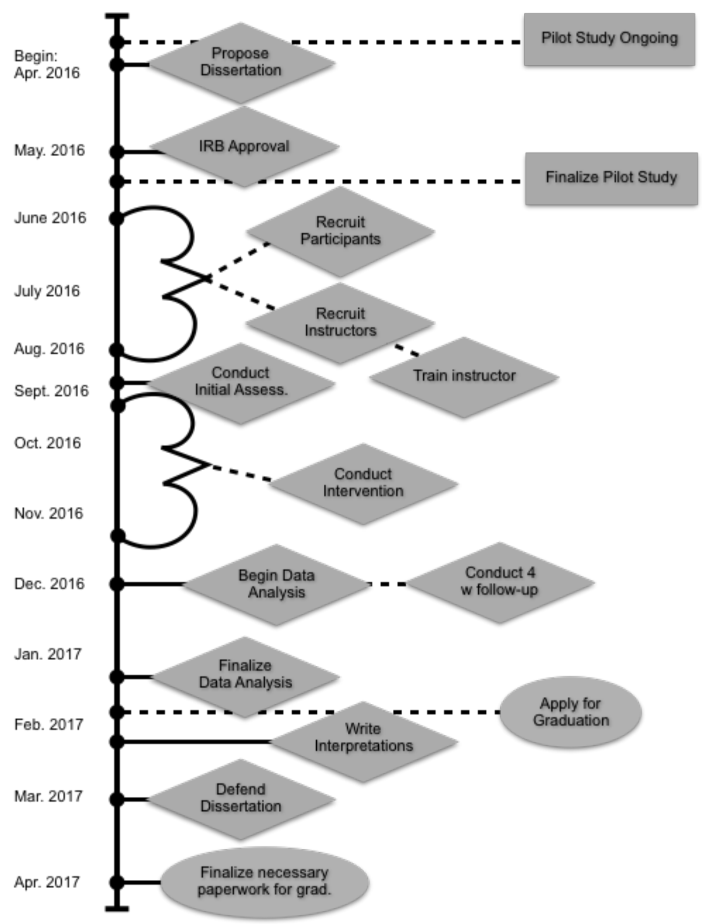
Methodology

In response to the research discussed in the previous chapter, which supports the occurrence of apparent motor delays in children with ASD and the lack of interventions to alleviate these delays, a motor intervention designed for children with ASD is desperately needed. Therefore, the purpose of this study is to determine the effectiveness of a motor intervention using task modification for improving gross motor skills in children with ASD. Furthermore, this study will seek to provide information on the relationship between gross motor ability and adaptive behavior and social skills in children with ASD. Lastly, this study will provide exploratory information about the effect a motor intervention can have that goes beyond the face-to-face interaction between an individual and her/his instructor. To achieve these goals, this dissertation will proceed in three phases: (1) a pilot study, (2) intervention and data collection, and (3) data analysis. The following sections outline each phase; see Table 7 and Figure 5 for written and visual breakdowns, respectively, of the phases.

Table 7: Narrative Timeline of Dissertation

Approximate Time	Event
May 2016	• Propose Dissertation • Pilot study ongoing
May - June 2016	• Seek IRB approval • Pilot study ongoing
June 2016	• Finalize pilot study
June - August 2016	• Visit local schools/meet administration • Recruit participants • Recruit instructors
Late August 2016	• Train instructors • Conduct initial participant assessments
September - November 2016	• Data collection
December 2016	• Begin data analysis • Conduct 4 week follow-up
January 2017	• Finalize data analysis
February 2017	• Write interpretations
March 2017	• Defend dissertation

Figure 5: Visual Timeline of Dissertation



Phase 1: Pilot Study[10]

Using a multiple-baseline, single-subject research design, the pilot was conducted to answer three main research questions:

RQ1. How do task modifications influence the motor performance of children with ASD?

RQ2. Do changes in motor performance persist in the absence of task modification?

RQ3. How much time is required to effectively fade a prompt for a child with ASD?

Institutional Review (Pilot Study)

Prior to collecting data, approval for the pilot study portion of the dissertation was obtained from the University of Virginia Institutional Review Board (IRB). The study (protocol number 2016-0034, approved 02/25/2016) was deemed exempt from review because it posed minimal risk to participants.

Participants

A total of 19 children receiving adapted physical education (APE) services at a central Virginia school for autism were recruited. Information packets and consent forms were sent home with each child. Seven parents responded and a purposive sample of two participants were selected for this pilot study. Selected participants had a formal diagnosis of autism or ASD; this was verified through parent report on the Social Communication Questionnaire (see instrumentation; Rutter, Bailey, & Lord, 2003). Additionally, participants demonstrated at least one component on one ball-control and

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[10] At submission of this disseration, a manuscript titled, “A dynamic systems approach to improve motor performance in children with autism spectrum disorder.”, was in preparation.

one locomotor skill, as measured by the Test of Gross Motor Development, 3rd Edition (TGMD-3; Ulrich, in press). By demonstrating one component of the skill, it was assumed that the child is developmentally ready for that skill. In contrast, a child who demonstrated all components of a skill would not need, nor benefit from an intervention. Similarly, a child who does not demonstrate any components of a skill may not be developmentally or physically ready for that skill, and may not benefit from intervention. Lastly, participants demonstrated the ability to receive prompts verbally or visually.

Setting

The intervention was provided one-on-one by each participant's APE instructor in a multipurpose room. The author was also present, along with a teacher's aide. Measures were taken to minimize overall distraction in the environment; however, not all distractions were able to be accounted for, as the intervention was provided at the participant's school. Moments of distraction were documented within the data and analyzed to determine whether any effect on performance was potentially due to a less than ideal environment. Sessions were videorecorded for later assessment and reassessment.

Instructor training. Each of the child's APE teachers were trained in how to administer prompts and prompting procedures. Instructions were given over two 1-hr training modules. After each session of administering the intervention, the instructor was asked to self-report on her performance for that session (see Appendix E). Additionally, three sessions were randomly selected to assess each instructor's adherence to prompting procedures.

Procedure (Pilot Study)

Using a single-subject design, this pilot study sought to understand the effects of task modification on the gross motor performance of children with ASD. The intervention took place in two phases: (1) assessment and (2) intervention. The procedures for each phase are described below.

Part 1: Pre-Assessment (Pilot Study)

In this part, all participants were assessed on gross motor performance using the TGMD-3. This measure tests individuals on skills deemed to be necessary to produce most physical activities and other complex movements. Skills are broken divided into two subtests: (1) locomotor and (2) ball-control. The locomotor skills assessed are (1) run, (2) skip, (3) gallop, (4) horizontal jump, (5) hop, and (6) slide. The ball-control skills assessed are (1) two-hand strike, (2) one-hand strike, (3) two-hand catch, (4) overhand throw, (5) underhand throw, (6) kick, and (7) one-hand stationary dribble. Each skill is broken into 3 to 5 components that are scored as either 0=*not present* or 1=*present* for two subsequent trials, resulting in a potential score of 6-10 for each skill. Previous versions of the TGMD provided normative data for the assessed values that allowed for determination of an individual's level of delay compared to peers; normative data for the TGMD-3 are still being compiled. As data collected for the pilot study were not compared to "norms," these values were not relevant to this study.

The pre-assessment was used to determine which of two skills—one locomotor and ball skill—from the TGMD-3 was targeted for the intervention. To make this decision, the participant had to demonstrate at least one skill criteria in at least one locomotor and one ball-control skill. Each participant chosen demonstrated one compont of the horizontal jump (i.e., locomotor) and two-hand strike (i.e., ball-control).

Part 2: Intervention (Pilot Study)

In this part, participants received the intervention for the chosen skills. Since the study has a multiple-baseline, single-subject research design, the intervention took place in 5 phases. A multiple-baseline design allows changes in performance to be identified as having resulted from the intervention, as opposed to maturation or simple practice, since some participants receive the intervention and others do not (Kazdin, 2011). Since the intervention involves instruction, an ABAB reversal design would not be appropriate, as the subsequent A phase will be inherently different from the previous A phase at baseline. Additionally, to determine the necessary time required to fade the prompt, an A-B-B'-B''-C design was used, where A is baseline, B is the intervention, B' and B'' are the intervention with a different prompting procedure, and C is performance without prompting.

The first part of the intervention was the baseline (denoted A). During this part, participants were given a verbal and or visual prompt to perform 20 trials of each of the skills. The skills were assessed based on a set of criteria (See Appendix A) developed from the combined criteria of the TGMD-3 and the *Everyone Can!* skill assessment items (Kelly, Weisel, Dummer, and Sampson, 2010). Both the TGMD-3 and *Everyone Can!* were developed from the *I Can—Achievement-Based Curriculum (ABC)* project (Kelly & Wessel, 1991), which provided regular and special education teachers and physical educators information on how to individualize instruction for students with disabilities, including performance objectives for areas of motor development, such as aquatics, locomotor skills, body awareness, physical fitness, etc. The TGMD and *Everyone Can!* skill breakdowns and competencies came directly from the initial work of *I Can* (Kelly & Wessel, 1991).

Average scores of 4 or 5 (out of 5) for each criterion point were deemed acceptable; if a reviewer scored a skill criterion below 4, he/she was asked to provide an alternative criteria. In total, each skill has 5 to 8 criteria points, which will be referred to as "skill criteria" or "SC" hereafter. Additionally, each SC will be rated on a 5-point scale—0=*not present*; 1=*partly emergent*; 2= *emergent*; 3=*nearly present*; and 4=*present*—for an overall scale of 20-32 points to detect changes in performance. The two extreme scores are self-evident; either the participant cannot execute the skill component (0, *not present*) or executes the component successfully (4, *present*). To earn a score of *partly emergent* (1), the participant executes the SC primitively. For example, when performing the second SC of the catch, if a participant has his/her arms either above or below shoulder level, greater than 45 degrees from the midline for the body, and rigid in preparing for the throw, he/she would earn a 1. To earn a score of *emergent* (2), the participant's actions must begin to resemble a pattern that resembles the mature form, but is either rigid or errant and lacks coordination. Continuing with the catching example, participants would earn a 2 if his/her arms range between less than 45 degrees from the midline to directly in front at shoulder height, but are still rigid (0% bend) or greatly overbent (>80%) in preparing for the throw. To earn a score of *nearly present* (3), the participant's movements must be close to the mature pattern, but look rigid or jerky. For example, continuing with the SC from above, a participant's arms may be slightly under (< 20%) or over (> 60%) bent, with his/her hands in front of his/her body. During the baseline, a child's performance determined which criteria point was the focus of the intervention. For example, if the participant performed the first two criteria, the intervention focused on development of the third criterion point. Intrarater reliability (IRR) was calculated on 3 random cases to ensure reliability in coding performance. IRR was calculated at 92.8%, which was above the criterian goal of 80%.

Once the participant demonstrated a trend of performance (i.e., a minimum of three consecutive sessions at a similar performance level; Kazdin, 2011), the intervention phase began; this is denoted as B. Since this is a multiple-baseline design over two skills, each participant started the intervention for the locomotor skill, while continuing at baseline for the ball control skill. By delaying the intervention for the second skill, the ability to detect changes that can be attributed to the active intervention is significantly enhanced. During the intervention phase, participants received a prompt using predetermined task modifications (see Appendix A). To validate the task modifications, the same experts who validated the SC were asked to rate the modification. Again, average scores of 4 or 5 for each modification was deemed acceptable; if a reviewer scored a task modification below a 4, he/she was asked to provide an alternative modification. During the intervention phase (B), instructors gave the task modification for the identified skill criteria on a one-to-one basis. As before, once a trend in performance was demonstrated by the participant, he or she was moved into phases B' and B'', respectively.

In phases B' and B'', the participant received a modified version of the same prompt as in the B phase. For example, with the ball-control skill, one modification was to apply tape to the hand in order to signal where each hand was placed; in the B phase, the tape was very evident and was made smaller each phase so that in B'' it was only two dots. This fading procedure was continued until a trend in performance was demonstrated. Finally, in phase C, the participant was asked to perform the skill, as during baseline, without the task modification.

Data Analysis

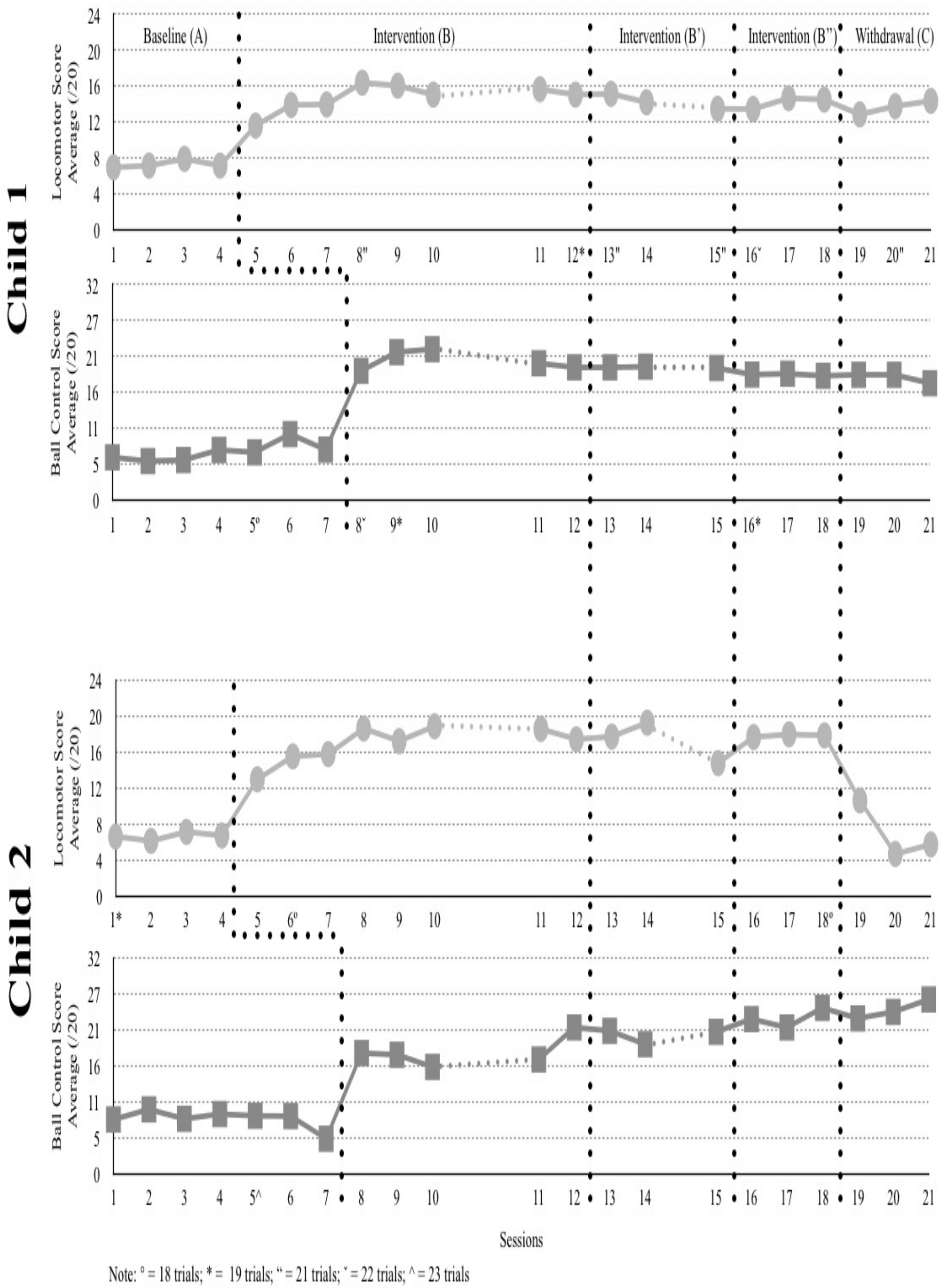
Visual inspection criteria (Kazdin, 2011) was applied—to examine apparent changes in means, level, overlap, stability, trends, and latency—by evaluating graphed data. Additionally, the effect size was calculated based on the difference in performance score based on the means of scores for phases A (baseline) and C (post-intervention). In addition to performance scores based on the SC, the number of practice trials per session (maximum of 20) and time-on-task (i.e., time spent performing trials) was used to understand differences in growth between participants. The graphed data allows for analysis of each research question. Question 1, "How do task modifications influence the motor performance of children with ASD?," was analyzed by comparing performance during the intervention phase (B) to that of the baseline performance. A difference in performance demonstrates the task modification's influence on performance (Question 1), and higher scores in the intervention phase (B) demonstrates the task modifications' effectiveness for improving performance. Question 2, "Do changes in motor performance persist in the absence of task modification?," was analyzed by comparing phase C to the intervention phase (B). If performance is the same as that of the intervention phase, we can assume that the performance will persist. If it is slightly lower, the intervention may be required for a longer period. Lastly, Question 3, "How much time is required to effectively fade a prompt for a child with ASD?," was analyzed using phases B' and B''.

This provided a framework for the time needed to move an individual from receiving a task-modification prompt each time (phase B) to no task modification prompts (phase C).

Results (Pilot)

The participant results can be seen in Figure 6 for each participant. The graphs demonstrate an increase in the gross motor scores of each skill at the introduction of the task modification; this result is to be expected as the each of the skills was assessed with the task modification in place. However, what was not expected was how much of an increase occurred due to the introduction of the task modification. This result provides reinforcing evidence to DST's claim that an individual's movement pattern will self-organize to a new pattern with the addition of any new constraints. Furthermore, when looking at the differences of introduction of the task modification to each skill, the resulting increase can be attributed to the addition of the task modification and not natural factors, such as maturation. When looking at the shift from phase B to subsequent phases, the increased performance is maintained. This suggests that while fading the task modification, performance remain high as the participant has started to move into a more stable, mature motor pattern. At the withrdrawl phase (C), the motor skill persists in most cases in the absence of the task modification. However, the increase did not persist for all cases; the locomotor performance of Participant 2 returned to near baseline levels in the absence of the modification.

Figure 6: Graph of Motor Skill Performance by Participant



Lastly, the calculated effect size demonstrates a large effect (Cohen's $d = 1.945$) as a result of the addition of the task modification. This statistic should be used with caution (Baguley, 2009; Cohen, 1977) due to the limited numbers of participants; however, in considering that the effect size demonstrates that the combine means of both skills in phase C were nearly 2 standard deviations above the mean of baseline data, there is strong evidence that task modifications may provide a strong foundation for quickly building sustained motor skills in children with ASD.

Conclusions from Pilot and Implications for Dissertation

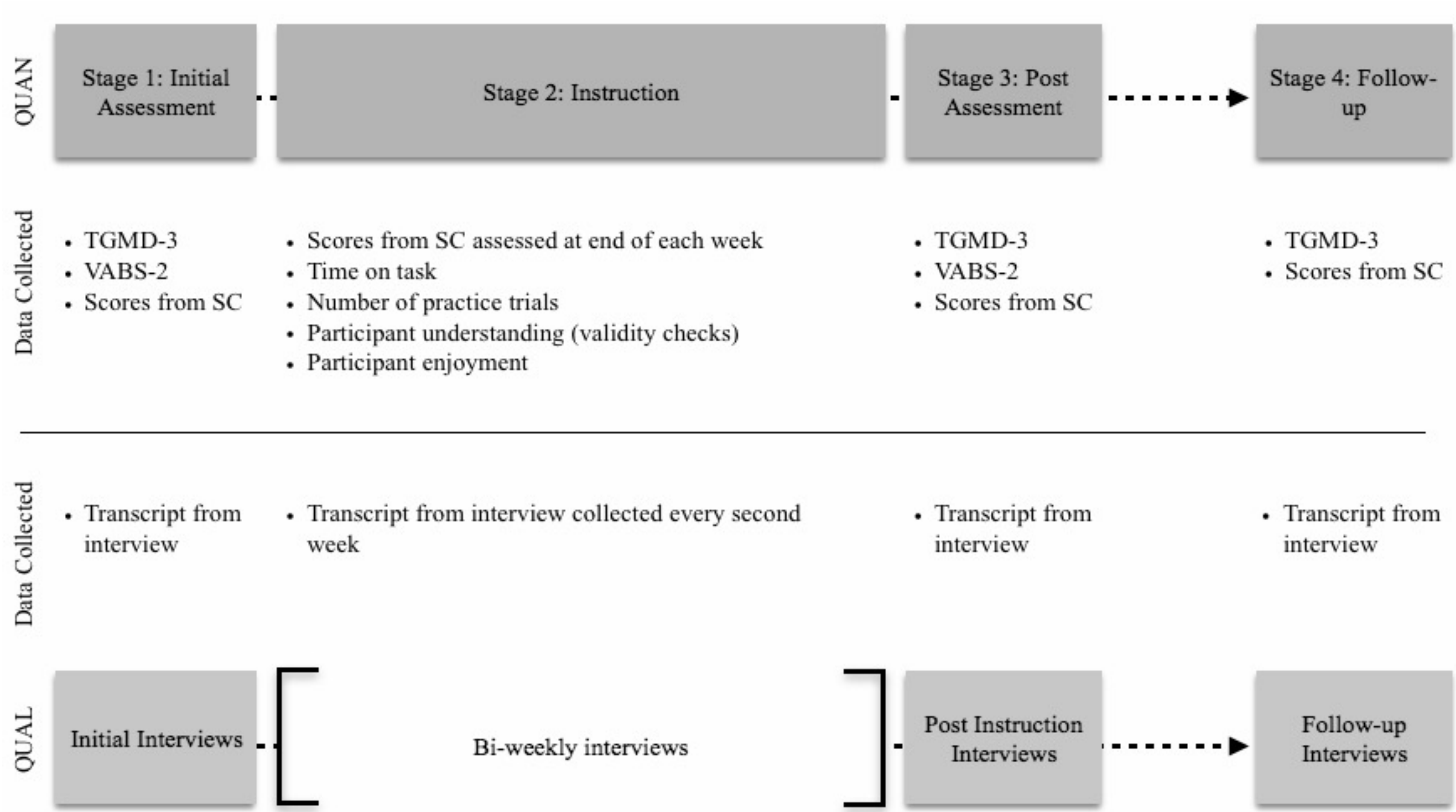
Results from the pilot study demonstrated positive support for task modifications to be used (1) as an intervention tool to influence motor performance and (2) as a model for intervention with children with ASD. As demonstrated in the figure above, the addition of a task modification influeneced an improvement in the motor performance of each participant. Furthermore, the continued trend seen in the ball-control skill, while the locomotor received the task modification shows that the improvement was not due to exposure or maturation, but by the task modification. Furthermore, the continued increase in performance demonstrates the strong influence task modificaitons can have on motor performance in children with ASD. Lastly, the persistence of the increase in motor performance demonstrates the ability of task modifications to perturb a stable motor pattern into a more mature pattern.

The results do demonstrate, however, that task modification and the length at which they are administered may need to be done on an individual level. As seen in Figure 6, participant 2 demonstrates a decrease in performance in Phase C in the locomotor skill, but not the ball-control skill. This result suggests that for this locomotor skill, the skill with the modification was not performed long enough for the new motor pattern to stabilize; providing evidence that task modificaitons may not act universally between individuals and that individualized instruction needs to be considered for any intervention using DST. Further, these results demonstrated that changes in motor performance can occur in a very short amount of time (< 20 trials) and that a task modification focused on improving one SC can have unintended influence on other SC. Lastly, the large effect sizes (d = 1.945) demonstrated for each skill show how powerful task modification can be on the motor performance of individuals.

Phase 2: Dissertation Study

In this phase, knowledge gained from the pilot study was incorporated into a 6-week intervention aimed at improving the motor performance of children with ASD. This phase employeed a parallel, convergent, mixed-methods design for a motor skills intervention based on purposeful task modifications. Mixed-methods research has been found to be more likely to reveal unanticipated results and offer deeper understanding of why change is or is not occurring as planned, and can often capture a wider range of perspectives than might be possible with a single method (Teddlie & Tashakkori, 2009). Multiple methods were incorporated into the design to both confirm and expand the conclusions that emerge from the data (Creswell & Plano Clark, 2007; Green, Caracelli, & Graham, 1989). During the intervention, a quasi-experimental design was used to understand the changes in motor skill performance over time based on the intervention and make comparisons to both developmentally and age-matched groups. Parent interviews were embedded throughout the intervention to triangulate the changes in motor ability, adaptive behaviors, and social skills (Figure 7). Additionally, interviews

Figure 7: Flow of Data Collection



Note: SC = Skill Criteria; TGMD-3 = Test of Gross Motor Development, 3rd Ed.; VABS-2 = Vineland Adaptive Behavior Scales, 2nd Ed.

were used to expand the scope of the intervention to understand the overall effects of changes in motor skills on a child's life (Table 8); a mixed-method design enables more in-depth interpretation of data and greater understanding of each aspect of the phenomena (Tolan & Deutsch, 2015) of motor-skill improvement.

This study sought to answer the following research questions:

RQ1: Do task modifications, based on the principles of dynamic systems theory, increase motor performance in children with ASD?

Sub-RQ1: Are positive effects from the motor intervention demonstrated in individuals with ASD?

RQ2: How do changes in FMS influence the adaptive behavior skills or social skills of individuals with ASD?

RQ3: How do parents' perceptions of the child's physical ability change as a result of participation in a motor intervention?

RQ4: In what ways, if any, do changes in FMS interact with other aspects of a child's life?

By employing a mixed-methods design, in this dissertation study, the author sought to understand, first, how an intervention derived from DST affects the motor performance of children with ASD, and second, what effects are seen in the daily lives of families of children with ASD, in terms of the family's physical activities and quality of life, as a direct or indirect result of participation in a motor intervention.

In the following sections, the participants, setting, instrumentation, intervention procedures, interview procedures, and data-analysis procedures will be described. As the study used both qualitative (QUAL) and quantitative (QUAN) data collected simultaneously and given equal weight, in the following sections the procedures for separately collecting and analyzing the individual strands of QUAN and QUAL data will be described, followed by how independent strand results were merged to explore the data in greater depth.

Institutional Review

Prior to collecting data, approval for the study design was sought through the University of Virginia IRB. The study (protocol number 2016-0329, approved 08/30/2016; modification was approved 01/11/17) was deemed exempt from review because it posed minimal risk to participants. The IRB application included consent procedures, assessment items, and study protocols. The Director of Education and the Executive Director at the school for autism, along with principals of local private elementary and preschools, were contacted to gain approval prior to beginning recruitment at each site.

As this study focuses on a vulnerable population, a consent/assent procedure was used. Parents and legal guardians of children were contacted with information regarding the study and asked to provide consent to include their children in the study. Children for whom consent had been given were asked for assent on an individual level and given information both verbally and visually. Assent was assumed when the child either verbally or nonverbally signaled agreement or engaged with the instructor, materials, or both. The child's assent was sought on an ongoing basis throughout the study prior to each session. If a child demonstrated increased frustration or behavioral issues, he/she was first provided with a break from activity. If behaviors continued after a break, the session was ended for that day. If behaviors persisted across two consecutive days, the child was deemed to be objecting to participating further, and was withdrawn from the study; all participants finished each phase of the study. Parental consent during the interview process was reaffirmed verbally at the beginning of each interview.

Participant—Intervention Sample (QUAN)

To understand the effectiveness of the intervention for individuals with ASD, a purposive sample of three separate groups was employed: (1) a group with a primary diagnosis of autism or ASD, (2) an age-matched peer group without autism or ASD, and (3) a developmentally matched peer group without autism or ASD. Both comparison groups was limited to individuals without documented disabilities. See Table 10 for participant demographics.

ASD Group. Participants in this group were recruited from a school for children with autism spectrum disorder in Central Virginia. Students from this school have been referred by his or her home district due to an inability to maintain the level of coursework rigor without significant assistance. Attendees work one-on-one with a tutor who uses common applied behavior analysis (ABA) strategies and a variety of reinforcement plans. Some participants, as a part of his or her daily routine, receive APE services as directed in the student's Individual Education Plan (IEP). Currently, the school has around 50 children with a primary diagnosis of autism or ASD and, potentially, a variety of comorbidities such as Cerebral Palsy, Down Syndrome, Attention-Deficit Hyperactivity Disorder (ADHD), etc. To meet the criteria for this study, participants were recruited between the ages of 5 and 11, with a primary diagnosis of autism or ASD. Participants' ASD diagnosis was confirmed through the Social Communicative Questionaire (SCQ; Rutter et al., 2002). The SCQ recommends a cut-off score of 15 or higher to be at-risk for

ASD; mean participant score was 25.2. Further, participants had a demonstrated delay in motor performance, as determined by the TGMD-3 (Ulrich, in press). Participants included in this study also demonstrated an ability to follow prompts (either verbal or visual). A total of 5 children (4 boys, 1 girl; M_{age} = 7.92, SD =1.09) with ASD were selected for this study.

Comparison groups. The developmentally and age-matched groups act as comparison groups for the ASD group to understand the overall effectiveness of the intervention itself. As the literature provides little empirical guidance as to the frequency and dosage (see Table 2) necessary for motor interventions, the overall length chosen for this intervention may prove to be too short for noticeable changes in individuals with ASD. By including groups without ASD, the author could determine whether (1) the method of delivery was age-appropriate, (2) the instruction based on task modifications is beneficial for children with developmental delays, and (3) the intervention should be longer for individuals with ASD.

Age-matched group. Participants in this group were recruited from a local private elementary and middle school and matched by chronological age to participants in the ASD group. This group was limited to children with no formally diagnosed disabilities between the ages of 5 and 11 (M_{age}= 7.75, SD = .93). Participants demonstrated a limited performance in at least one locomotor and one object-control skill; participants with perfect scores in one subtest or overall were excluded. Partcipants in this group received weekly physical education; the research team coordinated with the physical educator to ensure that no direct instruction was given on the focus skills during the duration of the intervention. Participation in extracurricular activities that worked on similar skills was not controlled for.

Developmentally-matched group. Participants in this group were recruited from local private preschools and matched to the ASD group based on the outcome of his/her gross motor score. An attempt was made to match paticipants overall TGMD-3 performance; however, motor performance of the ASD group was so delayed for some participants that it was difficult to match. Therefore, participants were matched on one locomotor and one object-control skill, and based on the priori skill criteria (SC). Participants in this group were approximately half the chronological age (M_{age}= 4.40, SD = .34) of the previous two groups. Participants from this group received no formal physical education during the duration of the intervention; participation in extracurricular activities that may have worked on similar skills was not controlled for.

Participants - Interview sample (QUAL)

To understand the effects of the intervention on the daily lives of participants with ASD, their parents or guardians were asked to participate in semistructured interviews. As a research tool, the interview allows for deeper inquiry than simply asking a series of questions and waiting for a response (Kvale, 1996). To elicit the necessary information, a researcher must act as a “helping voice” (Lillrank, 2012) by allowing participants to respond in their own words, express personal perspectives, and bring the researcher into their world (Patton, 1990).

When considering situations that involve individuals with disabilities, the researcher should seek to include the individual with the disability whenever possible, as they offer firsthand information about what is occurring in his or her own world

(Caldwell, 2014). However, as children with ASD often have limited communication skills, the next best “expert” for any given situation is usually the child’s parent or legal guardian. Due to the sheer amount of time spent with the child, parents and guardians can offer insight into his or her daily life that cannot be captured by those outside the home. Because of their proximity to the individual, parents are often used in research that seeks to gain insight about the effectiveness of programs for children with disabilities (Columna et al., 2008; Na, 2015; Obrusnikova & Miccinello, 2012). Furthermore, parents provide opportunities to see what is happening to the individual with a disability outside the context of many programs or interventions.

Intervention Setting (QUAN)

The intervention for this study was provided in a one-on-one setting with an instructor and any necessary support personnel. Each session was provided in either a multipurpose room, gymnasium, or outside; whichever provided a minimally distracting environment. At certain times, due to the nature of providing an intervention outside of a clinical setting, other students or distractors were present that are outside of the research team’s control. Each session was videorecorded to allow for the analysis of time-on-task and practice trials in each session, to account for variation due to outside factors.

Instructor training. For the autism group and, in certain cases, in the comparison groups, an instructor other than the author provided the instruction; each instructor was trained prior to the start of data collection on how to administer the intervention’s prompts, as well as the prompting procedures. Prior to data collection, intructors had the ability to work with their children and form a bond of familiarity prior to the intervention. Instruction was given over two 1-hr training modules. Two measures were used to monitor the instructors' performance. First, after each administration of the intervention, the instructor was asked to self-report (see Appendix F) on his/her performance for that session. Responses were monitored daily and issues that arose were quickly evaluated. Second, 5 minutes of videorecorded intervention was randomly selected to monitor for adherence. All instructional changes and modifications throughout the intervention were made by the author, and not the instructor (Figure 8); the instructor acted as a conduit for the instruction. Continual communication was made with the instructors on a weekly basis to provide overall feedback, as well as instructional changes.

Interview Setting (QUAL)

Interviews, and much of the interview process, are not one-sided; the researcher always has an effect on the outcome of an interview; so much so, that each interview can be viewed as a collaborative construction of the meanings of the topic dependent on both the interviewer and interviewee (Watson, 2006). In addition to this collaborative construction, the interviewer must be aware of the power dynamic between him or herself and the person being interviewed, which can potentially be construed as coercive. In most cases, the researcher is already in a position of power, regardless of age, gender, social status, or position, because they are the primary conductor of the interview (Wang & Yan, 2012). Very quickly, in any interview, it becomes evident who is in control, since the researcher asks the questions and the interviewee responds (Creswell, 2013). In most situations, this is unavoidable and generally harmless; however, when in situations that involve sensitive topics, this may place the interviewee in an awkward position. To reduce the effect of such a power dynamic, the researcher must be conscious of the environment he or she is creating (Karnieli-Miller, Strier, & Pessach, 2008) and the "respect" one is giving to the interviewee (Rubin & Rubin, 2012).

To reduce the influence of the power dynamic, interviews were conducted at the most convenient time (ranging from 8 am to 8 pm) for the parent interviewee and in the most comfortable environment (i.e. at home). Additionally, phone interviews were conducted when necessary due to travel issues or time conflicts. Furthermore, due to unforeseeable time constraints on the part of one set of parents, interview questions were provided in-writing and written responses were accepted; follow up was done for any clarifications on written responses.

Instrumentation—QUAN Measures to Be Collected (all groups)

Demographic information. To determine the similarity between groups and to account for potential confounding variables, several descriptive variables were measured within each group. These variables include age, gender, race, body mass index (BMI), diagnoses, and current parent reported levels of activity and sport participation (See Table 10).

Change in motor performance. As the TGMD-3 is meant as a screening tool for those who have motor deficiencies, it is not ideal for understanding small changes or providing guidance for areas of instruction. SC for the TGMD-3 are not become applicable at even intervals, and therefore make growth difficult to gauge using only the TGMD-3. To provide for instruction, as well as to better gauge change in performance, an extrapolated criterion breakdown of each of the motor skills included in the TGMD-3 was employed as a framework for providing skill-based instruction. Using the *Everyone Can!* as a guide in combination with the TGMD-3, each motor skill was expanded to include between 5 and 8 criterion points (see Appendix A). This list was validated by a set of experts in the fields of motor development and APE. Criteria were rated on a 5-point Likert scale, scores with a mean average of 4 or above were deemed acceptable[11]. Criteria with a mean score of less than 4 were reworded based on the experts' suggestions. When measuring each participant on individual criteria, a 5-point scale will be used: 0=*not present*; 1=*partly emergent*; 2= *emergent*; 3=*nearly present*; and 4=*present*.[12] Including a greater range than simply present/not present allows a maximum total score for each skill of 20-32. To understand growth based on the intervention, changes in criterion scores were assessed at the end of each week during the intervention, as well as at the 4-week retention. For the pre-, post-, and retention measures of the SC, 2-3 trials were averaged per skill and totaled for a possible range of 0-144 and 0-204 for the locomotor and ball-control skill performances, respectively.

Test of Gross Motor Development–3rd Edition (TGMD-3). The TGMD-3 is a valid and reliable assessment of gross motor ability for children. It contains two subtests: locomotor skills and ball-control skills that measure 13 fundamental movement skills deemed essential to physical activity. The TGMD-3 is a preferred measure of motor competency, as it measures specific qualitative performance criteria matched to the mature form of a skill, as opposed to an outcome or product of a movement (Staples & Reid, 2010). Each skill is measured on 3-5 criteria. Multiple performances allow children to receive credit for any aspect of the skill they can perform. Scoring is based on the presence (1) or absence (0) of the criteria. For each skill, two trials are scored, providing a raw score for each skill; scores can range from 0 to 52 for the ball skills and 0 to 46 for

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[11] See Appendix B for results from experts.
[12] See Appendix C for the breakdown of the SC scoring rubric.

the locomotor skills. Currently, the TGMD-3 is being norm-referenced; however, since it is recommended that the raw score be used to compare individuals, the normative scores are not necessary for this analysis. In previous versions of the TGMD (2^{nd} Ed.; Ulrich, 2000), internal consistency of the overall and subtest scores ranged from 0.82 to 0.94, and the test-retest reliability coefficients ranged from 0.88 to 0.96. Visuals will be provided to allow for better communication between participants and instructor (Breslin & Rudisill, 2011). This measure was given as a pre-assessment to determine overall motor impairment and post-assessment to measure overall growth, as well as at the 4-week retention.

Time on task. Breslin and Rudisill (2013) found a moderate to strong inverse relationship between motor performance and length of assessment, meaning that as length of assessment increased, gross motor performance decreased. Additionally, results showed a non-relationship between time-on-task and performance; however, the authors suggest that the controlled environment (window coverings and blank walls) could have had an effect. Nevertheless, time-on-task is a powerful tool for enhancing short-term skill retention (Iserbyt, 2015), even in populations with severe cognitive impairments (Owlia, French, Ben-Ezra, & Silliman, 1995). Therefore, each intervention session will be videorecorded to collect the amount of time on task. Time on task was defined as the time during which the participant was engaged either with the instructor, performing the skill, or watching a demonstration. Furthermore, a participant was considered on-task if they were on an “earned” or scheduled break. Time-off task would therefore be anytime in which the participant was performing a task outside of what was requested or expected, this included, but was not limited to, performing another skill (i.e. running away) or a self-stimmulating (e.g. self-stimming or stimming) behavior. In the event a participant travelled outside of the view of the camera, the participant would continue to be counted as whichever classification (i.e. on- or off-taask) was being counted when they left the camera's view. For example, if the participant was on-task as they left the field of view, they would continue to be counted as on task; however, if the participant took greater than 10 seconds to reappear, the designation would be moved to off-task until they reappeared.

Number of practice trials and successful practice trials. In addition to coding for the above, the videorecording of the intervention was also coded, quantitatively, for the number of practice trials, as well as the number of trials completed successfully. A successful trial was defined as any performance of the skill that demonstrated the focus SC; a successfult trial was defined as any skill attempt that met the focus SC for that week. Recent research (Chow, Lea, & Leaver, 2016) suggests that learning can be influenced by the number of trials completed, and success in those trials provides opportunities for greater benefit. Often, practice trials are a controlled variable in research to understand the differences between other influences (Corrêa, Walter, Torriani-Pasin, Barros, & Tani, 2014). Due to its effects, researchers often standardize the number of practice trials between groups to ensure that groups receive equal amounts of practice time. Because this can be difficult from session to session with children with ASD and potential behavioral troubles, this variable will be monitored for variability between groups. After the first week of the intervention, it became clear that given the session time and variables outside the influence of the intervention, it became clear that they comparsison groups had the opportunity of performing a significantly greater amount of trials per session. To limit an undue variance between groups, instructors were directed to provide between 30 and 40 trials per skill each session.

Level of enjoyment. One's level of enjoyment during an activity can have a great effect on overall motivation to participate in the activity and commitment to continue with the activity. Building on self-determination theory (Deci & Ryan, 1985) and the sport commitment model (Scanlan, Carpenter, Schmidt, Simons, & Keeler, 1993), Garcia-Mas et al. (2010) found a clear pattern for the influence that enjoyment has on one's motivation for and commitment to a task. Furthermore, in an assessment of college students, Kilpatrick, Hebert, and Bartholomew (2005) found that enjoyment (among other characteristics, such as competition and challenge) was vital to individual motivation to participate in exercise and sports. Moreover, enjoyment was ranked by both men and women as second out of 14 characteristics considered potentially important for sports participation (Kilpatrick et al., 2005). Since motivation plays an essential role in the performance of any given activity and can be a determining factor in the effort an individual puts forth to learn an activity, it is important to capture how individuals feel about a task.

Therefore, a two-item picture scale was incorporated to capture the participant's enjoyment, which was measured between three and five intervals during each session: (1) at the beginning of each session, (2) after the warm up; (3) directly following the first practice session, (4) directly following the second practice session; and (5) after the choice activity at the end of the session. The first picture was a happy face (scored as a 1) and the second was a sad face (scored as a 0); see Appendix G for an example. Participants could respond verbally or by pointing; "I don't know," "Unsure," shoulder shrug, or no response was not scored. Scores were calculated as a percentage of enjoyment (i.e. the closer to 1 or 100% the more time the participant was unhappy or happy, respectively). Scores were calculated by week and overall.

Participant's validity of understanding. Children with ASD, as mentioned previously, have been shown to develop motor skills differently than their peers (Liu et al., 2014; Lloyd et al., 2013; Staples & Reid, 2010). However, it is difficult to ascertain whether the delays are inherent to the condition or due to limitations in understanding. Colombo-Dougovito and Kelly (draft in preparation) attempted to modify the assessment protocol for children with ASD to increase performance based on the method of communication. Little change in performance occurred due to the modifications; however, participants more frequently understood what was being asked of them when they were given directions both visually and verbally. Using a similar method to check for understanding, a three-item picture scale (see Appendix H) will be used to ask participants, "What skill did you just perform?" Participants responded either verbally or by pointing to the picture of the skill. Responses were scored as either correct (1) or incorrect (0); "I don't know" or "unsure" will be recorded as incorrect. Scores were averaged by week and overall; scores are represented as a percentage (total number of correct responses/total number of possible correct responses).

Social validity. Social validity, as conceived of by Foster and Mash (1999), speaks to the social importance and acceptability of treatment goals, procedures, and outcomes. Kazdin (1999) further suggests that while certain interventions may be clinically significant, the feasibility and impact on the participant must be viewed as equally important. To understand how the dissertation intervention will function within the physical education (PE) and APE classroom, the instructors for the intervention were questioned about the practicality and feasibility of an intervention based on making task modifications. Independent of their beliefs about its practicality, instructors were asked who would receive the greatest benefits from the intervention and invited to provide their suggestions, if any, for improving it. To understand the potential of this intervention the Intervention Rating Profile-15 (IRP-15; Martens, Witt, Elliot, & Darveaux, 1985) was modified to include language for the APE/PE setting[13]. As this variable is independent of any analysis, it was treated independently from others and collected for interpretation of the intervention, as well as to guide future modifications.

Instrumentation—QUAN Measures to be Collected (ASD group only)

Vineland Adaptive Behavior Scales, 3rd Edition (VABS-3). The VABS-3 (Sparrow, Cicchetti, & Balla, 2016) will be used to assess adaptive skills. The VABS is a standardized parent-report measure of everyday adaptive functioning, and yields domain scores in the areas of communication, daily living skills, social skills, and motor development (fine motor and gross motor skills). A standardized behavioral composite score is derived from all domains. This measure will be administered, in person or by phone, to the child's parent or primary caregiver. Internal consistency of the domain scores were 0.90-0.96 and 0.98 for the overall Adaptive Behavior (ABC) composite; the test-retest reliability coefficients ranged from 0.73 to 0.92 for the domains and between 0.80 to 0.92 for the Adaptive Behavior composite (Sparrow et al., 2005). This measure was taken pre- and post-intervention. The overall ABC was utilized to understand

[13] See Appendix D for modified-IPR-15

changes adaptive behavior and the socialization sub-domain (COM) was used to understand changes in social skills.

Social Communication Questionaire (SCQ). Each participant in the ASD group was diagnosed independently by either a developmental pediatrician or psychiatrist (*M*age of diagnosis=2.4, SD=1.14), and attended a school for autism. However, to increase the reliability of findings, this study used the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2002) to confirm diagnosis of the participants. The SCQ is a reliable and validated screening questionnaire to assess at-risk children for ASD (Chandler, et al., 2007). The SCQ is a parent-report questionnaire that asks, separately, about either lifetime developmental history or current behavior over the last three months. This assessment is brief and easily administered to parents as an "efficient way to obtain diagnostic information or screen for autism symptoms" (Ozonoff, Goodin-Jones, & Solomon, 2005). The SCQ provides a possible range from 0-39, with a cut-off of greater than 15 for an individual at risk for autism (Rutter, et al., 2002; Chandler, et al., 2007). Each of the participants included in this analysis scored above the cutoff (*M* = 25.2, SD=6.38). The author gave parents questionnaires with implicit instructions to complete and return.

Instrumentation—QUAL Measures to be Collected (ASD group only)

Semistructured parent interviews. Parent/guardian interviews were conducted at the beginning and end of the intervention period, as well as every other week throughout the intervention, to understand how the changes in motor skills/performance interact with other aspects of the child's life. Semistructured interviews were conducted with parents or guardians in which they were encouraged to elaborate on and give voice to their experiences. Expert feedback was used to analyze the questions to ensure that questions were open ended and non-leading. Interviews were audio recorded and transcribed; to ensure accuracy, interviews were transcribed within one week of collection. See the Interview Procedures section for detailed description of how the interviews were conducted, and Appendix I for the outline of parent questions by occurrence; the outline was validated by experts prior to administration.

Procedure

To lessen potential confusion of quantitative and qualitative data, each strand of data collection will be addressed separately. In the following paragraphs, the protocols for the intervention (quantitative) and parent interviews (qualitative) are described in detail. Next, analysis of each strand are discussed, followed by the convergence of both strands. See Figure 7 for the flow of data collection.

Intervention Protocol

The following intervention was conducted in four stages: (1) initial assessment, (2) instruction, (3) post-instruction assessment, and (4) retention assessment at 4-weeks after instruction. The procedure for each stage is explained below.

Stage 1: Initial Assessment

This intervention focused on two skills over 6 weeks of instruction. The intervention was provided two times per week for 30 minutes per session for a total of 6 hours of instruction over the intervention. To ensure that the skills focused on would yield the greatest benefits, prior to beginning the intervention phase of the study, each participant was assessed using the TGMD-3. For each participant, two skills (one locomotor and one ball skill) was chosen based on the results of the TGMD-3; this varied from participant to participant. To ensure that the skills chosen for each participant were developmentally appropriate, the participant demonstrated at least one component, as determined by the TGMD-3, consistently (i.e., it must be present in two consecutive trials). If a participant had more than one component, the intervention might appear to be effective even though the child would have achieved the criteria through natural maturation, with or without the intervention. Conversely, if a participant had no demonstrated components, he/she may not be developmentally ready for that skill, lack the prerequisite skills, or have such a great deficit that the intervention would not provide enough instruction. While an attempt was made to ensure the individual attention was provided based on the developmental stage of the participant, three similar locomotor skills—gallop (n=3), hop (n=2), and jump (n=10)—and ball-control skills—throw (n=8), kick (n=5), and strike (n=2)—emerged. Also, during this stage, parents of participants in the ASD group were asked to complete the VABS-3.

Stage 2: Instruction

Each session of the intervention, as well as the pre-post assessments, was videorecorded allowing for participance to be assessed based on the expanded SC described above, which has been validated by experts in the field of motor development (see Appendix B). These SC were used to determine the starting point for the instruction, as well as the progression of the sessions throughout the intervention. Based on the initial assessment, the first week of skill instruction focused on the next logical component of the skill. For example, if, after the initial assessment, the participant could perform the first two criteria for the skill, the lessons during the first week would focus on the third criterion.

An instructor or the author conducted each session following a similar format for each group: a warm up, locomotor skill practice, object-control skill practice, and a choice activity. For a 30-minute session, the breakdown of time was about 5 minutes for warm-up and choice activity, and 10 minutes for each skill practice. The warm up included a brief walking/running period and stretching. After the first week, it became evident that 10 minutes of instruction for the comparison groups was to long for the given instruction. As mentioned before, instructors were instructed to provide instruction on each skill up to 30-35 trials before switching. This often occurred within 3-5 minutes or less for each skill practice. If more instruction time was provided, the decrepancy of practice between ASD and comparison groups would have been much more dramatic. Additionally, due to the variability of the daily schedule and general school day, some lessons were not a full thirty minutes. In these circumstances, instructors took time from the beginning and end of each lesson in order to ensure enough skill practice was maintained. Further, instructors attempted to keep the amount of skill practice even between the two skills; for example, if the instructor only had 16 minutes, they provided 8 minutes of practice for each skill.

Each skill practice included a task modification during instruction designed to target the specific SC. As research has demonstrated (Clemente et al., 2012; Farrow & Reid, 2010; Ulrich et al., 1998; Vernadakis et al., 2015), the manipulation of a task constraint (i.e., task modification) can encourage behavior to assume a more mature pattern. By modifying the absent skill criterion, a participant can be influenced in a way that offers him/her the opportunity to practice that component in a successful manner. As mentioned before, task modifications were developed prior to commencing the intervention, and each was validated by a panel of experts as logical modifications for a specific criterion. Specific instruction was modified, where appropriate, to best meet the needs of the participant; modifications were made at the author's discretion under the advisement of the child's classroom instructor and aide[14]. For instance, many children with ASD experience success when instructions are provided visually, with or without verbal instructions (Arthur-Kelly, Sigafoos, Green, Mathisen, & Arthur-Kelly, 2009; Barton, Lawrence, & Deurloo, 2011; Breslin & Liu, 2015), therefore visual cards were used with participants who

Table 8: Weekly Skill Progression for Each Participant

Part.	Group	Age (yr)	Gender	Skil	Week 1 Criteria	Week 2 Criteria	Week 3 Criteria	Week 4 Criteria	Week 5 Criteria	Week 6 Criteria
1	ASD	5.2	M	Jump	2	3	**3**	4	5	6
				Throw	1	2	3	4	5	6
6	Developmental-match	3.3	M	Jump	1	2	3	4	5	6
				Kick	2	3	**3**	4	5	6
11	Age-match	5.1	M	Jump	1	2	3	4	5	6
				Throw	1	2	3	4	5	6
2	ASD	6.3	M	Jump	1	2	**2**	3	**3**	3*
				Kick	1	2	**2**	3	4	**4**
7	Developmental-match	4.8	M	Jump	1	2	3	4	5	6
				Throw	1	2	3	4	5	6
12	Age-match	6.5	M	Jump	1	2	3	4	5	6
				Kick	3	4	5	6	7	8
3	ASD	7.8	M	Gallop	1	2	3	4	5	6
				Kick	2	3	4	5	**5**	6
8	Developmental-match	4.9	M	Hop	1	2	3	4	5	6
				Throw	1	2	3	4	5	6
13	Age-match	8	M	Jump	2	3	4	5	6	**All**
				Throw	1	2	3	4	5	6
4	ASD	8.9	M	Gallop	1	2	3	4	**4**	5
				Throw	2	3	4	5	**5**	6
9	Developmental-match	5.1	M	Gallop	1	2	3	4	5	6
				Throw	1	2	3	4	5	6
14	Age-match	8.6	M	Jump	1	2	3	4	5	6
				Strike	4	5	6	7	8	**All**
5	ASD	11.4	F	Jump	1	2	**2**	3	**3**	4
				Strike	3	**3**	**3***	4	**4**	5
10	Developmental-match	4.0	F	Jump	3	4	5	6	**6**	**-**
				Kick	2	3	4	5	6	7
15	Age-match	10.6	F	Hop	1	2	3	4	5	6
				Throw	1	2	3	4	5	6

Note: *= Task modification was modified to meet unique needs of individual. - = missed both sessions for week.
ALL=Focus on movement as a whole and addressed lacking areas.

[14] See Table 8 for the weekly progression of skills by each participant.

needed additional guidance. Furthermore, many task modifications are visual or have a visual component (e.g., spots on the floor or wall); this assisted in the instruction. Instructional modifications were employed to meet the needs of all participants in the study, not only the children in the ASD group. After each skill practice, the participant was asked, “What skill were you just working on?” The participant was then shown a page with three pictures of skills and prompted to verbally respond or point to the skill (see Appendix H). One of the skills was the targeted skill, the others were in the same family of skills (e.g. locomotor or ball control). The pictures were randomized each session so that the child could not simply learn which picture was correct by its location. This provided insight into the participant’s understanding of what was being asked of him/her during each skill-practice session.

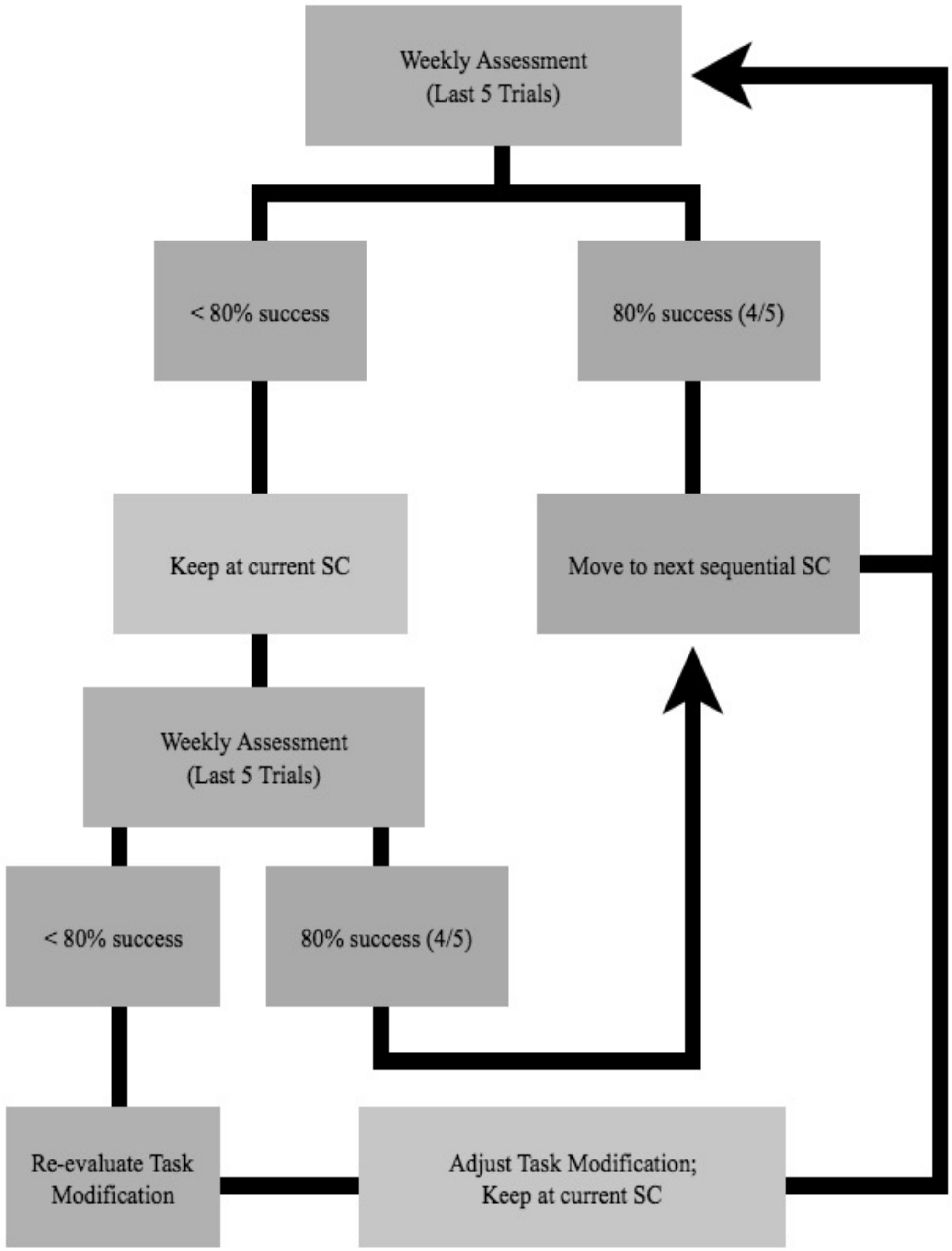
The last part of each intervention session was a choice activity to provide motivation during the skill practice. After the warm-up, participants were offered a choice of activities that could be “earned” during that session. The activity will be selected from a list activities created by teachers, parents, and the child. This is a common practice for children with ASD, and is often referred to as a “reward schedule” or “token economy” (Wong et al., 2013). Essentially, children earn a token for performing skills correctly or displaying certain behaviors. In theory, by rewarding small occurrences of performance, the likelihood that those performances or behaviors will be repeated increases. If a child earns enough tokens (for example, 10), they then can exchange them for a larger reward; for children with ASD, this might be watching a favorite YouTube video, time on a computer/iPad, or an activity such as swinging. Often, for children with ASD, this reward schedule varies; some children need a 1:1 ratio, while others can perform tasks in a 5:1 or

10:1 ratio[15]. This was individualized to best meet the needs of the child and to increase the likelihood of decreased frustration by continuing similar routines as found in the classroom. This method was used for participants in the comparison groups as well, although the token economy was not followed as formally. Participants in these groups were offered a choice of activity (or returning to class/recess) for the end of the session and verbally reminded of their choice to help correct off-task behaviors.

Determining Progression of Practice. At the end of each week (i.e., after the second weekly meeting), participants were asked to perform the targeted skills for 5 trials without the task-modification prompts; directions were still given verbally or visually, depending on the participant. Since each session was video recorded, each child was assessed based on the last 5 skill trials to determine the next week's lessons. If the participant met the targeted criteria (e.g., the skill is fully present) in 80% (4 of 5) of the trials, the next week's instruction focused on the next SC. If the child did not meet the SC at 80%, the next week's instruction continued to focus on that SC. If the child did not meet the SC for two consecutive weeks, the task modification for that criterion was reassessed for that individual and an alternative was provided (see Figure 8).

[15] See Appendix J for an example.

Figure 8: Flow Chart of Instructional Decisions



Missed Days. Any sessions missed during the intervention was made up at the earliest availability of the participant or added to the end of the intervention. Subsequent assessments, interviews, and follow-ups will be adjusted for participants who have missed days. Two participants (1 in DM and 1 in AM) missed sessions that were unable to be made up. Participants in the ASD group received the entire prescribed intervention.

Stage 3: Intervention post-test

Immediately following the intervention stage of this dissertation study, participants in each group were assessed using the full assessment battery of the TGMD-3. The protocol for this assessment was similar to the initial assessment to retain consistency and predictability for each of the participants. As the assessment was videorecorded, each participant was assessed using the SC for a more in-depth analysis of all changes that occurred during Stage 2. Additionally, parents completed the VABS-2 to determine whether any changes have occurred.

Stage 4: Retention at 4 weeks

During the retention assessment, participants in each group were assessed utilizing the TGMD-3; the protocol will be similar to the previous assessments. As before, assessments were videorecorded to allow for analysis of performance using the SC. Due to the time of the intervention, participants were on a holiday break during the majority of retention period receiving no instruction whatsoever beyond individual sports teams outside of the control of the study. By 4 weeks, participants returned to a typical schedule, and retention of the intervention was more easily detected.

Interview Protocol

Certain aspects of the world cannot be quantified or easily measured by an assessment; they reside within an individual. Within an individual's lived experiences lie a wealth of information about topics that are more abstract, such as social injustice, education, psychology, or even health care (Hewitt, 2007; Seidman, 1998). By accessing this information, researchers can, through "close observation, careful documentation, and thoughtful analysis" (Maykut & Morehouse, 1994, p. 21), discover patterns that exist in the seemingly unseeable. An individual's responses can provide researchers insight into the most complicated of issues, because the abstractions of human consciousness are based on the concrete experiences of people (Fossey, Harvey, McDermott, & Davidson, 2002; Patton, 2002; Seidman, 1998) and are seen as reflections of the individual's reality (Rapley, 2001).

As mentioned previously, interviews were conducted at the beginning and end of the intervention, every other week throughout the 6 interventions, and at the 4-week retention after the end of the intervention, for a total of 5 interviews. Interviews were semistructured; this format enabled the interviewer to ask follow-up questions about topics that come up during the interviews, probe responses for deeper understanding, and ask for clarification or elaboration (Arksey & Knight, 1999; Brinkmann & Kvale 2015). The main questions and any known follow-up questions were determined prior to conducting the interviews; to limit undue influence on the part of the author during the interviews, measures were taken to limit bias in questions. Interview questions were assessed by experts in APE and motor intervention who are also skilled in qualitative inquiry to increase the likelihood that the questions are open-ended, unbiased, and nonleading and, in turn, likely to elicit the parents' true feelings and opinions of the parents (see Appendix I). Interviews conducted at the beginning and end of the study, as well as during the retention, were longer and more in-depth. The interview conducted at the beginning of the intervention was used to elicit the parents' current perceptions and understand the family's dynamics (see Appendix I). By establishing a baseline of family behaviors, subsequent interviews were used to identify change, or lack of change, in these behaviors. Interviews conducted every other week throughout the intervention were shorter than the first and final interviews. They were guided week to week by a basic set of questions (see Appendix I), but were added to based on responses from previous weeks. Using a constant comparative method (Boeije, 2002), data collected were analyzed for emergent themes, which was then pursued in the following week's questions. As with the initial and weekly interviews, the terminal and retention interviews was conducted using a prior set of questions (see Appendix I), but, like the weekly questions, were added to as new themes and topics emerge.

Interviews at the beginning and end of the study, as well as at retention, were conducted face-to-face in the most appropriate environment, as described previously, and biweekly interviews will be conducted by phone to prevent the need to make travel arrangements. Phone interviews were also offered for the beginning and ending interviews if conflicts arise with the parents scheduling to alleviate their stress. Ideally, the parent or guardian who typically spent the most time with the child or shares most of the household duties was the person interviewed, as he or she was likely to spend the most time with the child. When and where appropriate, multiple parents or guardians were interviewed to capture the views of the whole family, but priority was given to interview one individual consistently for the entirety of the study. All interviews were audio recorded to allow for verbatim transcription.

Researcher as Research Instrument

Due to the nature of qualitative research, and interviews in particular, the quality of the researcher as a means to access information becomes an inherent part of the design of the study. Piantanida and Garman (1999) state that, "… the researcher is as much a part of the inquiry as the intent of the study and the inquiry process" (p. 24). As an essential part of the study, having the potential to bias or gain limited access to the insights of parents, it is important for me to outline myself as an instrument used within this study.

In preparation for this study, I have sought to prepare myself in a manor to best conduct the research methods I wanted to encorporate within the dissertation. Therefore, during my course studies at the University of Virginia, I took methodology courses in qualitative and mixed-methods design. Further, I conducted research using the proposed methods in two lead-up studies to this study. I, also, sought out experts not only in my field, but within my intended methodology, to gain useful feedback and critique. By discussing the intention of the study and methods thereof, I could hone in on critical elements to include and be aware of.

Futhermore, my background played an important roll in how I sought to answer the intended research question within this study. Formally, I was trained as a physical educator and worked for four years as an elementary teacher working with students with and without disabilities. This experience gave me vital background in understanding the development of children and how to talk with parents about their child's development.

Additionally, during my doctoral training, I furthered my expertice in understanding motor development through coursework and research. This background gave me important insight into what aspects to consider when gauging a parent's perception of their child's ability.

Lasty, it is important to position myself within an idealogical paradigm; as my paradigm provides insight into how I expect information to be gained and what, ultimately, I am inquiring. I, considering my use of methology, fall squarely within the pragmatist paradigm. Within this paradigm, I do not seek to provide "truth" or suggestions of the culture of those participating in this study, but I seek to understand what "works" or the solution to an inherent problem. When considering the delays individuals with ASD have in their motor skill development and the evidence for limited physical activity, as well as the importance of both those skills, it is my goal to gain insight into what parents perceive about these issues. Therefore, creating insight into areas in which there could be intervention to improve outcomes. For this study, I want to understand how changes, or perception of changes, that occur due a motor intervention is perceived at home and incorporated into the daily lives of individuals with ASD and their families.

Phase 3: Data Analysis

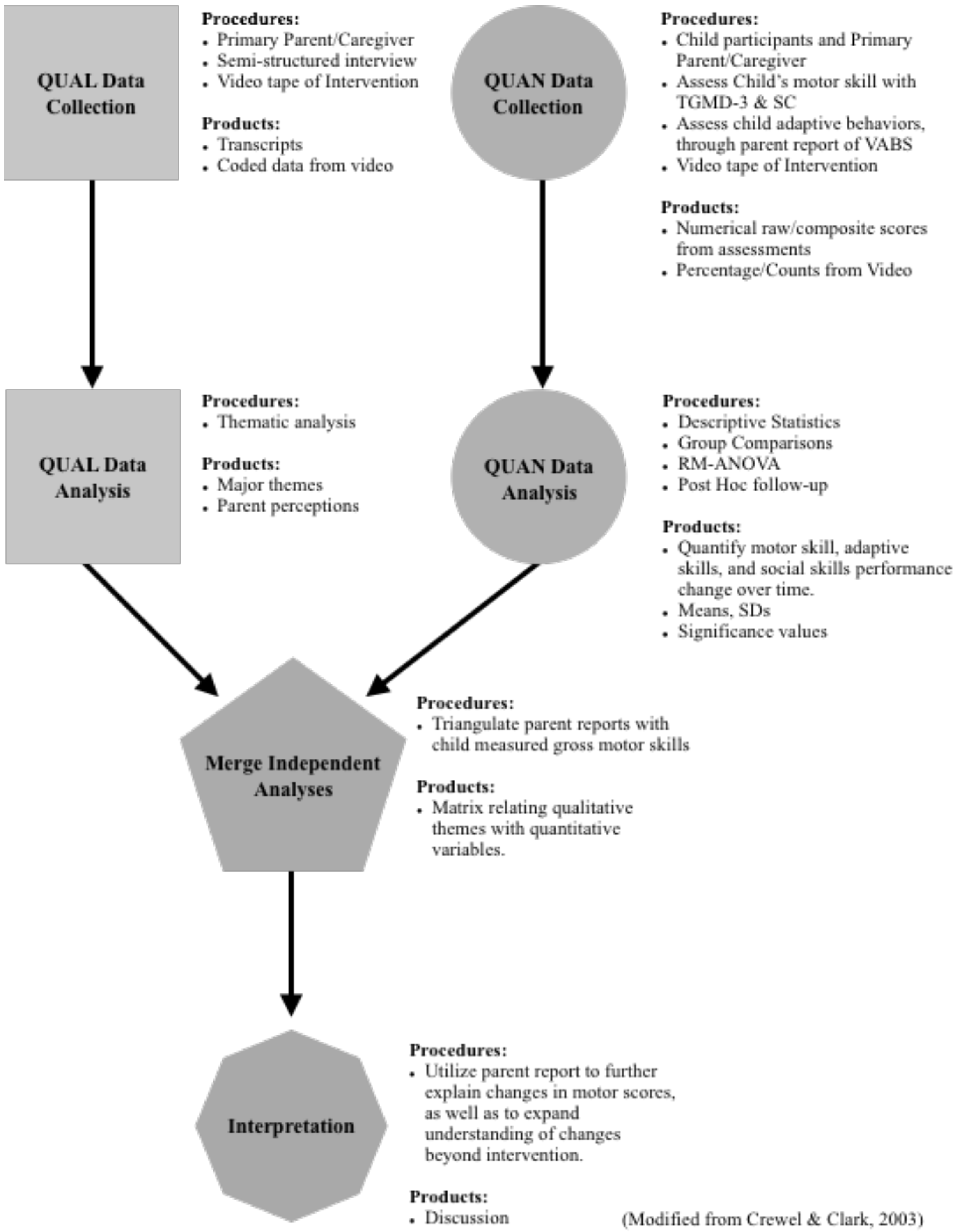
A convergent mixed-methods design involves collecting and analyzing two independent strands of quantitative and qualitative data in a single phase, then merging the results of the two strands to understand convergence, divergence, contradiction, or relationships between the two sets of data (Creswell & Plano Clark, 2003). As shown in Figures 7 and 9, data from quantitative sources and qualitative sources were collected and analyzed independently, but simultaneously. In the following sections, how each strand of data was individually analyzed and subsequently merged for interpretation is discussed. See Figure 9 for the flow of data collection and convergence; see Table 9 for how each research question were answered by the subsequent method and source.

Table 9: Research Questions, Methods, and Analysis

Research Question	Source	Method	Analysis
Do task modifications based on the principles of Dynamic System Theory positively influence motor performance?	Child (All)	TGMD-3 SC	• RM-ANOVA • Post-hoc follow-up
What effect does an intervention based on task modifications have on the development of FMS in individuals with ASD?	Child (ASD)	TGMD-3 SC	• RM-ANOVA • Post-hoc follow-up
What influence do changes in FMS have on the adaptive behavior skills or social skills of individuals with ASD?	Parent	VABS	• Dependent t tests
How do parents perceptions of his/ her child's physical ability change as a result of participation in a motor intervention?	Parent	Interview s	• Coded for parent perceptions. Compare coded themes across entirety of intervention and at followup
What role, if any, do changes in FMS interact with other aspects of a child's life?	Child	-	• Convergence of independent data analysis strands
	Parent	-	

Note: SC = Skill Criteria; TGMD-3 = Test of Gross Motor Development, 3rd Ed.; VABS = Vineland Adaptive Behavior Scales

Figure 9: Parallel Convergent Mixed-methods Design



(Modified from Crewel & Clark, 2003)

Quantitative Analysis

Following completion of the QUAN data collection, a repeated-measures analysis of variance (RM-ANOVA) was conducted using the SC values calculated each week and at retention to determine individual locomotor and object-control changes across the intervention. Further, a RM-ANOVA was run using the TGMD-3 data collected pre-, post-, and at retention to identify differences in overall gross motor ability. A Tukey's post hoc test was used to conduct individual comparisons for each RM-ANOVA analysis to identify individual changes between assessments. A Holm's sequential Bonferroni procedure was performed to account for and limit the family-wise error rate. Time-on-task and number of practice trials were compared using an ANOVA to identify any differences between groups on the means across the intervention. Any differences found between groups were used to interpret findings of the RM-ANOVAs.

Within the ASD group specifically, in addition to the measures described above, values for level of enjoyment and understanding was graphed and analyzed visually to identify these changes over time. By distinguishing changes in understanding, implications were made about the amount of growth demonstrated by participants. Lastly, dependent *t*-tests were performed to identify changes in adaptive behavior and social skills, as measured by the VABS-2. Since the VABS-2 consists of four subtest items and a composite score, data can be analyzed for individual, as well as whole, changes across the entire intervention. Any changes in measurement were correlated with change in SC pre/post intervention to determine how interrelated the changes in motor score are to scores in adaptive behavior and social skills.

The author understands the limitations of using such parametric measures with small sample sizes and the limited generalizability of findings. Statistics were used to identify trends, detect differences, and provide evidence to support visual findings. As an exploration of a new intervention method, data were used to search for differences in outcomes, as well as to identify what might account for changes or lack of changes and should be interpreted with caution. All data were analyzed using the latest version of the Statistical Package for the Social Sciences (SPSS 24.0; IMB, 2016).

Qualitative Analysis

All interviews were audio recorded and transcribed within 1 week of the interview. Transcripts were thematically coded (Braun & Clarke, 2006) using emergent themes to identify themes within the data. During qualitative coding, a peer debrief and member checks were employed to ensure the validity of codes and fidelity of coding procedures throughout the analysis phase. Additionally, during the qualitative analysis, analytic notes were used to capture the process of coding and development of new codes. The constant-comparison method (Glaser & Strauss, 1967) was used to compare themes within and across interviews; this enables similarities and differences to be revealed in the data (Boeije, 2002). This process was used throughout the study to identify trends in the data and allow for follow-up questions during the subsequent interview. By pursuing emergent themes, additional data was collected that confirmed or contradicted these themes and enabled in-depth analysis of what was occurring throughout the intervention. All data was analyzed utilizing NVivo 11 for Mac (QSR International, 2015).

Convergence of Data

Once individual analysis of each thread was complete, data were merged to identify any convergence of findings (Creswell & Plano Clark, 2007). When data have been merged, qualitative themes were used to triangulate with the quantitative variables to expand findings. By merging data, each individual strand of data was given equal weight and used to interpret findings in the other data set (Creswell & Plano Clark, 2007). Qualitative parent themes were analyzed as another way to understand the motor-skill changes demonstrated by the child across the intervention. Additionally, parent themes were used to identify how changes in motor skills interact with other aspects of the child's life. A data matrix of qualitative themes and motor-score changes was produced using NVivo for Mac (QSR International, 2015). The matrix enabled analysis of how changes in motor scores relate to the perceptions of parents regarding the child's physical activity and various aspects of his or her life.

CHAPTER 4

Results

The purpose of this study was to determine the effectiveness of a motor intervention using task modifications, based on DST (Newell, 1986), for building FMS skills in children with and without ASD. Specifically, this dissertation aimed to answer the question: Can task modifications improve the motor performance of children with ASD? Further, this study sought to capture parents' perceptions of the benefits of and barriers to physical activity for their children. Finally, this study aimed to determine the impact of changes in motor performance on the daily lives of individuals with ASD and their families. The study was designed and conducted using a parallel, convergent mixed-methods design. Overall results of the study are presented in three parts: (1) quantitative results, (2) qualitative results, and (3) merged interpretations of both sets of data. Quantitative results are presented in five sections: (a) descriptive, (b) motor performance results, (c) adapted behavior and social skills results, (d) time on task and practice trials results, and (e) the social validity of the intervention. Qualitative results are presented in two sections: (a) overall findings and (b) emergent themes. Lastly, interpretations of the convergence of both independent strands of data is presented.

Quantitative Results

Descriptive

A total of 15 children (n_{males} = 12, n_{female} = 3) divided into three groups (ASD, developmentally-match control [DM], and age-matched control [AM]) participated for the duration of the 6-week intervention. Each of the groups had 5 participants (n_{male} = 4, n_{female}=1) each. Only two participants (1 = DM and 1 = AM) missed sessions; regardless, they completed 83% and 92% of the sessions, respectively. All other participants completed 100% of the sessions. Due to scheduling constraints (i.e. two/three participants had APE time during the same session and were unable to be in the same location), 3 participants in the ASD group were unable to be videorecorded in every session. A total of 6%, 13%, and 46% of the sessions for each participant were unable to be videorecorded; however, each participant received the prescribed amount of instruction. When a videorecording was unavailable, the instructor was asked to provide number of practice trials for that session; no information for successful practice trial or time-on task was collected, as that was determined by the author. Of the participants, 80% were Caucasian (*n* = 12), 13% Hispanic (*n* = 2), and 7% African American (*n* = 1).

Regarding the ASD group, each participant was reported by the parent as being diagnosed with "autism"; this was confirmed through the SCQ (*M* = 25.2, *SD* = 6.4). Each of the participants was diagnosed by a developmental physician, neurologist, or behavioral physician. Furthermore, four of the participants reported having comorbid disorders, such as sensory processing, motor planning, epilepsy, ADHD, low tone, or a general learning disability. Each of the participants was diagnosed before the age of 4, with the majority between 2 and 3 years of age (*n* = 3). Participants in the ASD group demonstrated a wide range of autism-specific behaviors. The majority (80%) lacked functional language; of those participants, 1 demonstrated simple one word requests, 1 demonstrated echolalia, and 2 demonstrated no verbal communication. All used iPads as communicative devices, or as their "voice".

All participants reported an estimate of height and weight, which was calculated to a body mass index (BMI) using the CDC standards for children and teens. A majority of the participants in the AM and DM groups, 90% (n = 9) were in the healthy weight classification, and one participant was classified as underweight. In the ASD group, 40% (n = 2) were considered healthy, 40% (n = 2) were considered overweight, and 20% (n = 1) was considered obese. See Table 10 below for a breakdown of means and standard deviations of participants at entry to study.

To understand differences in activity levels prior to the intervention, a survey was sent to parents (see Appendix K) that asked them to report on the activity levels of the child and of the family and their favorite sports and leisure activities. Each of the parents returned the survey completed. Regarding overall activity, all parents reported that their children were active 5-7 days per week. The differences were seen in the types of activities: Parents of children in the DM and AM groups reported that some of the favorite activities were soccer (50%), biking (30%), tennis (10%), and football (10%). Parents of children in the ASD group reported that favorite activities were running around (80%), swimming (40%), and dancing (20%). Further, when considering team

Table 10: Initial Group Means and Standard Deviations

	ASD	Developmental-match	Age-match
	M (SD)	*M* (SD)	*M* (SD)
n	5	5	5
Age (yr)	7.92 (1.09)	4.40 (.34)	7.75 (.93)
Gender	4 boys, 1 girl	4 boys, 1 girl	4 boys, 1 girl
BMI	18.26 (1.18)	15.38 (.49)	15.34 (.49)
TGMD Pre- Total	20.00 (4.66)	33.40 (2.86)	71.60 (4.08)
TGMD Pre- LM	7.20 (2.354)	17.60 (3.59)	30.60 (2.25)
TGMD Pre- BC	12.80 (2.82)	18.00 (1.41)	41.00 (2.07)
SC Pre - Total	148.07 (14.56)	197.50 (5.11)	251.97 (10.66)
SC Pre - LM	57.77 (10.28)	86.00 (3.26)	103.93 (5.27)
SC Pre - BC	90.30 (4.50)	111.50 (3.59)	148.03 (7.07)
Focus SC Pre - Total	27.30 (3.34)	29.20 (2.03)	27.83 (.55)
Focus SC Pre - LM	11.27 (1.16)	11.60 (.90)	10.63 (.56)
Focus SC Pre - BC	17.90 (1.13)	17.60 (1.48)	17.20 (.61)

Note: BMI = Body Mass Index; TGMD = Test of Gross Motor Development; SC = Skill Criterion; Focus = the skill addressed during intervention; Total = sum of LM & BC; LM = Locomotor subtest; BC = Ball-control subtest.

sports, 100% ($n = 5$) of the AM group and 40% ($n = 2$) of the DM group played team sports, compared to only 20% ($n = 1$) of the ASD group. Lastly, 100% of the DM and AM groups reported participating in some form of non-physically active, leisure activity, such as reading or building activities. In contrast, 40% ($n = 2$) of the ASD group reported non-physically active leisure activities, with the most common response "using an iPad".

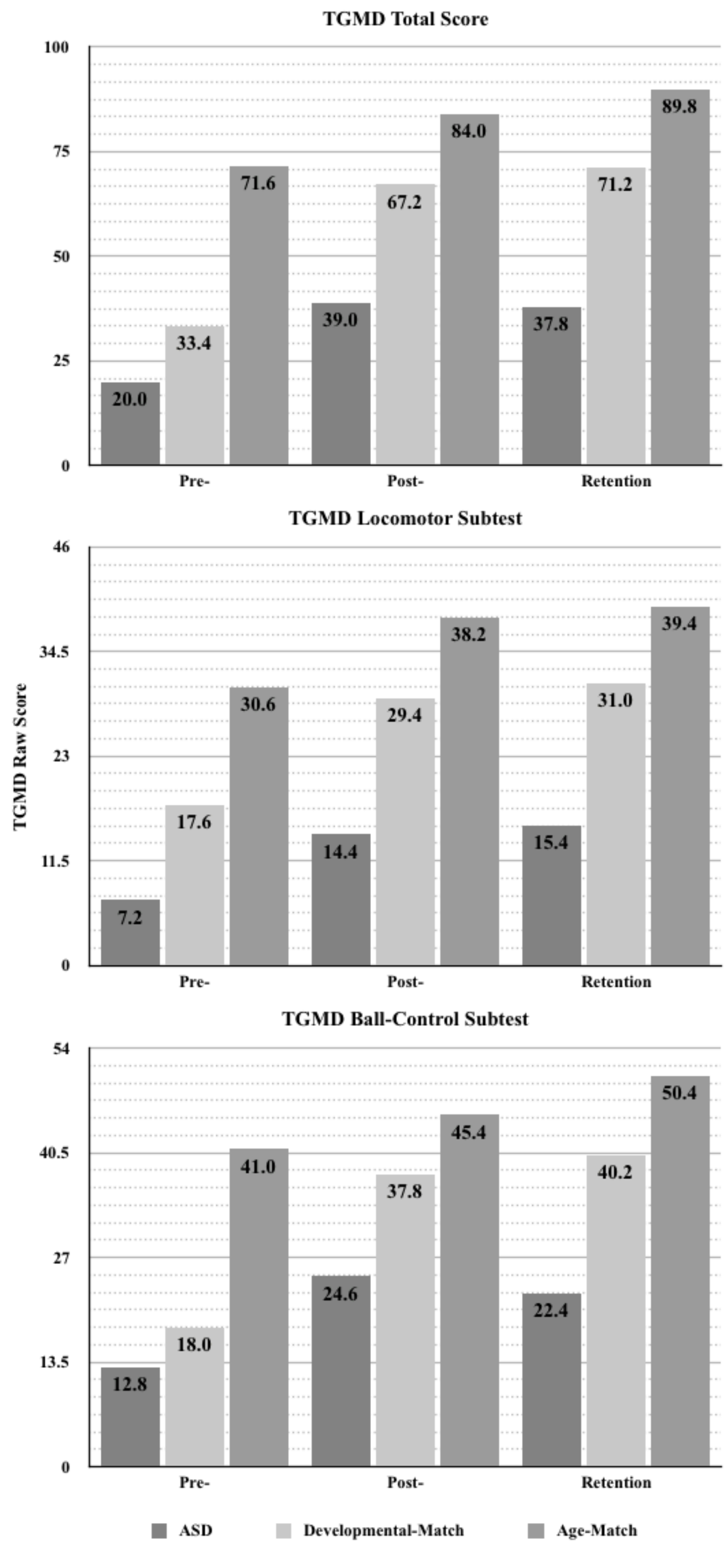
Upon entry into the study, all participants were pre-tested on the TGMD-3 and scored based on the skill criteria (SC) described in previous chapters[16]; see Table 10 for initial means. An initial analysis was performed, testing for group differences among the demographic information and pre-tests. An analysis of variance (ANOVA) was conducted to examine group differences in age and BMI; both analyses resulted in a significant difference between the groups on age, $F_{(2, 12)} = 5.44$, $p = .021$; and BMI, $F_{(2, 12)} = 4.46$, $p = .036$. To further examine group differences in age and BMI—to ensure similarity prior to beginning the intervention—independent *t*-tests were run to compare the focal group (i.e., ASD) against the comparison groups (i.e., DM and AM). Comparison of age and BMI between the ASD and AM group resulted in nonsignificant differences, $t_{(8)} = .116$, $p = .91$ and $t(8) = 2.27$, $p = .052$, respectively. Comparison of age and BMI between the ASD and DM group resulted in a significant difference in age, $t_{(8)} = 3.09$, $p = .015$, but not for BMI, $t_{(8)} = 2.25$, $p = .055$. As the DM group was matched based on developmental skills and not age, this result was expected.

Next, one-way ANOVAs were conducted to test for group differences on the initial pre-test SC and TGMD-3 scores. Prior to this a correlation had been performed on SC and TGMD-3 pre-test scores to determine the reliability in coding between the two

[16] See Appendix C for scoring rubric for each skill component.

assessments; the two pre-test were very strongly correlated, $r_{(15)} = .936$, $p < .001$, suggesting that coding between the two assessments was done similarly. As noted previously, since interrater reliability (90%) with the lab responsible for creating the TGMD-3 and intrarater reliability (92.8%) for the pilot assessment was above the priori criteria of 80%, it is likely that coding for the assessments throughout the intervention was performed with high reliability. The ANOVA for the pre-test of the TGMD and SC were both significant, $F_{(2, 12)} = 46.23$, $p < .001$, and $F_{(2, 12)} = 23.04$, $p < .001$, respectively. However, because the intervention focused on two FMS (i.e., one locomotor and one ball control), a one-way ANOVA was conducted on the focus skills between each group. The ANOVA showed a nonsignificant difference between the groups on the combined focus SC scores, $F_{(2,12)} = .19$, $p = .833$, and on subsequent analysis of the locomotor, $F_{(2,12)} = 1.21$, $p = .751$, and ball-control, $F_{(2,12)} = .1$, $p = .91$, skills. See Figures 10, 11, and 12 for performance scores on the total SC, focus SC, and TGMD-3, respectively.

Figure 10: Performance Scores of Total Skill Criteria



Analysis of Motor Performance

The primary focus of this study was to test the effectiveness of an FMS intervention based on task modifications for children—specifically, children on the autism spectrum. Due to the nature of the intervention, several assessments of each motor skill were completed over the course of the 6-week intervention. A pre-, post-, and retention measure was obtained on the SC and TGMD-3. Further, each of the focus skills (i.e., the individual skills practiced by each participant; see Table 8 for skill breakdown and progression) was measured at pre-, post-, and retention assessment, as well as at the end of each week of the intervention (see Figure 11 for a breakdown of raw scores per week). As a reminder, SC scores were derived from scoring the expanded skill criterion on a 5-point scale from 0-4. This resulted in a maximum possible score of 24 for locomotor skills and 32 for ball-control skills, and a maximum combined score of 56. Group means by week of the focus skills can be seen in Table 11. The following results, while demonstrating strong support, should be interpreted with caution due to small sample size and the robustness of the statistical analysis.

Due to the focus of the intervention on the focus skills (i.e. the one locomotor and one ball-control skill) a repeated measures analysis of variance (RM-ANOVA) was conducted to examine the changes in skill performance across each week, as well as between groups. Further, since the full TGMD-3 assessment battery was given at the pre-, post-, and retention time points, the author could calculate scores for the TGMD-3, as well as for the total SC of the thirteen skills of the TGMD-3. Based on the five-point scale described above, the total score maximum score of 144 for the locomotor skills, 204 for the ball-control skills, and a maximum combine score of 348. Therefore, two additional independent repeated measures analysis of variance (RM-ANOVA) tests were

Table 11: Focus SC Means by Group by Week

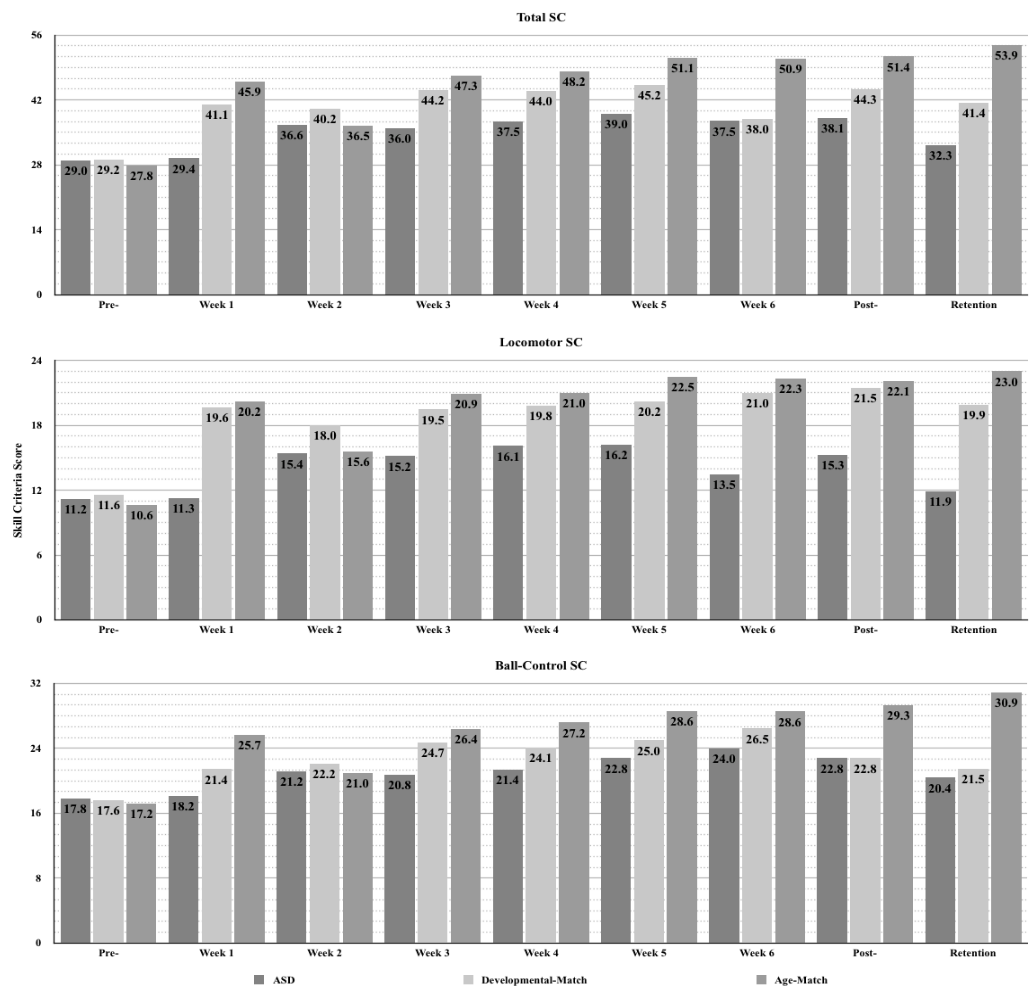
		ASD	Developmental-match	Age-match
Time		*M* (SD)	*M* (SD)	*M* (SD)
1	**Total**	27.30 (3.34)	29.20 (2.03)	27.83 (.55)
	LM	11.26 (1.16)	11.60 (.90)	10.63 (.56)
	BC	17.90 (1.13)	17.60 (1.48)	17.20 (.61)
2	**Total**	29.44 (2.49)	40.16 (1.64)	36.52 (2.17)
	LM	11.20 (1.26)	18.00 (1.43)	15.56 (1.26)
	BC	18.16 (2.08)	22.16 (.70)	20.96 (1.46)
3	**Total**	36.6 (2.57)	41.08 (1.30)	45.92 (1.32)
	LM	15.40 (2.35)	19.64 (.92)	20.24 (1.00)
	BC	21.20 (.80)	21.44 (.64)	25.68 (.92)
4	**Total**	35.95 (2.78)	44.20 (1.42)	47.32 (1.33)
	LM	15.15 (3.32)	19.48 (.71)	20.92 (.94)
	BC	20.80 (1.36)	24.72 (.88)	26.40 (.64)
5	**Total**	37.45 (3.84)	43.96 (1.24)	48.20 (1.33)
	LM	16.1 (4.40)	19.84 (.38)	21.00 (1.06)
	BC	21.35 (1.11)	24.12 (.93)	27.20 (.89)
6	**Total**	39.00 (3.78)	45.24 (.94)	51.12 (.78)
	LM	16.20 (3.38)	20.24 (.82)	22.52 (.67)
	BC	22.80 (1.65)	25.00 (1.23)	28.60 (.92)
7	**Total**	37.48 (3.63)	47.45 (1.03)	50.88 (.67)
	LM	13.48 (2.86)	21.00 (.73)	22.32 (.69)
	BC	24.00 (1.15)	26.45 (.94)	28.56 (.98)
8	**Total**	38.10 (4.31)	44.30 (1.33)	51.4 (1.76)
	LM	15.30 (2.85)	21.50 (.96)	22.1 (.87)
	BC	22.80 (2.01)	22.80 (.73)	29.30 (1.62)
9	**Total**	32.30 (3.97)	41.40 (2.91)	53.90 (.73)
	LM	11.90 (3.44)	19.90 (2.45)	23.00 (.57)
	BC	20.40 (1.07)	21.50 (2.22)	30.90 (.33)

Note: Mean and SD were rounded for presentation, this was done after analysis; Time # = Assessment Pre-, Weeks 1-6, Post-, & Retention, respectively; Total = Sum of LM & BC; LM = Locomotor; BC = Ball-Control conducted to understand changes across subsequent measurements (i.e. pre-, post-, and retention), as well as any differences between groups. Assumptions of the data were examined prior to each analysis.

Since the intervention focus was on the changes of the focus skills, the first RM-ANOVA was conducted using the focus scores from pre-, weeks 1-6, post-, and retention assessments. In the first RM-ANOVA to test the SC of the individual focus scores, Mauchley's Test of Sphericity was violated, $W = .00$, $\chi 2(35) = .87.32$, $p < .001$. As a result, the Huynh-Feldt ($p = .323$) correction was used adjust for the limited similarity in variance. Results showed a significant increase, $F_{(2.59,28.44)} = 12.02$, $p < .001$, partial $\eta 2 = .52$, in the individual focus skills over the course of the 6-week intervention through the retention assessment, which was administered 4 weeks post-intervention. A nonsignificant interaction between each group over time, $F_{(5.17,28.44)} = 2.05$, $p = .10$, partial $\eta 2 = .27$, suggests that the groups increased their scores on the focus skills proportionally over the course of the intervention.

A post hoc Tukey's pairwise comparison using a Bonferonni procedure to test for group differences demonstrated a nonsignificant difference between the ASD and DM groups ($p = .22$) and a significant difference between the ASD and AM groups ($p = .006$). When looking at Figure 11, we can see that each group increases similarly over the course of the intervention on its respective skills; yet, the ASD groups growth was slower than that of their peers. Again, dependent *t*-tests using only data from the ASD group to understand how changes occurred over time found a significant increase between pre- and post-assessments, $t_{(4)} = 4.19$, $p = .014$; a nonsignificant decrease between post- and retention assessments, $t_{(4)} = 3.5$, $p = .025$; and a nonsignificant result between pre- and

Figure 11: Focus Skill Criteria Total, Locomotor, and Ball-Control by Week



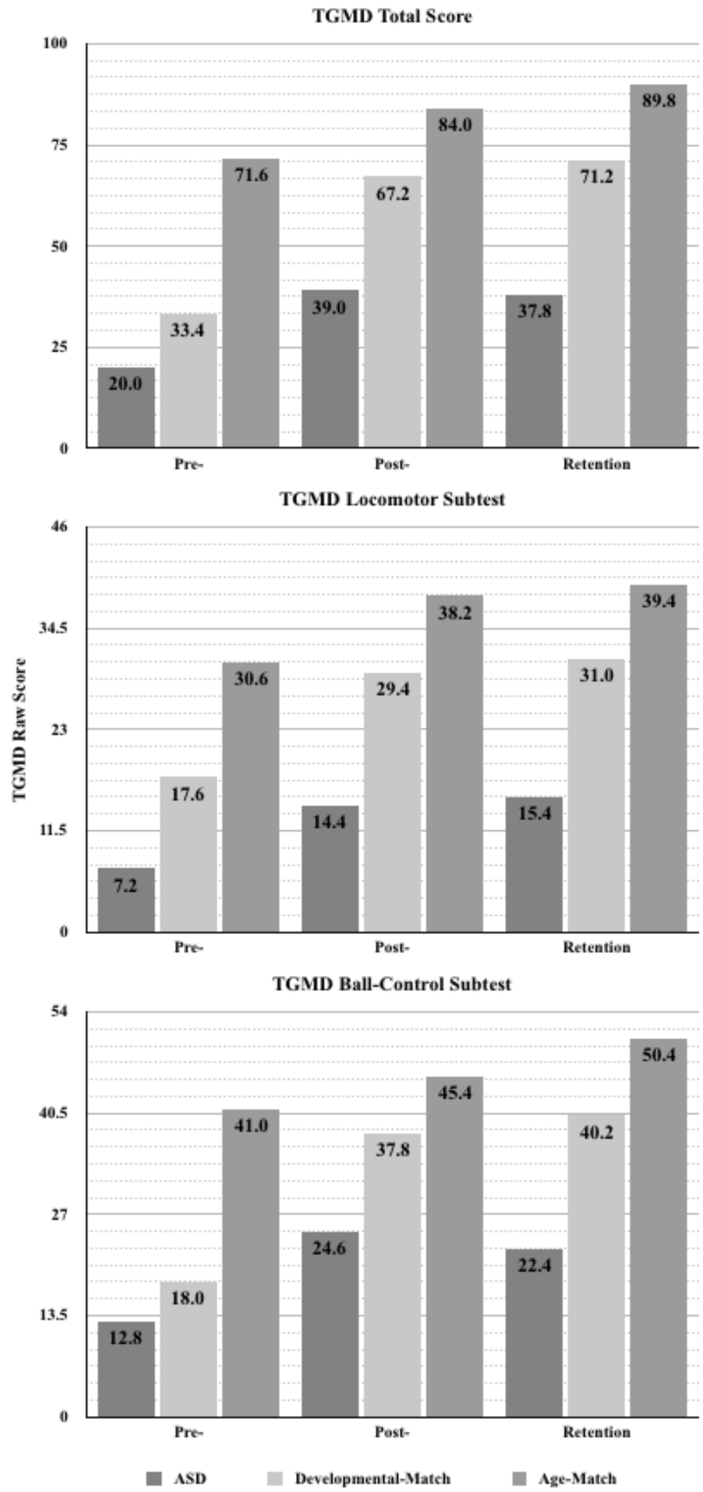
retention assessments, $t_{(4)} = 1.55$, $p = .196$,—further demonstrating an increase from pre- to post-, but limited retention.

Prior to the second RM-ANOVA to test the differences in SC scores at pre-, post-, and retention assessments, Mauchley's Test of Sphericity was, again, violated, $W = .47$, $\chi 2(2) = 8.31$, $p = .016$. As a result, the Huynh-Feldt ($p = .823$) correction was used. As a result of the adjustment, two significant results emerged similar to the first analysis; there was a significant difference in scores across time, $F_{(1.65,19.76)} = 874.09$, $p < .001$, partial $\eta 2 = .99$, and a significant difference between each group across time, $F_{(3.29,19.76)} = 22.16$, $p < .001$, partial $\eta 2 = .99$.

A post hoc Tukey's pairwise comparison using a Bonferonni procedure was done to evaluate group differences. Significant differences were found between the ASD group and the DM ($p = .004$) and AM ($p < .001$) groups. Further, a significant difference was found between the DM and AM groups ($p = .009$). In looking at Figure 10, it is evident that both the DM and AM groups' scores are higher overall, but, it is also evident that each group increased over the course of the intervention. Dependent *t*-tests using only data from the ASD group to understand how changes occurred over time found a significant increase between the pre- and post-assessments, $t_{(4)} = 4.98$, $p = .008$, a significant decrease between the post- and retention assessments, $t_{(4)} = 4.52$, $p = .011$, and a nonsignificant result between pre- and retention assessments, $t_{(4)} = 1.94$, $p = .124$. A Bonferroni p value of .0167 was used in the above measurements to account for the familywise error rate. This demonstrates an increase from pre- to post-, but limited retention.

The final RM-ANOVA tested for differences the TGMD-3 across the pre-, post-, and retention assessments. This analysis was included as reliability measure to the newly created SC due to the TGMS-3 validity as an appropriate measure of gross motor skills. Unlike in the prior two RM-ANOVA, Mauchley's Test of Sphericity was not violated, $W = .92$, $\chi 2(2) = .90$, $p = .64$. As with the overall SC, the RM-ANOVA resulted in a significant difference across assessments, $F_{(2,24)} = 220.57$, $p < .001$, partial $\eta 2 = .95$, and a significant interaction of group and time, $F_{(2,24)} = 17.88$, $p < .001$, partial $\eta 2 = .75$. Again, a post hoc Tukey's pairwise comparison using a Bonferonni procedure demonstrated a significant difference between the ASD and DM ($p = .003$) and the AM ($p < .001$) groups. Additionally, significant differences were found between the DM and AM ($p = .004$) group. Figure 12 shows the differences between groups across each assessment.

Figure 12: Performance Scores of Test of Gross Motor Development, 3rd



Lastly, dependent *t*-tests using only data from the ASD group to understand how changes occurred over time found a significant increase between the pre- and post-assessment, $t_{(4)} = 10.01$, $p = .001$; a nonsignificant difference between the post- and retention assessments, $t_{(4)} = 1.04$, $p = .358$; and a significant difference between pre- and retention assessments, $t_{(4)} = 6.81$, $p = .002$. This demonstrates an increase from pre- to post-assessment and a sustained result from post- to retention. The difference between TGMD-3 and SC results on retention may have to due with qualitative coding differences in variables. Participants in the retention assessment for the TGMD-3 may have performed the skill completely enough to gain credit for the included criteria; however, with the addition and expantion of the criteria in the SC, children may have not improved on the added criteria. For example, the SC adds the "T position" for the overhand throw that is not in the TGMD.

Analysis of Adaptive Behavior and Social Skills

Another aspect of this study was to explore the relationship between potential changes in motor skills and resulting changes in adaptive behavior and social skills. To capture potential changes in these behaviors, parents were asked to complete the VABS-3 prior to the intervention, and again immediately following. The VABS-3 results in standard Adaptive Behavior Composite (ABC), as a result of agrigating three to four subdomains, depending on age. The subdomains are: Communication (COM); Daily Living Skills (DLS); and Socialization (SOC); and a Motor skill composite (MOT). As the MOT was only standardized for individuals up to 10 years of age, it was not possible to calculate a composite for each participant; therefore, the MOT was left out of the ABC, as recommended by the VABS-3 manual. To understand changes in adaptive behavior and social skills, dependent *t*-tests were conducted to examine pre- and post-intervention scores. Results were nonsignificant, showing no change in the ABC, $t_{(4)} = .05$, $p = .97$, COM ($t_{(4)} = .34$, $p = .75$) DLS, ($t_{(4)} = -.99$, $p = .38$), or SOC ($t_{(4)} = .34$, $p = .71$) subdomains. This suggests that there was little immediate change in adaptive behavior or social skills due to significant changes in motor skills.

Understanding Changes in Motor Performance

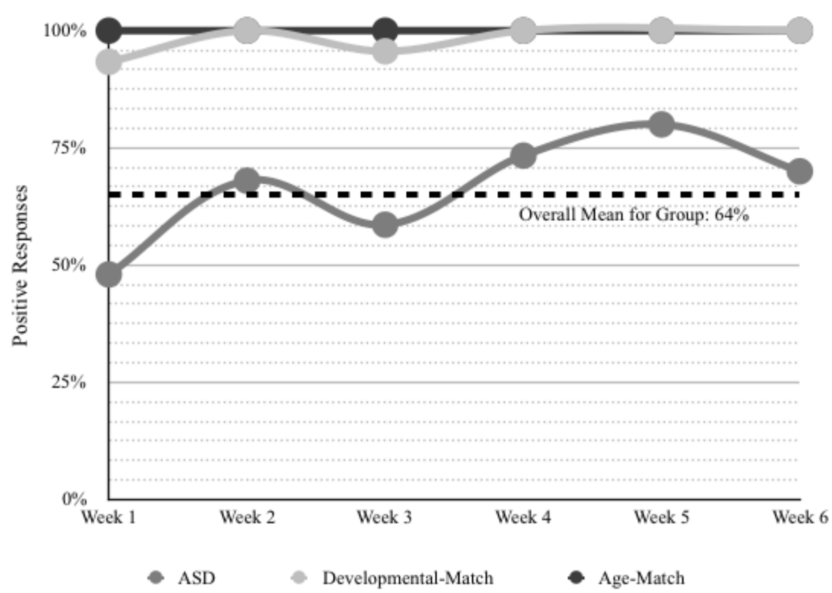
To understand differences between groups in terms of motor skill improvement, several measures were obtained to identify potential intervening variables; enjoyment (M-PACE), understanding, average practice trials per week, average successful practice trials per week, and average time on task. The mean scores from each assessment are shown in Table 12 below. An ANOVA was completed on each of the variables to test for group differences. As a reminder, M-PACE was calculated using a two-picture scale, scored as Happy or Not Happy. "Understaning" was measured by response due to a three-picture card with responses as either correct or incorrect; an "I don't know" or no response was scored as incorrect. The M-PACE and Understanding reported as percentages with 1 being 100% happy or correct, respectively, or 0 being 0%. As can be seen in Figure 13, with regard to enjoyment, there was a nonsignificant difference between the groups, $F_{(2, 12)} = 3.35$, $p = .07$; this suggests no difference between group levels of enjoyment during the intervention. Yet when looking at the graphed response, the ASD group, in contrast, is clearly lower than the other groups throughout the intervention. An upward trend is present, however, throughout the intervention. While the result of the ANOVA was non-significant, the result was approaching significance and due to the small sample size, this result should be interpreted with care. Further, due to the nature of this variable (dichotomous responses) and limited knowledge of the validity of these participant responses, the power of these findings on enjoyment and understanding should be interpreted with caution.

Table 12: Mean Enjoyment, Understanding, Time on Task, & Practice Trials

	ASD	Developmental-match	Age-match
	M (SD) Range	*M* (SD) Range	*M* (SD) Range
M-Pace*	.64 (.19) .02-1.0	.97 (.02) .90-1.0	1.0 (.0) 1.0-1.0
Understanding*	.54 (.14) .12-1.0	.98 (.02) .91-1.0	1.0 (.0) 1.0-1.0
Time-on Task*	.78 (.08) .55-.97	.96 (.02) .91-.99	.97 (.01) .92-.99
Practice Trial**	73.97 (21.48) 26.33-148.50	103.91 (1.84) 100.33-110.40	102.17 (6.63) 80.83-122.00
Successful Practice Trial**	55.1 (18.92) 13.00-122.67	87.97 (5.47) 75.33-105.00	97.63 (5.12) 80.50-111.833

Note: Mean, SD, and Range were rounded for presentation, this was done after analysis* = percentage of responses; ** = number per week.

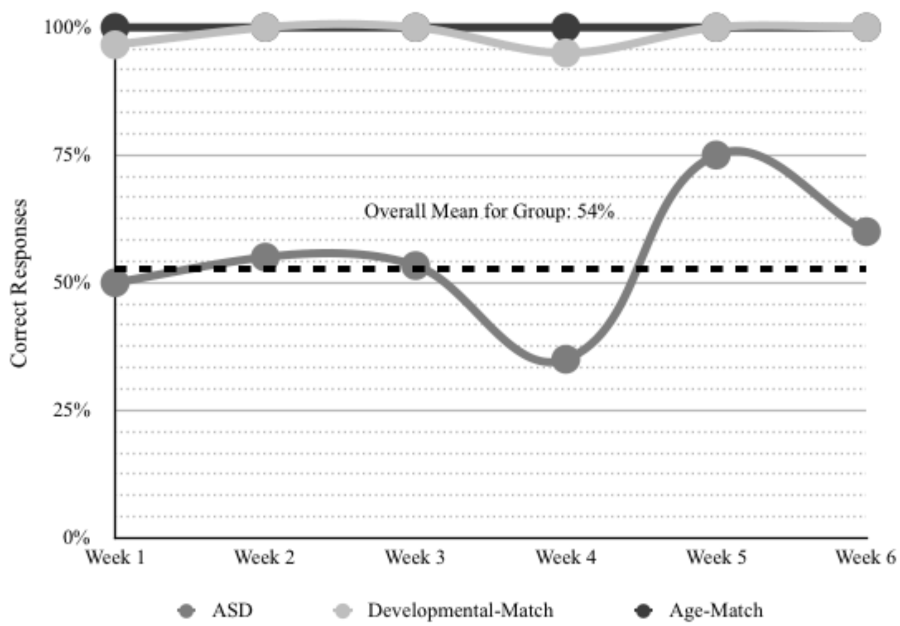
Figure 13: Participant Enjoyment by Week



Note: Percentages exclude decimal point; decimal points were used in calculations.

The next analysis was of differences between groups in participants' understanding throughout the intervention. Again as with the enjoyment variable, understanding should be analyzed with caution. An ANOVA resulted in a significant difference between the groups, $F_{(2,12)} = 10.08$, $p = .003$, on their understanding of the task they were performing. Further, a post hoc Tukey's analysis showed significant differences in understanding between the ASD group and the DM ($p = .007$) and AM ($p = .006$) groups. In looking at Figure 14, again, the ASD group is much lower than the comparison groups. Again, however, the ASD group's understanding increases overall across the intervention. However, there is huge swing in responses between weeks 3 and 5; this could be attributed to not fully understanding the task modification during week 4, then grasping it in week 5. Additionally, there was a holiday break between weeks 3 and 4. This could also explain the dips seen in both Figures 13 and 14.

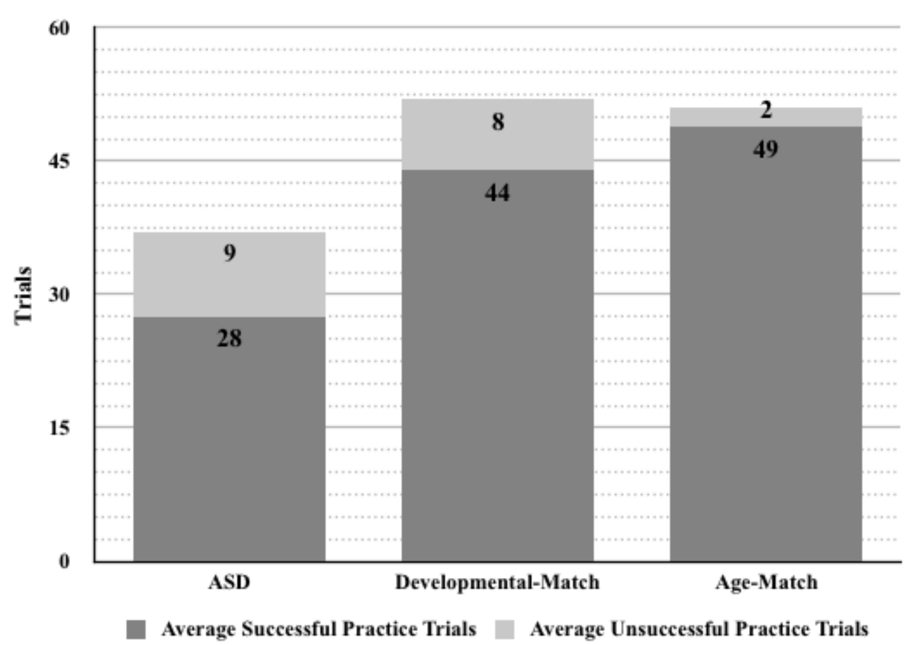
Figure 14: Participant Understanding by Week



Note: Percentages exclude decimal point; decimal points were used in calculations.

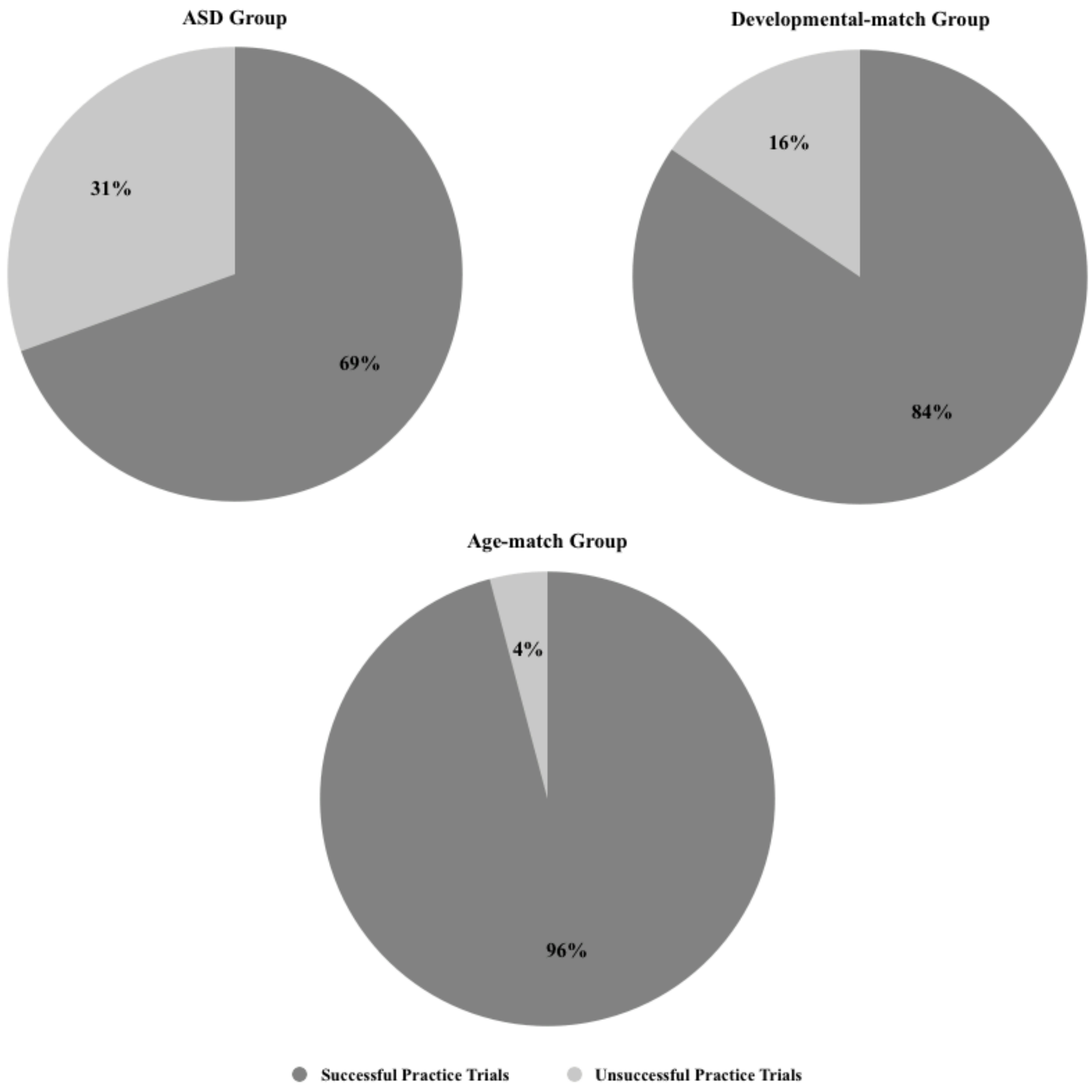
The next analysis resulted in a nonsignificant difference for each group in average practice trials, $F_{(2,12)} = 1.67$, $p = .23$, and successful practice trials per week, $F_{(2,12)} = 3.60$, $p = .06$. Interestingly, when looking at the breakdown of successful practice trials and overall practice trials, as seen in Figures 15 and 16, group differences are apparent even though they are not statistically different. It is clear in the figures that not only did participants in the comparison groups receive more practice trials per week (Figure 15), but they also performed a larger percentage of successful practice trials than their ASD peers (Figure 16). This potentially could have influenced the overall group difference in growth throughout the weekly, post-, and retention assessments, as there is evidence to suggest that the amount of practice time and number of successful trials can influence performance.

Figure 15: Breakdown of Practice Trials per Week by Group



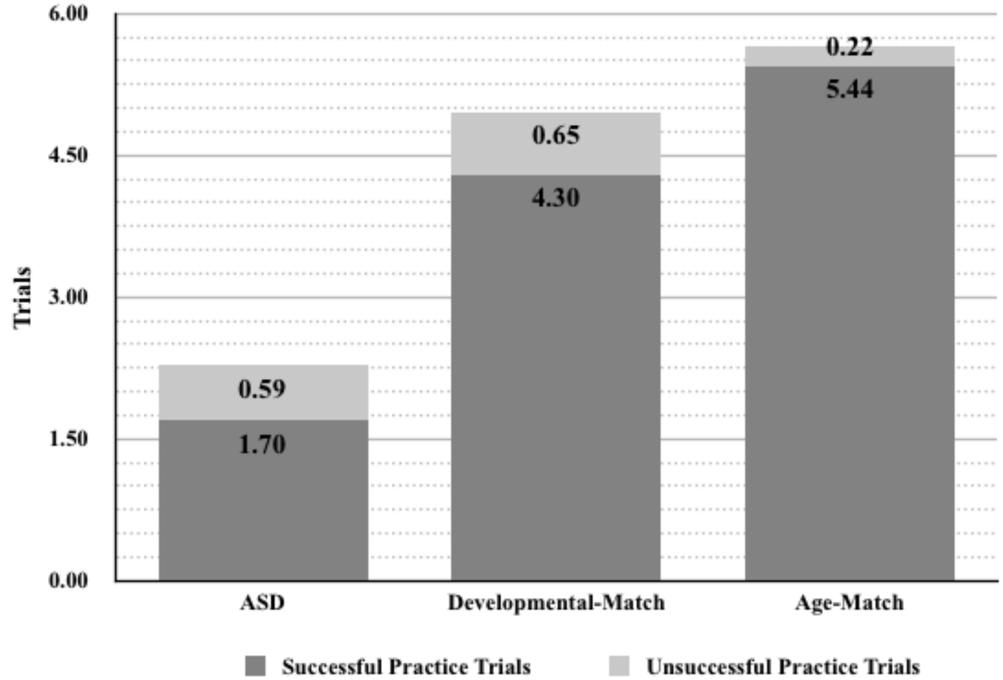
Note: Averages exclude decimal point; decimal points were used in calculations.

Figure 16: Percentionage of Practice Trials per Week by Group



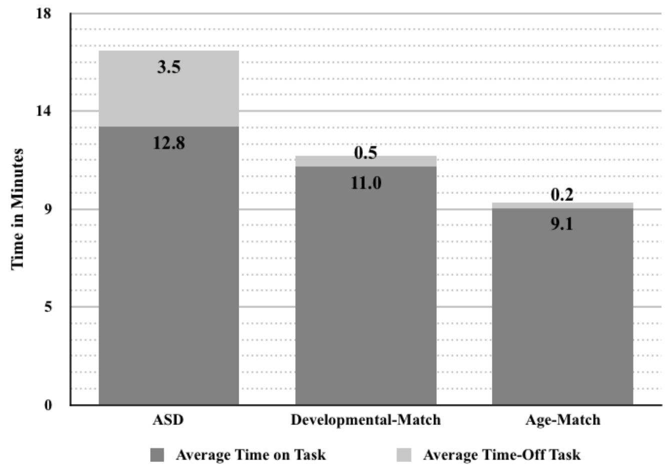
Going one step further, Figure 17 shows the results of breaking practice trials down by number per minute, with a clear difference between the ASD and comparison groups. Individuals in the ASD group, on average, completed about 2 practice trials per minute, with nearly a quarter unsuccessful. In contrast, the comparison groups completed around 5-6 trials per minute, with a much small number of unsuccessful trials.

Figure 17: Breakdown of Practice Trials per Minute by Group



The last ANOVA comparing the average time on task per week resulted in a significant difference between groups, $F_{(2,12)} = 4.49$, $p = .035$. As a reminder, time on task was operationalized as the time spent engaged in either the activity, the instructor, or on designated break; this variable is reported in rate per minute. This suggests that the time spent during each session was significantly different for each group. However, a Tukey's post hoc analysis did not show individual differences between the ASD group and the DM ($p = .087$) or AM ($p = .058$) groups. When looking at a breakdown of the percentage of time spent during each session (Figure 18) and the breakdown of each minute, differences between the groups stand out—namely, that sessions were longer for the ASD group—and much more time was spent off-task compared to the other groups.

Figure 18: Breakdown of Average Time Spent per Minute by Group



To further explore differences between groups, several correlations were conducted to look for relationships between enjoyment, understanding, time on task, and mean changes from pre- to post-assessment overall and on the focus skill. Results can be seen in Table 13.

Table 13: Correlations with Mean Changes of Motor Performance

	1	**2**	**3**	**4**	**5**	**6**
1. Change Pre- to Post-SC	1					
2. Change Pre- to Post-Focus SC	0.683**	1				
3. Successful Practice Trials	0.601*	0.699**	1			
4. Time on Task	0.618*	0.609*	0.789**	1		
5. Understanding	0.778*	0.717**	0.893**	0.828**	1	
6. Enjoyment	0.644*	0.534*	0.516*	0.34	0.751**	1

Note: * = $p<.05$; ** = $p<.001$.

Several interesting relationships stand out as significant. Enjoyment, understanding, average successful practice trials per week, and average time on task were all significantly correlated to changes in both overall and focus-skill pre-post changes.

These results suggest that the more an individual understands an activity, the more he or she will enjoy the activity; in turn, the higher rates of success and engagement are likely to result in greater overall changes in motor performance scores.

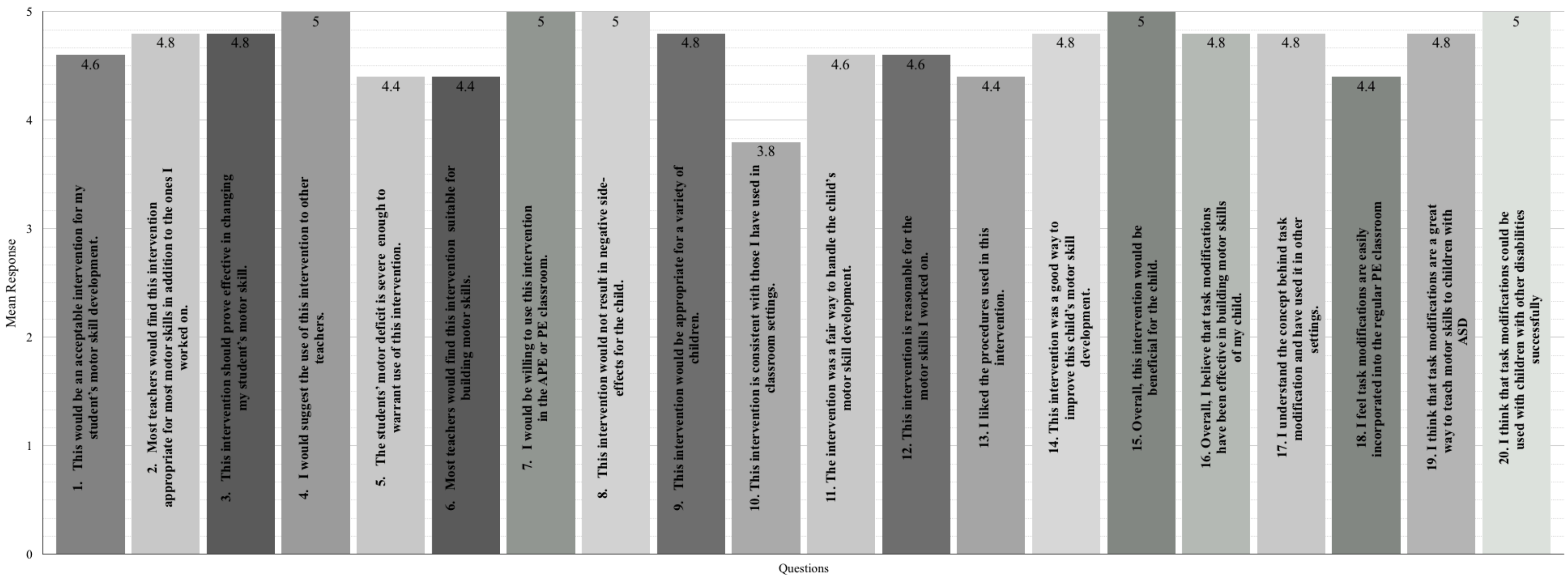
Social Validity Results

Lastly, each of the eight instructors was asked to provide feedback about the intervention itself to determine its practicality and serve as a means for improving on the design to provide the best outcomes for participants. Sixty-two percent of the instructors (*N*=5) returned the social validity questionnaire; participation in the questionnaire was not required to be an instruction. Instructors were asked at the end of the intervention to consent to their response on the questions, so that they may be included within the study report. Additionally, the questionnaire was sent during the time that instructors had final exams for their university and just prior to a holiday break. This may have influenced the response rate of the participants. Regardless of reason, due to a non-response from all the instructors, the following results can not be assumed to be representative of every instructor's experience.

Of the instructors to response, each answered a total of 24 questions. Questions 1 through 20 were scored on a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*), and questions 21 through 24 were open-ended. Results from the survey are broken down by question in Figure 19. Respondents rated the intervention very favorably overall, with most the responses between 4 and 5. The lowest response (*M*= 3.8) was for question 10 ("This intervention is consistent with those I have used in classroom settings"). Five questions received the maximum possible response (*strongly agree*): "I would suggest this intervention to other teachers"; "I would be willing to use this intervention in the APE or PE classroom"; "This intervention would not result in negative side-effects in the child"; "Overall, this intervention would be beneficial for the child"; and "I think that task modifications could be used with children with other disabilities successfully".

On the open-ended questions, when asked whether the length of the intervention was sufficient, respondent comments included "Progress was seen during the 6 weeks"; however, one instructor stated that "6 weeks was not long enough to master or fully develop the skill." When asked what was most beneficial, one instructor responded, "The breakdown of the task and the tactile modifications allowed our student to better understand what and how he needed to do the tasks." Another stated, "The task modifications really helped students receive embedded feedback for the component of the skill." Lastly, when asked what could be improved, one respondent stated, "A significant amount of time is needed to make a notable difference in the motor abilities of my child."

Figure 19: Mean Responses of Social Validity Questionaire



Qualitative Results

To understand the effect of an FMS motor intervention delivered in a school environment on parent perception and potential motor changes at home, interviews were conducted with each participant's closest guardian. Over the course of the intervention, parents were asked to participate in several interviews that corresponded to individual aspects of the intervention process. Interviews were conducted both in person and by phone to accommodate parents' schedules and the geographical separation. Six parents were interviewed over the course of the intervention. To be included in the analysis, parents were required to respond to the pre-, post- and retention interviews. In addition, they were invited to participate in biweekly interviews throughout the intervention to capture any changes in the home environment. Five of the six parents participated in these biweekly interviews. To protect their anonymity, pseudonyms were used. Major themes that emerged from parent interviews are discussed in the following section, along with examples of each finding. The following parents participated:

Kathy is the grandmother of ***Adam***, an 8-year-old boy with autism. She has custody of Adam and is his primary caregiver. She has one other grandchild who is not autistic.

Fahima is the mother of ***Nishaat***, an 8-year-old boy with autism. Fahima is married and has no other children.

Taylor is the mother of ***Isaiah***, a 6-year-old boy with autism. She is a single parent with one older son, who is not autistic.

Gary is the father of ***Liz***, an 11-year-old girl with autism. Gary is married and has one younger daughter, who is not autistic.

Mike and ***Elaine*** are the parents of ***Robby***, a 5-year-old boy with autism; they also have a younger son with autism. Mike was the primary respondent.

Overall findings

Each interview was transcribed and coded for emergent themes over the course of the intervention. To capture weekly changes, codes and emergent themes were checked the following week to affirm the findings' trustworthiness (Lincoln & Guba, 1985). Regarding the RQ2, there was little evidence emerged that changes in motor skills resulted in changes in behavior or activities at home. Over the course of the interviews, it became evident that increases and decreases in the apperances of desired or unwanted behaviors happened independent of any motor gains from the intervention. When asked whether any new behaviors had emerged, Gary stated, "The same. The behaviors cycle every 2-3 months in their intensity." Fahima said that Nishaat was "more willing to imitate—I mean, his imitation is on the increase, which makes me really, really happy." Kathy stated, mid-intervention, that Adam was "still spastic when he runs and he still runs forward like he's getting ready to fall."

However, while there was little relationship between changes in the intervention and changes at home in terms of motor skills and physical activity, several parents said that their view of physical activity had changed since taking part in the study. Kathy said:

> You've actually made me rethink the physical activity piece . . . I'm always so negative—we can't go outside, we can't be active like we were. But we were still doing these things, I just wasn't thinking about it. And now I'm trying to be more creative with how we're physically active, how I get him to be physically active.

While there may not have been a direct relationship with changes in the home because of increased motor skills, it appears simply talking with parents about physical activity can impact their views. Some may argue that having repeated conversations with parents and guardians about their child's physical activity could be regarded as an intervention. The author acknowledges this possibility and while some parents in this study mentioned that their views regarding physical activity had changed, others, like Gary, said, "Nope, nothing's changed". The parent's viewpoints notwithstanding, perhaps not surprisingly, interviews with parents revealed several barriers and benefits to physical activity. In considering the guiding theory for this dissertation, DST, the benefits and barriers described by parents could be considered environmental constraints for children in theirdevelopment and production of motor skills.

Emerging from the interviews and independent of their own viewpoints, it became evident that parents understood the benefit of physical activity; however, multiple barriers act as inhibitors to being physically active. Taylor stated that Isaiah can "burn a whole lot of energy . . . and when he [can't be active], you can see how much more restless he is." Mike said that physical activity is "a really positive thing," and added that it helps Robby "stay focused on academics . . . and helps him with his bad behaviors, or stimming." Fahima stated that without physical activity, her son "doesn't know how to deal with autism" and that "being physically active helps him mentally." She went on to state that as a family, it was "good for the overall mental health" and that they "come back smiling, even though they have tons of errands to run or whatever." Kathy said that physical activity "plays a big role in [Adam's] life. The more physically active he is, the happier he is, the more he is willing to—the more he is able to be focused on other things."

In contrast to the benefits of physical activity, however, parents described several barriers to physical activity. The themes that emerged from the interviews regarding barriers were acceptance, child behaviors, financial strain, safety concerns, support networks, and time. Each parent recognized each of the emergent barriers in their lives in some way, but often felt unable to do anything about them. For example, in response to questions about the limited support network, Kathy said that "you can't impose on people all the time." In response to a question about the activities her family enjoys doing, Fahima said that she does rely on support to help provide care for Nishaat, but went on to say, "I would like to do more, but unfortunately, I do the best that I can right now."

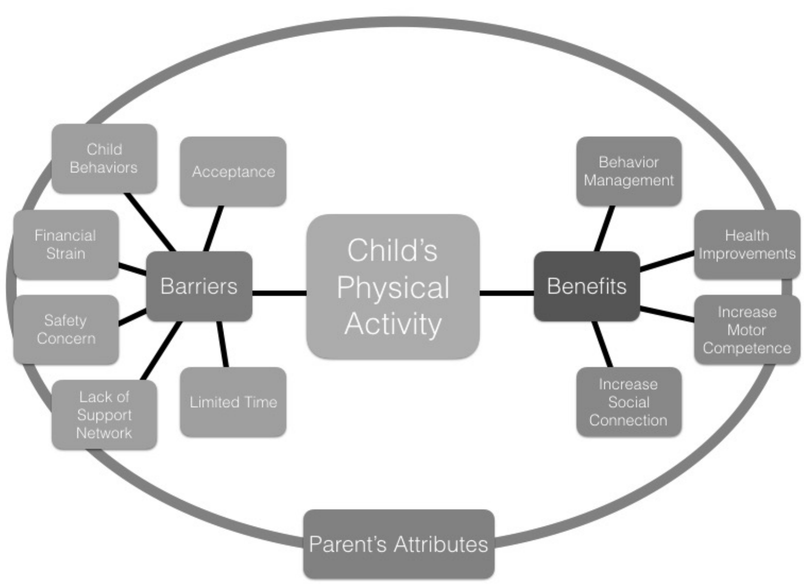
However insurmountable the odds seemed to them, parents maintained an overwhelmingly positive attitude and remained grounded in their expectations. Taylor said:

> Sometimes when you don't have that support, you've kind of got to figure it out by yourself, and you've got to motivate yourself at times. Sometimes I have a support group, and—I mean, sometimes I *don't* have a big support group. So at times, it's just me motiving myself to—you know, "Hey, I've really got to work harder on things to get things the way they need to be.

To do so, parents celebrated small victories and maintained a positive view on what still needed to be done. Kathy said, "Then you have that achievement. That smile. Or when they say, 'Love you,' and everything is just okay again. Everything's okay again." Fahima said that while reading a book together, she and Nishaat had had a back-and-forth dialogue. “That made me feel very happy. I think it made him happy as well. It happened [for], like, five minutes, but the video he’s been watching became more meaningful for the both of us.”

The remainder of this section outlines the themes that emerged regarding physical activity and parents perceived barriers and benefits; the major themes are presented in Figure 20 below. As can be seen in the figure, parents discussed multiple different facets of each. However, it emerged that they themselves played a role in those benefits and barriers. Their attitudes and attributes could overcome any barrier and increase the likelihood of any benefit, yet benefits and barriers influence how they viewed their own impact and opportunity. When considering this in terms of DST, parents themselves can act as an environmental constraint as powerful as any other barrier; the parent’s behavior has a tremendous power to influence their child’s motor development and physical activity, either negatively or—in most cases—positively. The following section will discuss each area in further detail.

Figure 20: Map of Major Themes



Emergent themes

In the following section, the topics that emerged in relation to physical activity are discussed. Primary themes were classified into two categories: benefits and barriers. These categories, in this analysis, are framed as environmental constraints; external to the child participants, but still very influencial to the development of skills and activity. The emergent benefits consisted of everything parents attributed to outcomes of physical activity; whether the child could do it or not, parents attributed a great deal of weight to the benefits of physical activity. Equally, however, parents discussed overwhelming barriers that prevented their child from being able to participate in as much physical activity as they, the parents, would have liked or knew their child should get. Encompassing all the benefits and barriers, however, was attributes—positive and negative—that the parents had, acting as their own environmental constraints, to ease some of the barriers and access some of the benefits.

Physical Activities Barriers

Much of the conversations with parents involved aspects of physical activity and how they view it. This inquiry's purpose, understandably, would have caused our conversations to largely relate to PA; however, aspects of parents' experiences revealed elements of their lives that could only be seen as barriers. For example, the way families were organized revealed difficulty with finances that, in turn, served as barriers to physical activity. In two families, one parent stopped working to be flexible enough to care for their child or children. In the single-parent homes, parents were compelled to work longer hours and therefore needed to rely much more on a social network for support. Six related subthemes emerged during data collection and were discussed several times with parents to understand the barrier and gauge whether it affected their lives to any degree; the subthemes that emerged are (a) acceptance, (b) child behaviors, (c) financial strain, (d) safety concerns, (e) lack of support network, and (f) limited time.

Acceptance. Overall, parents cited their child's lack of acceptance as a barrier to being physically active—or even being socially active. When asked about how acceptance plays a role in his child's level of physical activity, Gary said that is "definitely" does. "Her behavior can lead to constant staring from others. You get the feeling you are the center of attention." When considering what skills might be needed for his child to be active later in life, Mike replied that it's "not something I've thought of. . . I guess access to a gym that would be more, I guess, autism-friendly." Further on, he said that "even most childcare [where he lives] is not set up for somebody who is kind of resistant to social interaction, and new scheduling, and new experiences." Kathy said, "We get vile looks and vile comments all the time. And it makes the beast want to come out in me." However, not every parent was as affected similarly by social situations. Taylor said, "I get looks and stuff, but at the same time, I pay it no mind, because at the end of the day, that's my child, and . . . I don't really care about their opinions or their looks or anything like that." At the other end of the spectrum, Fahima had recently been "devastated" by a rejection from a summer camp for autistic children and said that she had been "caught off guard."

Child behaviors. Another limiting factor for physical activity is the behaviors from the child, themselves; children with autism often present unique needs and in many unique ways. Perhaps one of the connecting elements from above is that even with acceptance, most people do not understand the variety of ways behaviors can appear within the autism spectrum. For instance, the five children in the study displayed, at some point, all the characteristics that would be under the ASD umbrella including repetitive behaviors, restricted interest, social communication issues, sensory issues, transitioning issues, aggressive behaviors, refusals, lack of motor skills, limited motivation, and, perhaps most pervasive, constant need for attention. This need for attention, however, is not the child's desire to command attention, but rather the parent's need to be ever vigilant in keeping the child occupied and safe. Fahima said, "It's like a constant toddler or a baby. You have to watch him 24/7, and it feels like that for nine years." Kathy stated that the only time she has for herself is "when he's at school, and then I'm talking to doctors, nurses, . . . whomever, about Adam 99% of the time."

Financial strain. As mentioned earlier, the family dynamics changed with diagnosis of autism. In some cases, one parent stopped working or reduced their work to be able to have the flexibility to "keep all the boats afloat," as Mike put it. Even when considering engaging in physical activity or having an opportunity to socialize with other parents, Fahima said, "some families are rich, they are like, 'Let's go to the resort.' I'm like, 'I cannot do the resort; I can go to the park, which is free.'" There is much evidence on the "costs" associated with disability. especially autism. Some estimates suggest cost for a child with autism can be, on average, about $60,000 per year for care, education, and associated medical costs. Now, any new child will cause a family to have to readjust their lifestyle; yet, the additional costs associated with the needed care for a child with ASD causes parents to have to take extra measure to be able to afford the extra costs. This often leaves parents little to spend on extracurricular activities, which are usually not free.

Safety concerns. Most parents, regardless of whether their child has a disability or not, have safety concerns. However, parents of children on the autism spectrum often have this concern on a very different level. In many instances, parents worried about that they child might run away or walk into traffic or go off with a stranger. Mike said that his street is "not really safe for . . . somebody who has no real awareness or fear of traffic." Kathy talked about how Adam had "no stranger danger" sense and said that he would often "go up to people and hug them." When asked whether there were any activities that she did with her children as a family, such as walking in parks, Taylor responded that "a park is a really open area . . . If I am not having somebody else with me, I wouldn't go by myself," because Isaiah would just "want to explore it."

Lack of support network. As one parent put it, "I need another one of me." A support network and an additional caregiver "provide breaks for parents," Gary said. Yet it is often difficult to find care that is reliable or even available. Fahima said that Nishaat was unable to play in a soccer game, because "the coach who was helping him didn't come, so [the other coach] didn't want us on to be on the field, [and] there was nobody to help him." Two parents cited a lack of social networks; Mike said that they "don't have a lot of friends," and Kathy stated that she's "lost most of [my] friends because nobody wants to hang out when Adam's going to be into everything." However, one parent found that social media helps her connect with other parents and "find solutions to our problems"; as a result, she "doesn't feel so lonely." Another parent did not find that online support filled all her needs; she said that "there's nothing local, there's no real support groups," and that it "would be helpful, if nothing else, [to] give the parents a place to go."

The loss of a caregiver or changes in schedules can also provide extraneous stress, limiting the possibility of physical activity. Kathy said:

> There's a three-week time period where his therapists are going to be off, which means that we're going to have a week and a half of no therapist in the home for him. That means no daily walk, which is going to set his mood into—I see the onset of anger and depression and everything coming in. I can keep to his daily routine as best I can, find out what they've been working on for the last couple weeks, try to work on it at home, you know, for school. And I can still do the indoor therapy piece myself, but he's going to be sick to death of me, because he has such a large support network that he's not going to have. So it's going to be a major impact. Negatively.

As mentioned in the previous sections, changes in motor performance's impact on parents' perceptions of their child's physical ability may not be noticeable immediately. Parents' primary concern seems to be, at this point, getting through the day and making sure everyone is happy.

Limited time. Time was a universal concern for all parents. In trying to get anywhere, Mike said that they "have to pack like we are moving out. We take a cooler with us 'cause we could not ever stop at, like, a grocery store or a restaurant and have food that he would eat." He said at another time that "getting him ready to go could take about half an hour . . . If the whole damn family is going [and] we didn't prep the night before, then it's probably going to be an hour or so, [even] if were [not] going to spend more than, say, 45 minutes or an hour outside of the home." In addition to needing to prepare for any activity well in advance, parents themselves ended up work very long days, from the time they wake their child to the time they put them to bed. One parent stated that he only got only four to five hours of sleep, and another said that when they have an opportunity to get out on their own or have dinner as a couple, it is never for long—and if they stayed out late, they would have a "whole 24 hours with [their child] the next day."

Benefits of Physical Activity

The barriers described by parents paint a dark picture of life with a child with autism, which is often the cause with much of the body of research for autism, but parents also demonstrated a great deal of persistence, strength, and positiveness. This behavior could be explained by parents having a certain level of grit or a growth mindset[17]. In discussing physical activity and motor skills with parents, in some instances, they realized they were doing more than what they had originally thought. Fahima said she believes that "physical [activity] makes him feel more comfortable with himself . . . because he can actually feel better with the spectrum challenges, because he . . . has to deal with it all the time; [she and her husband] are just witnessing it." She has started rewarding his good behavior and focus by giving him a "physical treat."

Overall, four subthemes emerged from the conversations with parents about the benefits of physical activity: (a) behavior management (b) health improvements (c) motor competence and (d) social connection.

Behavior management. Parents stated that physical activity provided their child with opportunities to burn off energy, get in a better mood, decrease self-stimmulation behavior, improve concentration, and reduce aggression. Kathy mentioned that physical

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[17] For information on Grit see Duckworth & Quinn (2009) and for growth mindsets refer to the work of Carol Dweck.

activity “brings him to his happy place,” and Gary said that it “seems to calm her.” Fahima stated that “once he’s physically active, . . . he’s more willing to actually sit down at [the] table.” Both Gary and Taylor commented that there were “fewer intense self-injurious behaviors,” and it makes for “more play instead of anger.” By increasing their child’s activity levels, parents could notice changes in what their child was able to do in other areas.

Health improvements. Parents also recognized the physical benefits associated with physical activity. For instance, Gary said that Liz was “able to sleep better”—a point reiterated by Fahima, who equated activity with better sleep and, in turn, better moods. In addition, parents recognized physical activity’s benefit in helping to control weight gain. Certain medications and reward strategies, combined with sedentary lifestyles, make children with ASD more likely to be overweight compared to peers (Hill et. al, 2015). Parents recognized the benefits to physical activity, but like the rest of the population without disabilities, other factors inhibit activity. Fahima, in conversations with how medicine affected her child, said that while Nishaat wasn’t “asking as he used to” for physical activity, yet whenever she asks, “he never says no.” She makes a point of continuing his physical activity, because he “is gaining a little bit of weight, and he is not hyper right now”, even though his medications made him more lethargic and unmotivated.

Motor competence. Parents recognized a symbiotic relationship between motor skills and physical activity, in that improvements in one area motivate improvements in another. Fahima stated that “whenever he’s working on objectives [i.e., motor skills], he is getting better in physical activities, like soccer or basketball,” and “Motor activies have to come first to give him kind of a boost at the beginning to [accept] challenges in sports, or a variety of physical activities." Taylor said that Isaiah had been "throwing the ball thing, he's getting that. He has that. He's getting that going. Running, he got that down pat." This suggests that motor skills are encouraging Isaiah's increase in physical activity, and that moving around helps build up his skills.

Social connection. This aspect was not mentioned by all parents, but two recognized the potential for social interaction as a result or a benefit of physical activity. Mike told a story about a couple of neighborhood kids who started playing with Robby, chasing him back and forth. "They're like, 'Where's Robby? We want Robby to be our friend." Physical activity offers a potential bridge to more social interaction with same-aged peers; it provides a common interest that doesn't as quickly put differences on display. Also, children may seek attention from others in physical activity. Fahima said that Nishaat "is actually looking at people around him doing physical activities," and that "the key is to become social as well."

Converged Results

As a part of the mixed-methods analysis, significant quantitative results are merged with and compared to qualitative themes to find a deeper meaning within the data. Since the focus of this study was to understand how changes brought on by the motor intervention, played a role in other aspects of a child's life, changes in motor performance were categorically imported into NVivo—classified as change greater that 40 points, between 20 and 40 points, and less than 20 points—to see how potential barriers, or an increase in a parent's discussion of barriers, might be related to a child's growth as a result of an intervention. Categorical variables were attached to individual families, so that in the analysis, anytime that variable was used, all the codes and themes followed it.

When deviding motor performance changes into categorical groupings, it is important to recognize the starting motor skills in relation to growth, as this could change how this data is interpreted. One may assume that the children with the largest growth were those that started off with the lowest scores. Contrarily, one could assume that those with the highest scores would gain the most from the intervention. However, it is not so clear in this analysis; certainly, one of the participants who gained the most started with the highest score and a child with one of the lower scores gained the least. Yet, one child who had the lowest score demonstrated the seconded highest amount of gain. While, amount of gain may not be the best discriminator to understand differences in parental perceptions, it can give a glimpse at what is similar amoung children who gained similar amounts from the intervention. Additionally, due to the home environment acting as an environmental constraint for the child's development, it can give insight into differences where children started in relation to where they finished.

To analyze how barriers might have affected the increase in motor skills, a matrix was created using the change in motor performance and the major themes of the barriers that parents described; see Table 14. These results demonstrate how each of the barriers was discussed within each level of increase in motor performance. The result that stands out, initially, is that the theme of "time" was associated with the number of responses coded to highest levels of motor performance improvement. This suggests that parents for whom time is mentioned as a predominant barrier may be attempting to engage in more activities with their child; by doing so, parents feel constrained by time and feel that there is just not enough. This is further evidenced when considering the differences in how parents in each group described aspects of “time”. Taylor, whose son Isaiah gained “less than 20 points”, said:

> So I **set a time** and say, "Okay, okay, I want to be out by this time. I know I need to do this." Basically set up a time limit, because if you don't, the longer you take, it's like the more he gets **anxious**. He knows that you're going somewhere, but because he knows that, he's not really trying to-- if I'm lollygagging around, he's not going to want to-- if I'm not right there at him, okay, got everything right there in front of him.

“Time” for Taylor focused much more on how she viewed the day and getting tasks done. While Fahima, whose son Nishaat gained “between 20 and 40 points”, said, “And we try to come up with a schedule or try to tell him what is next, because I think he is living in chaos if he doesn’t know or has no idea”. When comparing both responses, Fahima’s response demonstrates more structure when compared to Taylor.

Table 14: Matrix of Change in Motor Performance and Barriers

	Barriers to Physical Activity					
Mean Change	Acceptance	Child Behaviors	Financial Strain	Safety Concern	Support Network	Time
Less than 20	3	25	0	2	11	6
Between 20 and 40	21	42	2	6	18	20
Greater than 40	19	47	3	13	28	26

Also, parents’ concern for or seeking out different social networks for support may have been to provide more opportunities to provide “services” or support for their child, instead of for free play with other children or social opportunties. Since support networks can include everyone from family and friends to various therapists, parents who cited this aspect as a barrier may be more aware of the potential benefits and attempt to build a larger support network for their children.

Two areas that were unexpected were higher rates of instances of parents discussing child behaviors and safety concerns for children who had greater improvement in their motor skills. One might assume that parents who had troubles with their child's behaviors might cause the child to improve less in motor skills during the intervention. However, as was the case with time and social networks, awareness of the issue may cause the parent to recognize its effects and seek out more opportunities to assist their child.

An additional matrix was completed to compare the benefits of physical activity to increases in motor performance (see Table 15). It was hypothesized that higher rates of increase would relate to parents' recognition of higher levels of motor skills. It is evident from the matrix that parents of children who improved at least moderately in their motor skill performance recognize how physical activity benefits behavior; this provides continued evidence that the home and parents act as an environmental constraint to motor development and activity. This could develop, for example, as parents notice that their children are calmer at home or in a better mood after they have taken part in the intervention.

As seen in the quantitative results, time on task was highly correlated to increases in motor performance; higher levels of time on task also mean higher levels of engagement in the intervention. It is possible that children who were more highly engaged demonstrated higher levels of performance; therefore, their parents could have recognized the added benefits as a result of participation. The recognition of benefits does not seem to be directly related to an increase in motor skills, but the intervention—by providing opportunities for physical activity—could have delivered many of the benefits that the parents were describing.

Again, when looking at how individual responses between the categorical groups, parent responses for gross motor were similar—although more frequent as the child improved in their skill level. When asked about whether it was important to gain gross motor skills or increase physical activity first, Taylor said, “Probably the gross motor… I think because of the simple fact then you do movement and everything like that and certain activities that you do do, helps him go throughout the day”. Similarly, Fahima mentioned that:

> Yeah. I think gross motor activities, whenever he’s working on the objectives. He is getting better in physical activities, in terms like playing soccer, or playing basketball. I think gross motor activities have to come first to give him kind of a boost at beginning to take challenges in sports, or in variety of physical activities.

Further, when asked the same question, Kathy said, “Well as far as [Adam] is concerned as a special needs child, I would say the gross motor skills have to be the priority because he has to learn how to do those things”. In this instance, parents of children who gained more from the intervention discussed the importance of “motor competence” and the need to build motor skills more frequently; however, it’s evident that parents, regardless of how much their child gained, discussed similar expectations of the benefit and necessity of gross motor skills. Suggesting that while parents understand the necessity of building motor skills first to be successful at physical activity, providing children with

ASD opportuntities to be physical activity—regardless of skill level—could be emensely beneficial for, both, the child and the parents.

Table 15: Matrix of Change in Motor Performance and Benefits

	Benefits to Physical Activity			
Mean Change	Behavior Management	Health Improvements	Motor competence	Social Connection
Less than 20	2	0	1	0
Between 20 and 40	10	2	6	1
Greater than 40	7	0	5	2

CHAPTER 5

Discussion

In the last few years, the motor development characteristics of children with ASD have caught the attention of researchers in a variety of fields. Recent research has started to demonstrate the importance of building motor skills (Cattuzzo et al., 2016; Logan et al, 2015) and the role motor development plays in other developmental processes for children with ASD (Bedford et al., 2016; Landa & Kalb, 2012). Further, recent research has demonstrated that the development of motor skills for children with ASD is delayed in comparison to peers, starting at an early age (Lloyd et al., 2013) and continuing into adolescence (Staples & Reid, 2010). Furthermore, while little research directly links motor development with levels of physical activity, rates for this population follow a trend similar to that of motor development patterns in that levels of participation in physical activity are low at an early age compared to peers, and the gap continues to widen as individuals age (MacDonald et al., 2011).

Despite the increasing evidence for the benefits of movement and physical activity for this population (Bremer et al., 2016; Lang et al., 2010), few studies have focused on building fundamental motor skills in children with ASD. Three recent examples of motor interventions (Bremer et al., 2014; Bremer & Lloyd, 2016; Ketchesen et al., 2016) demonstrate an increasing awareness of this issue and strong evidence for the potential effects motor programming can have on individuals in this population. However, this continues to be an area of great need, as only a handful of small-sample studies have been conducted.

This study adds to a slowly growing area of ASD research in two unique ways. First, this study used a well-established theory of motor development (i.e., DST) as the basis for developing the task modifications[18]. By using a well-documented supporting theory, the likelihood of having an impact on the motor skills of individuals through the intervention is increased (Brug, Oenema, & Ferreira, 2005; Rothman, 2004). Second, this study used a parallel, convergent mixed-methods design to examine the effectiveness of the intervention not only directly within the school-setting, but also its potential indirect effects on the child's life at home. By incorporating multiple methods in the design, unique aspects of the intervention could be analyzed. Using qualitative interviews to accompany the intervention allowed for the opportunity to capture what effects were seen at home that resulted from the motor intervention.

Too often, interventions, and especially those that involve motor skills, are conducted within a clinical bubble (e.g. a lab, school, or during a weekly program), and as a result have limited ability to determine the effects of the intervention in the rest of an individual's life. Development cannot and does not happen in a vacuum, especially the development of motor skills. By including parent's perceptions in the analysis of a motor-skill intervention, the full potential of the intervention is more likely to be captured.

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[18] For examples of modifications, see Appendix A.

Additionally, by collecting a greater wealth of data from the motor intervention, not only could the intervention's effects be better understood, but how outside life experiences have a potentially mitigating effect on the success or failure of any intervention, motor skills notwithstanding.

The present study, further, provides a unique analysis in what is a limited field, with the hope that the use of both theory and multiple methods will become standard practice for gauging how best to build motor skills in children with ASD. As this problem is multifaceted, it will require a multifaceted approach to understand how best to intervene. Data collection for this study allowed for the analysis of four guiding research questions: (1) Do task modifications, based on the principles of dynamic systems theory, increase motor performance, and are positive effects from the motor intervention demonstrated in individuals with ASD? (2) What influence do changes in FMS have on the adaptive behavioral skills or social skills of individuals with ASD? (3) How do parents' perceptions of their child's physical ability change as a result of participation in a motor intervention? (4) What effect, if any, do changes in FMS have on other aspects of a childcts of a childformance, and are positive effects from the motor intervention demonstrated in individuals with ASD?

The findings from this study demonstrate the potential for incorporating qualitative research within a quantitative intervention; without multiple forms of data, the ability to deeply analyze the data and triangulate certain findings would have limited the richness of the overall findings (Teddlie & Tashakkori, 2009). Yet, due to the limited sample size and robust statistical analysis, results should be interpreted with caution. In the remaining sections, the results from the analysis are discussed and further interpreted with respect to each of the research questions.

Effect on Motor Performance of Children with and without ASD

RQ 1: Do task modifications, based on the principles of dynamic systems theory, increase motor performance? & Sub-RQ1: Are positive effects from the motor intervention demonstrated in individuals with ASD?

The primary focus of this study was to determine the overall effectiveness of an intervention based on DST and task modifications. As this area of research is limited in terms of motor skills interventions that are designed with children with ASD in mind, the findings of this study provide important evidence for the future development of motor interventions directed at individuals with ASD. In previously well-designed studies, researchers have often used typical practices (Bremer et al., 2014; Bremer & Lloyd, 2016) or modified an existing evidenced-based practice (Ketcheson et al., 2016) that was not originally designed for motor skills implementation. While each of these studies provides important evidence for the ability to impliment interventions for children with ASD and, in turn, have shown positive effects on growth through intervention, these methods may not provide the most optimal solution to building motor skills for this population.

For instance, Bremer and Lloyd report that an instructor would often do “things very quickly with a lot of physical prompting to get them to do what [the instructor] wanted them to do” (p. 79); after the intervention, the instructor reported that the intervention “would definitely benefit program support teachers to get a better understanding … [by] giving them some strategies” (p. 82). Results from this study demonstrate a positive support for motor intervention for children with ASD and the potential impact interventions could have on support personnel. Unfortunately, these interventions may not provide the best mode of intervention to build motor skills, since each method attempts to circumvent aspects of or “deficits” in ASD children by modifying how instruction is given compared to the standard method. The benefit of DST is that ASD is no longer classified as a “dis-“ anything; the child’s disability becomes another constraint—something that could hinder certain aspects, while positively influencing others. Further, this approach is much more likely to take advantage of certain strengths the individual might have and leverages those strengths over any weaknesses. By changing this perception, autism is no longer a hurdle to overcome, but another neutral contributing factor to an individual’s ability to move. Thus, by adjusting other, more controllable, constraints—such as the task or environment—individuals with ASD’s motor performance can be influenced into a more mature pattern.

Additionally, prior to the pilot study and the present study, there was little evidence that DST could be used as a motor intervention guide, and no evidence that the theory was applicable to individuals on the autism spectrum (Colombo-Dougovito, 2016). In the pilot study for this study, strong evidence emerged for the potential ability of task modifications to have a positive influence on the motor performance of individuals with ASD. In the present study, the significant result of the RM-ANOVA on changes in the SC of the focus skills ($p < .001$) demonstrates, again, strong support for the potential use of task modifications as a means of motor intervention for children, and especially those on the autism spectrum. When looking further at the results of this RM-ANOVA, a nonsignificant result ($p = .10$) suggests that the sample groups in the present developed similarly across the intervention. Considering the vast evidence suggesting a deficit in motor performance, this result demonstrates that individuals with ASD could learn motor skill similar to peers, if given the right opportunity and methods.

When analyzing the data further, pairwise comparisons showed that there was no difference from the DM group (p = .22), but a significant difference from the AM group (p = .006). This result suggests that children with ASD in this study improved motor skills at a rate about half that of their chronologically-aged peers. Yet, when looking at the changes in the ASD group, visually (see Figure 11), it appears that the drop-in retention scores come predominantly from the locomotor subtest. This drop-in score, like the pilot data, demonstrates a potential need to further individualize modifications for locomotor skills and a need to increase the amount of instruction in this area.

Also, when the amount of change in SC are considered, throughout the intervention, the participants in the ASD group on average gained about 10 points by the assessment post-intervention. To provide context, that is the equivalent of gaining about 2.5 skill components across the locomotor and ball-control skills. In contrast, participants in the AM group gained about 23 points or the equivalent of nearly 6 skill components; nearly maximumizing their potential scores. Furthermore, when looking at the DM group, interestingly, participants retained locomotor gain, yet lost nearly all ball-control gains. This would suggest that perhaps children in this age range (3-5) need more practice with ball-control skills, or these children may not have been developmentally ready for these skills yet; which would align with prior research.

When considering this visual analysis with the statistical and non-statistical differences from above, it is important to recognize that while children with ASD may develop motor skills at a rate like peers about half their chronological-age, the types of skills learned may not be similar. In this analysis, much of the retention score for the ASD group was in the ball-control skills, while the DM group held their scores in the locomotor skills. This evidence suggests that children in the ASD group may be ready to develop skills closer to chronological peers, yet locomotor skills provide a greater deal of difficulty due the dynamic nature of the skill performance. Ball-control skills, on the other hand, are typically stationary and closed skills—at least for the TGMD-3 assessment. This type of skill may provide an easier opportunity for children with ASD to attend and reproduce what they observe.

Since, locomotor skills often move from point to point, as well as contain multiple steps, it may provide an overwhelming amount of information to attend to at one time; forcing individuals to attend to only one portion of the skill (such as moving from point A to B) and little else. This has been described in previous assessments of childrens motor skills (Berkely et al., 2001; Staples & Reid, 2010). Perhaps, task modifications for children with ASD regarding locomotor skills need to break the skill down further into more discreet tasks. By working from a part-whole persective, tasks can be built up so that children are not overwhelmed by the presentation of the task. Therefore, when building future interventions, researchers should account for this potential difference and design interventions for the individual and not simply based on age. Furthermore, in Figures 10 and 11, it is evident that the motor-skill performance of the children with ASD decreased 4 weeks after the intervention. This likely is due to the intervention not providing enough skill practice to ensure that the “phase shift” was strong enough to definitively move the participant into a more mature (i.e., new “attractor state”). While a six-week, roughly total hours of instruction, may be enough to provide the needed instruction for children without disabilities, children with ASD may need a greater amount of instruction. Recommendations for the frequency and dosage will be described in the implications.

When considering the the motor performance of children with ASD at the beginning of this study, while not the focus, it is evident that they were delayed compared to their same age-matched peers (see Figure 10). This result is in line with previous research on the motor development patterns of children with ASD compared to their peers (Liu et al., 2014). Further, the results of the TGMD-3 demonstrate that overall the participants with ASD were delayed compared to peers, half their chronological age. These findings support the findings of Staples and Reid (2010), who noted that while all their participants could perform the skills of the TGMD-2, they demonstrated difficulty in coordinating movements, especially between side of the body and legs. Challenges in coordingating movements was seen in the present study as well. However, these challenges were somewhat accounted for by "reducing the degree of freedom" (i.e. all the possible ways to move to complete a task) for certain movements through task modification, thus allowing for performance of a more mature motor pattern.

This result was also echoed in the parent interviews when discussing the motor abilities of their children. Elaine stated that the biggest barrier for Robby was "probably just coordination." Further, Fahima's said that Nishaat needs to be more physically active, saying, "He's still not hopping on one leg or jumping forwards. . . and the running is always switched to skipping or hopping, both." This result takes Staples and Reid's findings a step further, by demonstrating that not only do individuals with ASD potentially perform motor skills at a rate half that of others their own age. Yet, when looking at skill growth between locomotor and ball-control subtests, there is a distinct difference in the skills that were retained. Children with ASD seemed much more likely to maintain ball-control skills over locomotor skills. This is further evidenced by parents' descriptions of limited coordination as imposing a barrier not only to building motor skills, but to becoming more physically active. While it is important to note that children with ASD showed similar starting points as participants in previous studies and a limited amount of motor coordination, the children in this study demonstrated significant gains in motor skills after a relatively short intervention using the task modifications based on DST.

Effect of Motor Performance Changes on Adaptive Behavior and Social Skills

RQ 2: What influence do changes in FMS have on the adaptive behavioral skills or social skills of individuals with ASD?

Adaptive behavior and social skills are vital to most everyone's daily life; these skills help us negotiate our environment and maintain certain standards of living. These skills can pose a certain level of difficulty for individuals with ASD, however, and play a role in many of the hallmark characteristics af ASD (DSM-5, 2013). As motor skills required for our daily lives and overall motor competence allows us to move with relative ease, adaptive behaviors have been hypothesized to a possible relationship to gross motor skills. For instance, adaptive behaviors are often used as an outcome to examine the efficacy of early intensive behavioral interventions for toddlers with autism (MacDonald et al., 2014). Further, several studies have used adaptive behaviors to understand differences within this population and to explore how motor skills interact in children with ASD. MacDonald et al. (2013a), in a study of 233 children between the ages of 14 and 49 months, found that gross motor scores were predictive of daily living skills—which is a subdomain of adaptive behavior, as measured by the VABS-3.

Anecdotally, this makes sense. As one's motor skills increase, his or her ability to interact with the environment would also improve. Bremer et al. (2014), in an earlier motor intervention for children with ASD, searched for changes in adaptive behavior that might correspond to changes in motor skills. While the study was hampered by a small sample size, Bremer et al. concluded that there were no significant changes in adaptive behavior or social skills in relation to changes in motor performance. As the focus on motor development has entered a new research domain, some hypothesize that perhaps this relationship between motor skills and other variables has not been studied extensively enough (MacDonald et al., 2013a), and that perhaps motor skill deficits are hindering improvements in social communication skills (MacDonald et al., 2013b). In adding to this query, this study supports previous findings by Bremer et al. in that no changes to adaptive behavior (p = .97) or social skills (p = .34) were associated with small, but significant changes in motor performance. Further, the current findings provide slight, contrary evidence to MacDonald et al.'s finding of a relationship between daily living skills and gross motor skills, as there little change in Daily Living Skills (p = .99).

This conclusion is not meant to dissuade continued attempts to understand the relationship between these variables for children with ASD. Instead, it serves as evidence that these relationships may not be simplistic or directly related as many might think. Human development is complex and ever-changing; direct changes in one part of the developmental process may not have an immediate direct effect on the other. It is understood that motor skills are interconnected with other skills within the developmental process and play a vital role in later development for children with ASD (Bedford et al., 2016). However, the connection between these variables may not show up as immediately, or as directly, as researchers may hope.

In this study, adaptive behavior and social skills were measured immediately at the end of the intervention; this may not have allowed a suitable amount of time for the changes in motor performance to influence this aspect of the individual's life. Furthermore, standardized assessments may not be sensitive emough for measures taken so close together. As this analysis also considered parental perceptions of change, there was an understanding among parents that these concepts are, in some way, interrelated. During the intervention, for instance, Taylor noted that Isaiah was "becoming more affectionate," and Elaine added that Robby—in demonstrating handstands (not a skill of this intervention)—has also "added some attention seeking, like, 'Hey, look at me. I'm doing this handstand.'" While quantitatively there has been little evidence that changes in FMS influence adaptive behavior or social skills, on a qualitative level, parent are much more astute to slight changes. Future research should seek to understand, longitudinally, how changes in motor skills affect these other variables and, potentially, visa versa. There may be a delayed effect that is not being captured by traditional measurements and research designs.

Parent's Perception of Motor Skills and Physical Activity

RQ 3: How do parents' perceptions of their child's physical ability change as a result of participation in a motor intervention?

Parents of children with special needs provide an opportunity to access, intimately, the home environment to better gauge how interventions play out in their daily lives. By accessing this information, researchers can discover patterns that exist, but are seemingly invisible (Market & Morehouse, 1994). In analyzing for this question within the data, no direct relationship emerged between changes that were occurring because of the motor intervention and changes in home physical activity or the perception of the child's ability to perform physically. It became evident, however, that parents' focus and attention is often placed on the behaviors that deservidely require the most attention, such as communication issues or aggressions. When discussing a typical day, Kathy said, "We have a meltdown getting off the bus. I generally get the shit beat out of me. Then we make it in the house."

When considering the emergent benefits and barriers that parents described, while there was little direct relationship of motor changes and changes in behaviors at home, it is important to recognize how the home environment plays a role in the developmental process of the child. Ascribing these themes to DST, it is evident that the home environment acts as an environmental constraint in the production and development of the child's motor skills, as well as on the potential level of their physical activity. As a reminder, under DST, constraints are not a negative term; it is neutral, having the power to influence any behavior positively or negatively. Parents, during the interviews, described both aspects through their reference of various barriers and benefits.

The emergent barriers described by parents would be aspects of the environment that hinders the production of motor skills and participation in physical activity. Conversely, the benefits would be aspects that have a positive influence. When using DST to analyze this aspect, especially the barriers, become less about overcoming these aspects and more about how to adapt. When attempting to build future interventions to build the motor skills or increase the physical activity participation of children with ASD, researchers and practictioners should seek to leverage the positive (e.g. benefits) aspects the child's environment to influence potentially better outcomes. Additionally, through DST, modifying or adapting other aspects, such as the task, can be a way to negate the negative (e.g. barriers) aspects a given home environment.

Moreover, when looking at the data from the interviews with parents, it is evident the very large roll parents play in their child's development and on other aspects of the environment. By empowering the parent and including them within the research design and intervention, there is an increased potential of improving the outcomes of the intervention. With the parent's support, other aspects of the environment may not have as great of an impact. Since parents have the ability to affect other aspects the child's environment by giving them the tools they need to assist their child, it is possible to limit the effect of certain barriers.

Interaction of Motor Skill Changes in Child's Life

RQ 4: What effect, if any, do changes in FMS have on other aspects of a child's life?

To best understand the potential impact of any intervention, it important to try to capture as much of that potential as possible by analyzing more than one aspect of an intervention. Too often, intervention research looks only to the quantifiable impact as a direct result of the intervention, disregarding the potential impacts that go unseen in other aspects of an individual's life. This potentially causes impactful interventions to be disregarded because they don't demonstrate importance by achieving statistical significance.

Therefore, the analysis for this study attempted to capture not simply how children benefited in direct outcomes of the intervention, but in indirect ways (e.g. decreased undesirable behaviors, increased socialization, increased physical activity, etc.)

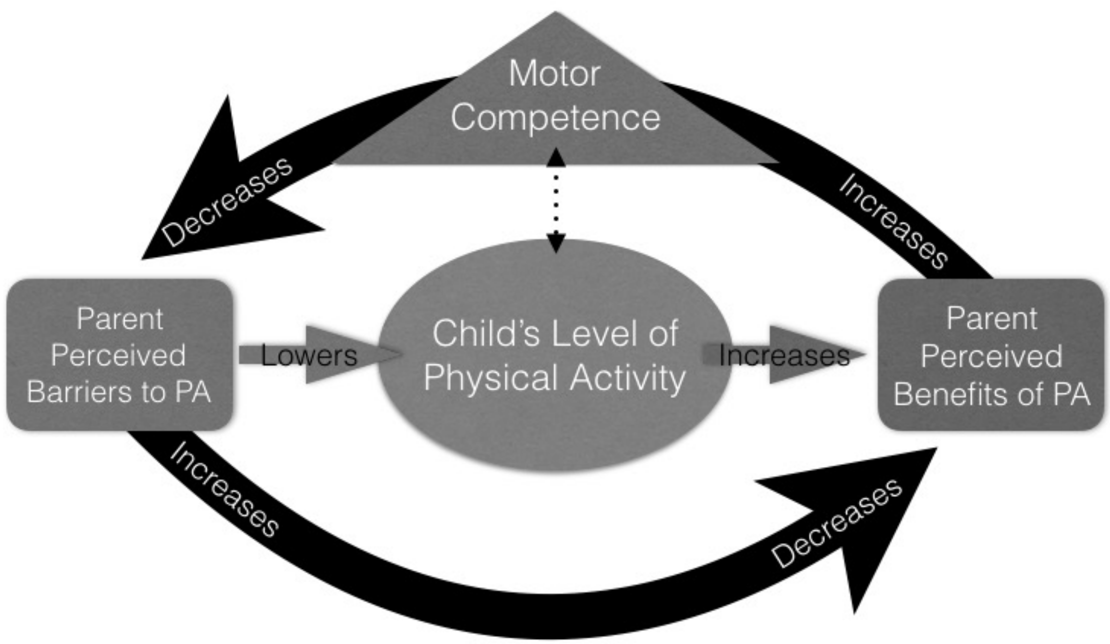
at home and in the community. Using both parent-reported themes and categorizing the significant changes in motor performance, this part of the analysis looked at how increases may have impacted outcomes at home. In looking at the results, however, the author's original belief of the direction of that assumption was misplaced. It was hypothesized that changes in FMS that were due to the intervention would motivate or influence changes at home; however, the data appears to suggest that the home environment and the emphasis parents placed on the benefits may have played a role in how much each child improved throughout the study. In other words, the home envrionment, seemingly, acts as an environmental constraint for the child's production of behavior.

One major, yet surprising, take-away is simply the impact of time in relation to growth of motor performance in the study; parents of children who gained the most through the intervention mentioned time more often than the parents of children who scored lower. This could mean that parents who mention time more often recognize the necessity of services, extracuriculars, etc. and feel more limited by the amount of time they can spend working on physical-activity goals. Further, parents may attempt to provide more opportunities and fit in as many services and activities as possible, making "time" seem limited. In looking at more specific responses, parents of children who gained more from the intervention discussed more formal aspects of "time", such as scheduling. This finding reiterates the barriers found by Obrusnikova and Miccinello (2012) in their study of the barriers to and facilitators of after-school activity for children with ASD. It is likely that when a high level of barriers is reported, parents would be more focused on more traditional services for children with ASD, which may limit the ability to ensure time for physical activity. However, parents with more ridge schedules may also understand the need for services and are more likely to focus on covering all aspects of their child's development, as the more often parents discussed time the more their child gained from the present intervention.

Furthermore, it was assumed that participation in a motor intervention and any motor gains thereof would have an impact on parents' positive perceptions of the benefits that changes in physical activity could confer on behaviors at home. Results from the mixed-methods analysis suggest that children who demonstrated a moderate increase in motor skills or better had a higher prevalence of better mood for the child at home. It could be that changes in motor skills act as a mediator to the amount of physical activity a child is able to perform, and thus physical activity plays some role in how barriers and benefits emerge in the child's life; see Figure 21.

Higher success rates in the production of motor skills in young children has been demonstrated to increased levels of physical activity (Cliff, Okely, Smith, & McKeen, 2009); however, the relationship is not clearly defined as others suggest that high rates of participation in physical activity have an impact in the development of FMS (Bürgi et al., 2011). This relationship, however, could be fluid by age; with early motor milestones occurring because of movement and activity, yet adjusting as the child ages to focus on motor competence of skills as a prerequisite for participation in physical activity (Holfelder & Schott, 2014). Regardless of how exactly FMS interact with levels of physical activity, data in this analysis further suggests that motor competence plays a mediating role in the physical activity levels, and thus effecting the potential perceived benefits or barriers a child with ASD faces when attempting physical activity; see Figure 21.

Figure 21: Model of Motor Skills as Mediator



Future research should take into consideration how FMS impact the home environment in more depth and visa versa, likely, for an extended period. It is evident from the results above that immediate impact in the daily lives of children with ASD and their families might not directly a result of increases in motor skills. There could be a delayed benefit associated with sustained increases in motor skills, not presenting until much later. Additionally, the home environment may have a greater impact on the motor intervention than most research account for, acting as an additional environmental constraint. In either case, it is evident that parents and eventually adults with ASD will need to be included with the research process to understand how motor skill impact other facets of their lives and visa versa (Cusack, 2017). The development of skills and behaviors across a lifespan is a multifaceted topic that will require a multifaceted approach and need to include the individual “voice” of the participant, as the autism spectrum contains too much variability to assume exact similarity between experiences.

Limitations

This study, like others, is not without its limitations. As with many studies involving individuals on the autism spectrum, this study faced five primary limiting factors to the generalizability of the findings of the study: (1) low numbers of participants within each group; in that a lack of an ASD-specific control group and potential for over analysis of the data, (2) uneven ratio of girls and boys; (3) limited control for comorbidities within children with ASD; (4) the overall length of the intervention; and (5) limited control for instruction outside of the intervention.

This study was plagued by a limited number of participants on the spectrum; at five participants, the use of robust parametric statistics regarding the findings must be done with a degree of caution. However, this seemingly is a common issue when considering research on children with ASD (see Bremer et al., 2014; Bremer & Lloyd, 2016; Staples and Reid, 2010). Further, due to the small number of individuals and the heterogeneity associated with ASD, the generalizability of the findings of this study are limited. Further, without an ASD-matched control group, it is difficult to ascertain if the improvements were in fact a result of the intervention or simply growth. Much more research will need to be done to gain a complete understanding of how effective this motor intervention could be for individuals with ASD. However, by the addition of the comparison groups and similar findings occurring in those groups, it provides support for the merit of an intervention based on task modifications. Further research will need to focus on gathering larger samples of children with ASD, as well as attempting to capture the various aspects of the autism spectrum.

Next, while the ratio of boys to girls was similar to that of the overall statistical prevalence of ASD in boys and girls (4:1; Baio, 2014), there is evidence that girls present and experience ASD symptoms differently (Halladay et al., 2015). Therefore, the singular girl included in this analysis should not be assumed to account for all girls with ASD. Attempts were made to recruit as many participants as possible and ensure equal participant ratios; however, due to limited time and location, this was not able to be accomplished. Future research should seek to include more girls within the analysis to gain a better understanding of gender differences and variety across the spectrum.

In addition to limitations of numbers and gender differences, this study did not control for difference in the comorbidities of the participants, which could have played an impact in not only the motor intervention, but in the findings from the parent interviews. Autism contains a plethora of differences from individual to individual, therefore making grand generalizations difficult; when including a variety of comorbities, the result can confound any findings within the data. However, with that being said, Simonoff et al. (2008) found, in a sample of 112 adolescents with ASD, 70% of the sample had at least one comorbid diagnosis and with 41% having two or more. Trying to isolate individuals with ASD, alone, may not prove to be the best method if the goal is to ultimately generalize the findings to the greater population of individuals with ASD.

Next, the overall length of the intervention may have been a limiting factor in regard to providing opportunity for any indirect affect to be observed. The overall intervention was only 6 weeks in length, with a retention measure 4 weeks after any instruction; while a significant change in motor skills was found, little change in the indirect variables associated to the motor changes could have been limited by the time it takes for those changes to occur. The intervention length for this study did not account for the time that associated skills may needed to adjust. While 6 weeks proved to be a enough time to make a significant—albeit small—changes in motor skills, the decrease in performance at retention suggests—in regards to DST—that the motor pattern was not perturbed enough to make lasting change. Future research should look to increase the amount of instruction not only to benefit motor changes, but to increase the opportunity to capture indirect associated changes. Additionally, follow-up and maintanence may also need to be provided at regular intervals to maintain increases and provide opportunity to capture changes.

Lastly, this study did not control for instruction, from outside extracurricular activities or services. In certain participants, they could have benefited from instruction of similar skills giving them an advantage. While providing interventions in a “real-world” environment, such as a school, researchers will most always run into this issue. Future research should look to capture this outside instruction to gauge who may have received instruction outside of the intervention.

Implications and Future Research

Overall, the results of this study provide encouraging supporting evidence for the use of task modifications as a foundation for motor interventions. Further, data suggest that this type of intervention may allow for a potential rapid increase in motor skills for most children, and effective for those with ASD. However, the dosage and frequency of the intervention should be taken into consideration in future research to ensure sustained growth and, as this study only included instruction on three locomotor (i.e. jump, gallop, and hop) and three ball-control (i.e. throw, kick, and strike), future research should additionally look to apply the principles to other gross motor skills. The dependent *t*-test results demonstrate that on the SC, motor increases are not sustained post intervention, with performance returning to pre-intervention levels. However, dependent *t*-test results from the TGMD-3 suggest that improvements are sustained in the absence of motor intervention. The difference here is likely attributed to the difference in scoring procedures between the two assessments. The TGMD-3 credits criteria as present or not-present, where the SC give partial credit for each criterion. Additionally, the SC contained a larger number of skill points compared to the TGMD-3 and could likely include skill criteria that are not fully captured in the TGMD-3 (see Appendix A for where SC criteria originated); therefore, if a skill is accounted for in both measures, but an individual is missing the extra criteria for the SC, then the overall score will be lower for the SC compared to the TGMD-3.

When considering implementation and recommendations for interventions for children with ASD, researchers often suggest longer would be better. Bremer et al. (2014) suggest that 12-18 weeks of intervention may be more suited to improve skills and capture change. However, "weeks" may not be the length of time that should be the initial focus. While ensuring the capture of changes in indirect changes of adaptive behavior, social skills, and other health outcomes, longitudinal analysis is necessary and despirately needed. Yet, when considering the needed frequency and dosage to improve a child's motor skills, six weeks of roughly 3-5 hours of instruction was enough to demonstrate significant motor skill change, but that change was not sustained. An easy answer would be to suggest that the intervention be given for longer time, thus increasing the potential for growth. Alternatively—especially considering many children with ASD's affinity to routine and schedules—perhaps a better frequency might be 4-5 times a week. That would provide nearly double the amount of instruction, in a similar time frame. Further, when considering the data collected from this analysis, children with ASD received about 15-18 minutes of instruction on average and in knowing how length can have an impact on children with ASD's performance (Breslin & Rudisill, 2013), perhaps instruction would be better if provided for 10-15 minutes each session. By providing shorter durations of instruction, the instructors would have a better chance of keeping children engaged and on task. Additionally, by providing a shorter amount of instruction more frequently, if greater gains aren't seen after a few short weeks (e.g. 6), the intervention could be lengthened with little impact on the researcher's efforts.

Further, when considering the number of practice trials an individual with ASD received during the intervention and the success-rate for those trials, future interventions need to consider ensuring a high amount of practice trials during the actual intervention. Further, when looking to the progression of skill components (Table 8), it is evident that the participants with ASD spent a longer time at each skill component; reaching success every two weeks for one component, while participants from the comparison groups progressed at about a skill component per week. For the comparison groups, 6 weeks was enough instruction as they could complete each of the skill components for locomotor skills and almost all the components for ball-control skills. Using the same frequency and dosage from this study, participants with would need at least 18 weeks of instruction to complete each skill componenet. Therefore, by increasing the frequency and dosage to 15 minutes per session for 4-5 times per week, the intervention should be between 10-12 weeks to ensure that all the components of each skill could be covered.

Additionally, this study underlines the importance of having a strong, engaging instructor. The type of instruction (i.e. the intervention) is only half of the equation; instructors need to be able to engage children with ASD and provide the necessary support where/when appropriate. Often, physical educators have little training to work with children with disabilities (Piletic & Davis, 2010), and even less understanding of how to work with children with ASD (Colombo-Dougovito, 2015). Training programs should increase the experience teachers have with children with ASD and provide them with practices that will help insure both parties experience success. Further, the results exploring time on task and practice trials emphasis the importances of having well-trained and highly motivated instructors. Even with certain barriers to engagement, this intervention may provide a relatively ease of implementation for the teachers and—given the results of the social validity report from the instructors of this intervention—could be easily modified to fit most situations and individuals. Future research should be done to test for how this intervention differs from traditional teaching styles, to see if the intervention model alone can provide an increase opportunity for practice.

Further, this study provides strong evidence for the using a mixed-methods design to explore motor intervention and subsequent effects in the lives of individuals with ASD. By including multiple references to a certain aspect in an individual’s life, deeper analysis can result in a greater understanding of the individual’s experiences. Evidence suggests that motor skills is a mediating factor of not only the physical activity of children with

ASD, but potentially other behaviors. While this supports claims found in the literature (MacDonald et al., 2013a; 2013b), the result does not seem to be an immediate direct effect; which is also supported by previous research (Bremer & Lloyd, 2016). However, in conversations with parents, it is clear these factors play a role in the child's life experiences and motor skills are among them, but our means of capturing their changes is insufficient. By including multiple methods, it will increase the likelihood of capture the aspects that are difficult to measure by standard means.

Lastly, parents should be included within future iterations of motor interventions, as this can likely have a greater effect on the overall outcome of the intervention and help reduce some of the burden parents face. Many parents within the study face uphill battles each day to "keep things afloat", yet, they are constantly looking for more they can do—more ways they can assist their child. By including parents within the research process and implementation of the intervention, the likelihood of greater gains and generalization of skills can be increased (Ingersoll & Gergans, 2007).

Conclusion

The motor development of children with ASD has only recently begun to gain a larger amount of attention. Recent research has demonstrated delays in how children with ASD development motor skills (Fournier et al., 2010; Liu et al., 2014; Lloyd et al., 2013; Staples & Reid, 2010). So much so that researchers have suggested motor skills be included within the diagnositic criteria (Flanagan et al., 2012; Liu, 2012). Further, given the potential relationship between FMS and physical activity levels (Holfelder & Schott, 2012) and the evidence supporting the benefits of physical activity for children with ASD

(Bremer et al., 2016; Lang et al., 2010), increasing the motor competence of children on the spectrum is of vital importance.

Following in the footsteps of only a few motor intervention studies (Bremer et al., 2014; Bremer & Lloyd, 2016; Ketcheson et al., 2016) directed at individuals with ASD, this study supports this previous work while adding findings beyond the scope of these earlier studies. Utilizing a well-documented motor development theory, DST (Newell, 1986), this study designed and tested a motor intervention founded on the premise of task modifications. Results demonstrated that task modifications may provide a clear prompting tool for teachers to enhance motor skills in children. Further, this study found that, while delayed when compared to peers, children with ASD may develop motor skills at about the rate of an individual about half their own chronological age; suggesting that future studies be designed and implemented as though for younger children. Further, it details the necessity for modifiying skills to account for the strengths and weakness of the individual.

Furthermore, by using multiple methods, the findings of the intervention were expanded and explored to understand how a motor intervention affects other aspects of an individual's life. Results were unclear as to the immeditate effects of growth during the intervention and future research should look to study this phenomenon for a greater length of time. However, with that said, it appears that there is a bidirectional relationship between the motor intervention and home with each contributing to changes in the other and the home acting as an environmental variable. Additionally, through the analyzing of the matrices of significant quantitative results and quantitative findings suggest that motor skills may play a potential mediating role in physical activity and, thus, the benefits and barriers to it.

Lastly, this study supports previous research of the importance of motor skills in the daily lives of individuals on the autism spectrum and their families. By analyzing multiple sources of data, a deeper understanding can be gained on the interventions impact in the lives of children with ASD, which may provide a strong foundation for future research on motor intervention built using task modifications and DST. Future researchers looking to have an impact on the motor development of children with ASD will need to take a multifaceted approach in order to continue to account for individual difference and all the various constraints. Yet, through DST and task modifications, instruction can be provided in a way that influences movement outside of the ability of more standard instruction. By creating modifications fitting the individual, researchers and practicitioners can, with better confidence, work to improve the motor skills of children with ASD.

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APPENDICES

Appendix A: Skill Criteria and Task Modifications

Locomotor Skills

Skill	Skill Criteria	Task Modification
Run	1. Period of Nonsupport, when both feet are off the surface ***	Running over low cones to promote getting body off the ground
	2. Non-support leg bent about 90 degrees so foot is close to buttock*	Hang flag-football flag off of belt behind each foot, touch flag with heel.
	3. Foot placement on or near a straight line **	Spots for feet to run on, set up in a line
	4. Arms move in opposition to legs**	Hold red (right hand) and blue (left hand) balls, place sticker on opposite shoes (red on left; blue on right). Match each when moving.
	5. Elbows bent^	Hold small foam ball in crook of arm, so that arm is flexed.
	6. Form continuous for 20 feet^	Large cones at each end; spots to run on for full 20 ft.
Gallop	1. Arms flexed, hands at waist level**	Hold small foam ball in crook of arm, so that arm is flexed.
	2. Arms swing forward to produce force*	Clap hands.
	3. Step forward with lead foot, followed by trail foot*	Spots for feet, color coded (right & left). Space so preferred foot is always in front.
	4. Trail foot does not cross feet, lead with the same foot***	Place sticker on front foot; do not allow back foot to pass the foot with tape on it.
	5. Period of non-support when both feet are momentarily off the ground**	Gallop over low mats or polispots.
	6. Maintains a rhythmic pattern for 4 consecutive gallops*	Set up four consecutive cones, spaced at each gallop.
Hop	1. Weight on hopping foot with elbows bent at 90 degrees**	Hold small foam ball in crook of arm, so that arm is flexed; stand one spot.
	2. Non-hopping leg is bent and swings forward in pendular fashion to produce force*	Spots close together; move apart to necessitate more force.
	3. Hop forward with a one-foot push-off, landing on the same foot**	Spots on floor; similar color.
	4. Foot of non-hopping leg remains behind hopping leg*	Hold bean bag on bent leg.
	5. Lift both arms in front of body, flexed, and swing forward to produce force***	Clap hands.
	6. 4 consecutive hops on preferred foot*	Four consecutive spots.

Skip	1. Stand facing and looking forward, body upright**	Two spots (one for each foot).
	2. Step forward with preferred foot***	Place tape on preferred foot.
	3. Followed by hop on same leg***	Foot prints to step and then hop on/different foots for steps and hops. Same color for each side.
	4. Arms move in opposition to legs, slightly flexed at waist level**	Hold red (right hand) and blue (left hand) balls, place sticker on opposite shoes (red on left; blue on right). Match each when moving.
	5. Period of non-support when both feet are momentarily off the ground**	Hop over low cones or a rolled towel.
	6. Completes 4 rhythmic alternating skips*	Set up four consecutive sets of foot patterns as SC 3.
Horizontal Jump	1. Stand with knees flexed with forward body lean**	Chair or low bench placed behind; prompt to sit.
	2. Arms extended behind body^	Place in front of wall; prompt to touch wall with hands.
	3. Arms extend forcefully forward and reach above the head*	Instructor holds noodle for child to touch with hands.
	4. Two-feet takeoff , leaving the ground together***	Two spots to start on; two spots to land on.
	5. Both feet contact ground at the same time ahead of body mass at landing**	Low hurdle or rolled towel to jump over.
	6. Both arms are forced downward during landing*	Two cones to touch on either side of landing zone for child to touch with hands after landing.
Slide	1.Body turned sideways so shoulders remain aligned with line on the floor. *	Place child with back to wall
	2. Step sideways with lead foot**	Spots on floor (similar color)
	3. Slide sideways with trailing foot*	Spots on floor (similar color; different than front).
	4. Period of nonsupport when both feet are momentarily off the ground**	Encourage to move more quickly; touch heels together.
	5. 4 continuous slides with preferred*	Four sets of spot with preferred foot lead
	6. 4 continuous slides with non-preferred*	Four sets of spots with non-preferred foot lead.

Note: * = item from Test of Gross Motor Development (Ulrich, in press); ** = item from Everyone Can! (Kelly, Wessel, Dummer, & Sampson, 2010); *** = combination or found in both items; ^ = additional criteria item not found on either source.

Ball Control Skills

Skill	Skill Criteria	Task Modification
Two-hand Strike of Stationary Ball	1. Grip bat with hands together with preferred hand above non preferred**	Two dots on bat handle where hands go (red preferred, green non-preferred).
	2. Stand sideways, feet shoulder width apart with non-preferred shoulder toward target**	Two spots on ground positioned perpendicular to the target (red preferred, green non-preferred).
	3. Hands start at shoulder level^	Position by wall; tap [spot] on wall behind preferred shoulder with bat.
	4. Swing bat forward in horizontal plane at waist level**	Set up limbo bar or pool noodle slightly above waist. Prompt to swing under.
	5. Trunk rotation and derotation during swing*	Place pin near rear foot for the individual to knock over with the outside of his/her heel.
	6. Step toward target with non-preferred foot*	Additional spot (blue) on floor, in front of green spot.
	7. Strikes the ball sending it straight ahead*	Target on wall
	8. Follow through beyond contact with the ball**	Position by wall; tap [spot] on wall behind non-preferred shoulder with bat.
One-hand Strike of Self Bounced Ball	1. Stands with side orientation^	Two spots on ground positioned perpendicular to the target (red preferred, green non-preferred).
	2. Hold base of racket using handshake grip with preferred hand, elbow bent slightly**	Place dot on racquet where preferred hand goes; cover dot with hand.
	3. Bounces ball at waist level^	Hold pool noodle above child's head; prompt to touch the noodle with the hand holding the ball, then drop the ball. Place spot on ground to drop ball on.
	4. Steps toward target with non-preferred foot*	Additional spot (blue) on floor, in front of green spot.
	5. Backswing of racket in horizontal plane**	Position by wall; tap [spot] on wall behind preferred shoulder
	6. Swing racket forward in horizontal plane**	Set up limbo bar slightly above waist. Prompt to swing under.
	7. Strikes the ball toward the target*	Target on wall.
	8. Racket follows through beyond contact with the ball**	Position by wall; tap [spot] on wall behind non-preferred shoulder.

One-hand Stationary Dribble	1. Feet shoulder width apart**	Place two spots (colored for preferred and non-preferred foot) shoulder width apart.
	2. Pushes ball forcefully to the floor with fingers**	Put dots on fingers; prompt to touch ball with spots.
	3. Contacts ball with one hand*	Have individual hold object in non-preferred hand.
	4. Contacts ball at about waist level*	Set up limbo bar or hold noodle slightly above waist. Prompt to dribble under.
	5. Ball contacts ground in front of or next to preferred side^	Place one spot by foot as a target.
	6. Maintains control of ball for 4 consecutive bounces***	Have four spots on ground; prompt to hit each spot once.
Kick Stationary Ball	1. Stand squarely behind the ball**	Place two spots (colored for preferred and non-preferred foot) squarely behind the ball.
	2. Rapid, continuous approach to the ball*	Spots leading up to ball.
	3. Elongated stride or leap prior to contact*	Have a separation, of about 1 foot for the person, between the last run up spot to the spot beside the ball.
	4. Place non kicking foot next to ball*	Spot next to ball for non-kicking foot
	5. Swing kicking leg back**	Place pin behind kicking foot, so that the heel hits the pin.
	6. Swing kicking leg forward**	Place next to wall/mat; so leg moved forward in sagittal plane.
	7. Contact ball with instep or inside of preferred foot*	Place a spot or ‘x’ with tape on the inside of the preferred foot. Prompt, “Touch x to ball”
	8. Follow through of kicking leg toward target**	Instructor holds noodle for child to touch with foot.
Overhand Throw	1. Side orientation with non-preferred side to target**	Place two spots (colored for preferred and non-preferred foot) in side orientation.
	2. Throwing motion started with a downward motion of the throwing arm *	Knock over pin placed slightly behind the child, at about waist height.
	3. T position with almost complete extension of throwing arm**	Position by wall; tap [spot] on wall behind preferred shoulder
	4. Throwing hand passes above shoulder**	Place spot on wall, slightly higher than shoulder.
	5. Step toward target with non-preferred foot^	Place spot in front of non-preferred foot.
	6. Body rotation toward target**	Spot, so toe points toward target
	7. Ball release toward target**	Make target a pin; place just past the child's reach.
	8. Follow through across body toward hip of non-throwing side*	Place bucket of balls next to the non-preferred foot

Underhand Throw	1. Stand body square to target**	Place two spots (colored for preferred and non-preferred foot) square to target.
	2. Preferred arm swings down and back with elbow extended***	Set ball on low cone by preferred foot.
	3. Preferred arm reaches behind trunk^	Position by wall; tap [spot] on wall behind preferred shoulder.
	4. Step with non-preferred foot forward toward target*	Place spot in front of non-preferred foot.
	5. Preferred arm swings forward**	Put next to a wall/mat; so that child can not swing side-arm
	6. Ball release toward target**	Make target a pin; place just past the child's reach.
	7. Hits target without bounce*	Place target on wall/start close, move away.
	8. Preferred arm follows through beyond release to chest level***	Instructor holds noodle for child to touch with hand.
Two-hand Catch	1. Stand body square toward “thrower”**	Place two spots (colored for preferred and non-preferred foot) squarely toward thrower.
	2. Hands positioned in front of the body with elbows flexed*	Prompt “Thumbs together” (verbal or picture).
	3. Arms extend to reach for ball as it arrives*	Toss ball up in front of child, not at.
	4. Catch ball with hands only***	Use small ball, light gatorskin ball w/ texture, or scarf.
	5. Absorb the force of the ball, bending the elbows to retract the arms**	Tap spot on chest with the ball only.

Note: * = item from Test of Gross Motor Development (Ulrich, in press); ** = item from Everyone Can! (Kelly, Wessel, Dummer, & Sampson, 2010); *** = combination or found in both items; ^ = additional criteria item not found on either source.

Appendix B: Expert Responses to Skill Breakdown and Task Modifications

Skill	Skill Breakdown	Task Modification
	Locomotor Skills	
Run	4.5	3.9
Gallop	4.3	4.2
Hop	4.3	4.2
Skip	4.5	4.0
Jump	4.5	4.2
Slide	4.5	4.0
	Ball Control Skills	
Two-hand Strike	4.3	4.1
One-hand Strike	4.3	4.0
One-hand Dribble	4.3	4.0
Kick	4.2	4.0
Overhand Throw	4.3	4.1
Underhand Throw	4.7	4.0
Two-hand Catch	5.0	4.0

Note: Criterion was mean > 4.0. Scores less than criterion were reviewed. All skills were impoved overall by expert feedback.

Appendix C: SC Scoring Rubric

Locomotor Skills

Run

SC1: Period of Nonsupport, when both feet are off the surface				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Neither feet leave the ground; shuffling motion	Airborne about 25% of run.	Airborne during 50% of run; inconsistent	Airborne about 75%	Airborne for 100% of run
SC2: Nonsupport leg bent about 90 degrees so foot is close to buttock				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Leg bent less than 5 degrees	Leg bent 6-34 degrees	Leg bent 35-54 degrees	Leg bent 55-84 degrees	Leg bent 85-90 degrees
SC3: Foot placement on or near a straight line				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Placement random, zigzag pattern	Placement on/near line 25%	Placement on/near line for 50%	Placement on/near line for 75%	Placement on line for 100% of fun
SC4: Arms move in opposition to legs				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Arms are held straight or out to the side	Arms inconsistent move with same; more oppo than same	Arms move with same side leg	Arms inconsistently move in opposition; more oppo than same	Arms opposite to legs 100% of run
SC5: Elbows bent				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Arm bent less than 5 degrees	Arm bent 6-34 degrees	Arm bent 35-54 degrees	Arm bent 55-84 degrees	Arm bent 85-90 degrees
SC6: Form continuous for 20 feet				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Form continuous for less than 5 feet	Form continuous for 6 to 10 feet	Form continuous for 11 to 15	Form continuous for 16 to 19 feet	Continuus for 20 feet.

Gallop

SC1: Arms flexed, hands at waist level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Arm bent less than 5 degrees	Arm bent 6-34 degrees	Arm bent 35-54 degrees	Arm bent 55-84 degrees	Arm bent 85-90 degrees
SC2: Arms swing forward to produce force				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Arms at side or out for balance	One or both bent, but held stationary	One arm bent & swings, other for balance	Arms bent, swing opposite	Arms bent, swing together
SC3: Step forward with lead foot followed by trail foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No Step	Shuffling motion with both feet	Lead foot steps, other does not (drags)	Lead foot steps, other follows but rear leg straight	Lead foot steps, other follows
SC4: Trail foot does not cross feet, lead with same foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Trail foot crosses in front of lead foot. Changes lead foot	Trail foot crosses in front of lead foot. Does not change lead foot	Trail foot comes even with front foot.	Trail foot nearly even with front foot	Trail foot stops behind lead foot
SC5: Period of non-support when both feed are momentarily off the ground				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Neither feet leave the ground; shuffling motion	Airborne about 25%	Airborne during 50% of gallop; inconsistent	Airborne for 75% of gallop	Airborne for 100% of gallop
SC6: Maintains a rhythmic patter for 4 consecutive gallops				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Unable to maintain pattern	Maintain pattern for 1 consecutive	Maintain pattern for 2 consecutive	Maintain pattern for 3 consecutive	Maintain pattern for 4 consecutive

Hop

SC1: Weight on hopping foot with elbows bent at 90 degrees				
"0"	"1"	"2"	"3"	"4"
Arm bent less than 5 degrees	Arm bent 6-34 degrees	Arm bent 35-54 degrees	Arm bent 55-84 degrees	Arm bent 85-90 degrees
SC2: Non-hopping leg is bent and swings forward in pendular fashion to produce force				
"0"	"1"	"2"	"3"	"4"
Use two legs to hop	NH leg slightly bent or held out for balance, no swing	NH leg bent, but stationary	NH leg bent, only moves one direction	NH leg bent & moves back and forth
SC3: Hop forward with one-foot push-off landing on the same foot				
"0"	"1"	"2"	"3"	"4"
2 ft push off	1 ft push off, land on two feet	1 ft push off, land on oppo foot	1 foot push off, land on same foot (short hop)	1 foot push off, land on same foot (long hop)
SC4: Foot of non-hopping leg remains behind hopping leg				
"0"	"1"	"2"	"3"	"4"
NH foot held in front of hop leg	NH foot held even with hop leg	NH leg starts behind, but end up in front	NH leg starts behing, but swings in front and back	NH foot held behind hop leg
SC5: Lift both arms in front of body, flexed and swing forward to produce force				
"0"	"1"	"2"	"3"	"4"
Arms at side or out for balance	One or both bent, but held stationary	One arm bent & swings, other for balance	Arms bent, swing opposite	Arms bent, swing together
SC6: 4 consecutive hops on preferred foot				
"0"	"1"	"2"	"3"	"4"
No consecutive	1 consecutive	2 consecutive	3 consecutive	4 consecutive

Skip

SC1: Stand facing and looking forward body upright				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body perpendicular	body facing away, but head looking where to go	body at 45 deg	Body parallel, but not upright	body parallel
SC2: Step forward with preferred foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No step	Shuffle step with non-preferred foot	Step with non-preferred foot	Shuffle step with preferred foot	Step with preferred foot
SC3: Followed by hop on same leg				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No hop	Jump between steps	Gallop-like steps	Hop, but land on two feet.	Hop on same leg
SC4: Arms move in opposition to legs, slightly flexed at waist level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Arms at side or out for balance	One or both bent, but held stationary	One arm bent & swings, other for balance	Arms bent, swing together	Arms bent, swing opposite
SC5: Period of non-support when both feet are momentarily off the ground				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Neither feet leave the ground; shuffling motion	Airborne during 25%	Airborne during 50% of skip; inconsistent	Airborne for 75%	Airborne for 100% of skip
SC6: Completes 4 rhythmic alternating skips				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Unable to maintain pattern	Maintain pattern for 1 consecutive	Maintain pattern for 2 consecutive	Maintain pattern for 3 consecutive	Maintain pattern for 4 consecutive

Jump

SC1: Stand with knees flexed with forward body lean				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Body upright, no knee bend	Slight knee bend, upper body upright	Knees bent about 20-30 deg., upper body slight forward	Knees bent near 45, body slight forward bend	Knees flexed about 45 degree, upper body bent forward
SC2: Arms extend behind body				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Arms by side	Arms slightly behind body	Arms reach behind about halfway to shoulders	Arms reach behind body, but arms bent	Arms fully extend behind body, even with shoulder
SC3: Arms extend forcefully forward and reach above the head				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Arms stay by side	Arms move at different heights	Arms reach straight out in front of body	Arms reach about to shoulder level	Arms reach straight above above head
SC4: Two-feet takeoff, leaving the ground together				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Shuffle	One foot leaves long before second	One foot slightly before second	Both leave, but not together in air	Both feet leave together
SC5: Both feet contact fround at the same time ahead of body mass at landing				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Leave on one foot, land on same foot	Leave on one, land on other	Leave/land on one; other two	Leave on two	Leave with two feet, land on two feed
SC6: Both arms are forced downward during landing				
“0"	**“1"**	**“2"**	**“3"**	**“4”**
Arms stay upright, or never leave side	Arms come down slightly	Arms return down, but in windmill movement	Arms come down in front, but do not come all the way down	Arms return to side (come down same direction as up)

Slide

SC1: Body turned sideways so shoulders remain aligned with line on the floor				
"0"	"1"	"2"	"3"	"4"
body perpendicular	body facing away, but head looking where to go	body at 45 deg	Body parallel, but not whole time	body parallel
SC2: Step sideways with lead foot				
"0"	"1"	"2"	"3"	"4"
No step	Step, confuses which is lead	Slide of lead leg	Shuffle of lead leg	Step with lead foot
SC3: Step sideways with trailing foot				
"0"	"1"	"2"	"3"	"4"
No step	Slide of trail foot	Step with trail, shuffle step	Step with trail, nearly to lead	Step with trail even with lead
SC4: Period of nonsupport when both feet are momentarily off the ground				
"0"	"1"	"2"	"3"	"4"
Neither feet leave the ground; shuffling motion	Airborne during 25%	Airborne during 50% of slide; inconsistent	Airborne during 75%	Airborne for 100% of slide
SC5: 4 continuous slides with preferred side				
"0"	"1"	"2"	"3"	"4"
Unable to maintain pattern	Maintain pattern for 1 consecutive	Maintain pattern for 2 consecutive	Maintain pattern for 3 consecutive	Maintain pattern for 4 consecutive
SC6: 4 continuous slides with non-preferred side				
"0"	"1"	"2"	"3"	"4"
Unable to maintain pattern	Maintain pattern for 1 consecutive	Maintain pattern for 2 consecutive	Maintain pattern for 3 consecutive	Maintain pattern for 4 consecutive

Ball Control Skills

Two-hand Strike

SC1: Grip bat with hands together with preferred hand above non-preferred				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Bat gripped with one hand	Two hands, wrong hand on top	Two hand, with one hand gap btwn hands	Two hands, two finger gap	Two hands, no gap
SC2: Stand sideways, feet shoulder width apart with non-preferred shoulder toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body parallel	Standing btwn parallel - 45 with feet together	body at 45 deg, feet apart	Body sideways, feet together	body perpendicular
SC3: Hands start at shoulder level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Hands at waist	Hands closer to waist	Hands btwn waist and should	Hands at chest height	Hands at shoulder
SC4: Swing bat forward in horizontal plane at waist level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Swing downward	Downward or upward at 45	Swing in U shape	Swing slightly U shaped	Swing horizontal
SC5: Trunk rotation and derotation during swing				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No movement in trunk	Rotation of trunk at end of swing	Slight rotation, derotation during swing	More rotation and derotation, but not complete.	Full rotation and derotation
SC6: Step toward target with non-preferred foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No step or step with wrong foot	Slide foot forward	Shuffle foot forward	Step no toward target	Step toward target
SC7: Strikes the ball sending it straight ahead				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Misses ball	strikes tee not near ball	Strikes tee near ball	Strikes ball sending it upward or down.	Strikes ball sending it forward
SC8: Follow through beyond contact with the ball				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Swing stopped at ball	Bat continues only a few inchs	Bat continues one foot past	Bat continues past near to body	Swing finishes near oppo shoulder

One-hand Strike

SC1: Stands with side orientation				
"0"	"1"	"2"	"3"	"4"
body parallel	Standing btwn parallel - 45 with feet together	body at 45 deg, feet apart	Body sideways, feet together	body perpendicular
SC2: Hold base of racket using handshake grip with preferred hand, elbow bent slightly				
"0"	"1"	"2"	"3"	"4"
Two hands, hand incorrect	Two hand grip, arms straight	Two hand grip, elbows bent	Handshake grip, arm straight	Handshake grip, elbow bent
SC3: Bounces ball at waist level				
"0"	"1"	"2"	"3"	"4"
Hits ball from hand	Throws ball forward	Ball bounced too hard or soft	Ball bounced chest high or knee high	Ball bounced around waist
SC4: Steps toward target with non-preferred foot				
"0"	"1"	"2"	"3"	"4"
No step or step with wrong foot	Slide foot forward	Shuffle foot forward	Step no toward target	Step toward target
SC5: Backswing of racket in horizontal plane				
"0"	"1"	"2"	"3"	"4"
No backswing	slight backswing, stays close to body	Slight backswing, past body	backswing up near shoulder	backswing even with waist
SC6: Swing racket forward in horizontal plane				
"0"	"1"	"2"	"3"	"4"
Swing downward	Downward or upward at 45	Swing in U shape	Swing slightly U shaped	Swing horizontal
SC7: Strikes the ball toward the target				
"0"	"1"	"2"	"3"	"4"
Misses ball	strikes ball with racket edge, face parallel with ground	Strikes ball with edge of racket	Strikes ball sending it upward or down.	Strikes ball sending it forward
SC8: Racket follows through beyond contact with the ball				
"0"	"1"	"2"	"3"	"4"
Swing stopped at ball	Swing continues only a few iches	Swing continues one foot past	Swing continues past near to body	Swing finishes near oppo shoulder

One-hand Dribble

SC1: Feet shoulder width apart				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Feet together	Feet 2 in separation	Feet slight separation, even	Feet should width apart not even	Feet should width even
SC2: Pushes ball forcefully to the floor with fingers				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No push	Ball dropped	Ball pushed too hard	Not hard enough to continue dribble at length	Balled pushed with force (controlled)
SC3: Contact ball with one hand				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No contact	Two hands	One hand alternating	One hand, other, near	One hand
SC4: Contacts ball at about waist level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No contact	Contact above shoulder or by foot	Contact at chest or knees	Slightly above or below waist	Contact ball at waist
SC5: Ball contacts ground in front of or next to preferred side				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Ball bounced away from body	Chase ball to continue dribble	Ball within one foot of feet, feet move to get ball	Shuffle feet to cont. dribble	Ball close to foot
SC6: Maintains control of ball for 4 consecutive bounces				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No consecutive	1 consecutive bounce	2 consecutive	3 consecutive	4 consecutive

Kick

SC1: Stand squarely behind the ball				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body parallel	Standing btwn parallel - 45 with feet together	body at 45 deg, feet apart	Body sideways, feet together	body perpendicular
SC2: Rapid, continuous approach to the ball				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No approach	Walks to ball	Inconsistent approach	continuous, but not quick	Rapid, continuous
SC3: Elongated stride or leap prior to contact				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No leap or stride prior to ball	Continues approach	Short 'normal' step	short leap	long leap
SC4: Place non-kicking foot next to ball				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Foot not near ball	Foot within 12 in of ball	Foot within 6 in of ball	Foot in front of or behind ball	Foot placed next to ball.
SC5: Swing kicking leg back				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No backswing	backswing less than 10 deg	Backswing btwn 11 and 30 deg	Backswing btwn 31 and 45 deg	Backswing greater than 45 deg
SC6: Swing kicking leg forward				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No leg swing	Leg swung at obtuse angle to body	Leg swung out 45 deg from body	leg between 45 and 0 to plane of body	Leg swung in plane of body
SC7: Contact ball with instep or inside of preferred foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No contact	Kicks with non-preferred foot	Uses toe of shoe	Uses side of forefoot	Contact with instep
SC8: Follow through of kicking leg toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No follow through	Follow through slightly past	Follow through about about 20 deg	Follow through about 45 deg	Follow through near waist level

Overhand Throw

SC1: Side orientation with non-preferred side to target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body parallel	Standing btwn parallel - 45 with feet together	body at 45 deg, feet apart	Body sideways, feet together	body perpendicular
SC2: Throwing motion started with a downward motion of the throwing arm				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No arm movement	Arm makes an upward arc	Arm straight back	Starts straight, then arcs.	Arm downward motion
SC3: T position with almost complete extension of throwing arm				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Arm close to body	Arm bent like dart player	L position	T position, slight bent in arm	T position
SC4: Throwing hand passes above shoulder				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Underhand throw	Arm below side arm	Side arm throw	Hand even with shoulder	Hand above shoulder
SC5: Step toward target with non-preferred foot				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No step	Step with preferred	Slide with non-preferred	Shuffle with non-preferred	Step with non-preferred
SC6: Body rotation toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Shoulders square to target	Turn btwn 0 and 30 deg	Turn between 31 and 60 deg	Turn between 61 and 89 deg	non-preferred pointed to target
SC7: Ball release toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No ball release	Ball release straight toward ground	Ball release up into the air	Ball release with bounce before target	Ball release toward target, no bounce
SC8: Follow through across body toward hip of non-throwing side				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No follow though	Arms stops shortly after throw	Follow through on same side as body	Follow through to midline	Follow through across body

Underhand Throw

SC1: Stand body square to target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body perpendicular	Standing btwn perpendicular - 45 with feet together	body at 45 deg, feet apart	Body square, feet together	body square, feet shoulder width
SC2: Preferred arm swings down and back with elbow extended				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No backswing	Backswing even with body, arm bent	Backswing even with body, arm straight	Backswing with arm bent	Backswing with arm extended
SC3: Preferred arm reaches behind trunk				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No reach back	Arm reach even with body	Arm reach just past body	Arm reaches past trunk about 45 deg	Arm reaches past trunk near shoulder level
SC4: Step with non-preferred foot forward toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No step	Step with preferred	Slide with non-preferred	Shuffle with non-preferred	Step with non-preferred
SC5: Preferred arm swings forward				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No arm swing or overhand	Arm swung at obtuse angle to body, even with shoulder	Arm swung out 45 deg from body	Arm between 45 and 0 to plane of body	Arm swung in plane of body
SC6: Ball release toward target				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No ball release	Ball release straight toward ground	Ball release up into the air	Ball release with bounce before target	Ball release toward target, no bounce
SC7: Hits target without bounce				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Ball rolls	Bounces thrice	Bounces twice	Bounces once	No bounce
SC8: Preferred arm follows through beyond release to chest level				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No follow through	Follow through stops before waist	Follow through to waist	Follow through between waist and chest	Follow through to chest level

Catch

SC1: Stand body square toward "thrower"				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
body perpendicular	Standing btwn perpendicular - 45 with feet together	body at 45 deg, feet apart	Body square, feet together	body square, feet shoulder width
SC2: Hands positioned in front of the body with elbows flexed				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Both hands down at size	Hands up, but elbow straight	One hand in correct position, other down or unfixed	One hand correct, other hand slightly bent.	Both hands up, both elbows flexed with hands about chest high
SC3: Arms extend to reach for ball as it arrives				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Both hands wait for ball, arms straight	Arms wait, but elbows bent	Reaches w one hand only	Reach with one first, then second follows	Both hands go to ball
SC4: Catch ball with hands only				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
No catch	Traps ball against body with arms	Traps ball against body with hands	"Claps" to catch ball	Uses only hands to "grab" ball
SC5: Absorb the force of the ball, bending the elbows to retract the arms				
"0"	**"1"**	**"2"**	**"3"**	**"4"**
Arms remain rigid	Arms bend slightly, but remain nearly straight	Arms bend about 45 deg	Arms bend all the way into the body	Arms absorb the ball, retract to body, but does not touch.

Appendix D: Social Validity Scale

Final Reflection
(Modified from Martens, Witt, Elliott, & Darveaux, 1985)

The purpose of this questionnaire is to obtain information that will aid in the refinement of the recent intervention. This intervention will be used by teachers to build motor skills of children with ASD. Please circle the number which best describes your agreement or disagreement with each statement.

	Strongly Disagree	*Disagree*	*Neither Agree or Disagree*	*Agree*	*Strongly Agree*
1. This would be an acceptable intervention for my student's motor skill development.	1	2	3	4	5
2. Most teachers would find this intervention appropriate for most motor skills in addition to the ones I worked on.	1	2	3	4	5
3. This intervention should prove effective in changing my student's motor skill.	1	2	3	4	5
4. I would suggest the use of this intervention to other teachers.	1	2	3	4	5
5. The students' motor deficit is severe enough to warrant use of this intervention.	1	2	3	4	5
6. Most teachers would find this intervention suitable for building motor skills.	1	2	3	4	5
7. I would be willing to use this intervention in the APE or PE classroom.	1	2	3	4	5
8. This intervention would *not* result in negative side-effects for the child.	1	2	3	4	5
9. This intervention would be appropriate for a variety of children.	1	2	3	4	5

10. This intervention is consistent with those I have used in classroom settings.	1	2	3	4	5
11. The intervention was a fair way to handle the child’s motor skill development.	1	2	3	4	5
12. This intervention is reasonable for the motor skills I worked on.	1	2	3	4	5
13. I liked the procedures used in this intervention.	1	2	3	4	5
14. This intervention was a good way to improve this child’s motor skill development.	1	2	3	4	5
15. Overall, this intervention would be beneficial for the child.	1	2	3	4	5

16. Overall, I believe that task modifications have been effective in building motor skills of my child.	1	2	3	4	5
17. I understand the concept behind task modification and have used it in other settings.	1	2	3	4	5
18. I feel task modifications are easily incorporated into the regular PE classroom	1	2	3	4	5
19. I think that task modifications are a great way to teach motor skills to children with ASD	1	2	3	4	5
20. I think that task modifications could be used with children with other disabilities successfully	1	2	3	4	5

Additional Questions:

21. Overall, how did the 6 weeks of intervention go? Do you believe that this time was long enough for the intervention?

22. Did you follow the protocol for the intervention correctly over the course of entire intervention? If yes, what did you do to make it go well? If no, what did you do incorrectly?

23. What did you find most beneficial about the intervention?

24. What could be improved about the intervention?

Appendix E: Instructor Self-Report (Pilot)

Instructor ID ________________

Date ________________

Student ID ________________

Please answer the following questions honestly and to the best of your ability (1 = completely disagree; 5 = completely agree):

1. Overall, the session went well:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

2. Overall, I followed the protocol for the whole session:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

3. I administered the task modification for the locomotor skill as directed by the protocol:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

4. I administered the task modification for the ball control skill as directed by the protocol:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

5. Things I need to work on or have questions about for next week (write your response below):

Appendix F: Instructor Self-Report (Dissertation)

Instructor ID ________________

Date ________________

School Code ________________

Student ID ________________

Please answer the following questions honestly and to the best of your ability (1 = completely disagree; 5 = completely agree):

1. Overall, the session went well:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

2. Overall, I followed the protocol for the whole session:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

3. I gave a short warm up that got the child read for activity:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

4. I administered the task modification for the locomotor skill as directed by the protocol:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

5. I administered the task modification for the ball control skill as directed by the protocol:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

6. I used the child's reinforcements as directed:

   (N/A) 1 ----- 2 ----- 3 ------ 4 ----- 5

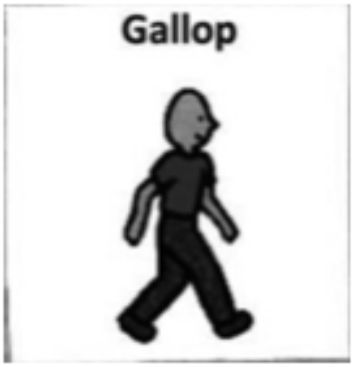
7. Things I need to work on or have questions about for next week (write your response below):

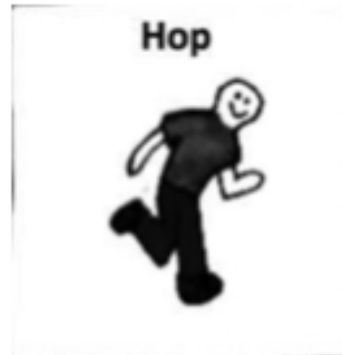
Appendix G: Sample Enjoyment Sheet

Happy

Sad

Appendix H: Samples of Validity Sheet





Appendix I: Outline of Interview Questions

Pre-intervention Interview:

- What is a typical weekday like for your family?
- What is a weekend like?
- What types of behaviors do you see in your child? at home? outside the home?
- What types of leisure activities do you as a family enjoy? Why?
- Are there any activities that are physically active (e.g. hiking, walking, running, biking)?
- Are there any activities you wish you could do as a family? Why?
- What barriers do you see for certain activities for your family?
- What types of activities do you (personally) enjoy? Why?
- Are they activities you wish your family could join you on? Why?
- What prevents your family from joining you?
- What leisure activities does your child enjoy?
- Any activities that are physically active?
- How active would you consider your child?
- What do you see as barriers to his/her physical activity?
- What activities do you see other children doing in your neighborhood that you think your child might enjoy?
- What barriers to you foresee with his/her participation?
- Are there any community based sport programs that you would like your child to participate in?
- What barriers do you foresee with his/her participation?
- What activities would you like your child to be prepared for in the future?
- What barriers to you foresee with his/her participation?
- What would you like to see your child do independently?

During Intervention Interview (Bi-weekly):
Over the last two weeks

- What behaviors have been demonstrated by your child?

- What activities have you done as a family? Any physical activities?
- What activities have you done on your own? Any physical activities?
- What activities has your child demonstrated? Any physical activities?
- What do you see as barriers to his/her activity in recent weeks?

Sample Additional Questions:

- Some parents have said that acceptance (i.e. how they are viewed in the community) has or could be a barrier to involving their child in physical activity; how do you feel this plays a role in your child being physically active?
- Some parents have said that time is a major factor in what they can do activity wise; for example, it takes a considerable amount of time to get from one place to another. How does time play a role in the activities that you or your child can do?
- Most parents stated that having a support network can be really helpful and not having one really limits what is possible; how does your support network affect the activities that you or your child are able to do?

Post-intervention Interview:

Over the past few weeks:

- What behaviors have been demonstrated by your child?
- Any behaviors that are different or new?
- What activities have you done as a family? Any physical activities?
- What activities have you done on your own? Any physical activities?
- What activities has your child demonstrated? Any physical activities?
- What do you see as barriers to his/her activity in recent weeks?
- What have the past weekdays been like for your family?
- What have the weekend been like?
- As a family, have you been able participate in any leisure activities? Any that were physically active?
- Are there any activities you still wish you could do as a family? Why?
- What changes have you noticed in your child over the course of the last several weeks?

- Some parents say that the lack of structure that occurs during long weekends and holidays causes some unwanted behaviors; how do you see this affecting your child?
- How to try to manage the changes in behavior?

More Broadly:

- What do you consider physical activity?
- How important is it to you? Why?
- How important is it for your child to be physically active? Why?
- What skills do you feel your child needs to be able to be physically active?
- What skills do they not have at this time that you hope they will develop in the future?
- What do you see as their greatest asset currently, in regards to being physical activity?
- What is their biggest barrier toward physical activity, currently?
- What do you see as being a barrier to physical activity in the future?
- *Some parents have said that acceptance (i.e. how they are viewed in the community) has or could be a barrier to involving their child in physical activity;* how do you feel think we could help change this and make it easier to be accepted?
- *Some parents have said that time is a major factor in what they can do activity wise; for example, it takes a considerable amount of time to get from one place to another.* What do you need as a parent to help to be better prepared to manage time?
- *Most parents stated that having a support network can be really helpful and not having one really limits what is possible;* What types of supports or support network would be most helpful to you?

4-week Retention Interview:

Over the past few weeks:

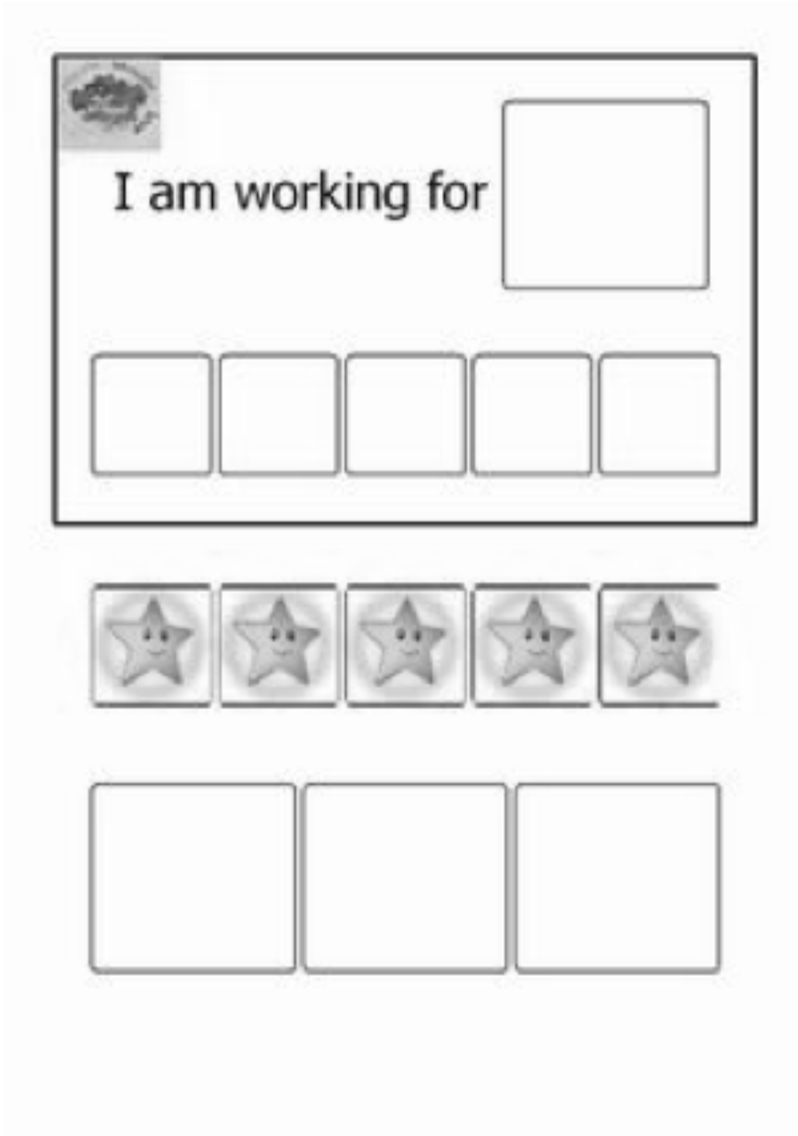
- What behaviors have been demonstrated by your child?

- Any behaviors that are different or new?
- What activities have you done as a family? Any physical activities?
- Are there any activities you wish you could do as a family? What would be needed to do that?
- What activities have you done on your own? Any physical activities?
- What activities has your child demonstrated? Any physical activities?
- How active has your child been (physically)? Is that different than before?
- What do you see as barriers to his/her activity in recent weeks?
- What changes, if any, have you noticed in your child over the course of the last several weeks?

More Broadly:

- Has your definition of physical activity changed? If so, how? If not, why?
- What emphasis do you put on (either daily or regular) physical activity?
- What role to you see physical activity playing in your child's life currently?
- What role to you see physical activity playing in your child's life in the future?
- What benefits, if any, do you see coming from physical activity for your child?
- In terms of priority, where do physical activity or gross motor skills fit into the skills your child needs to learn?
- What types of activity to you feel are appropriate for children similar to your child?
- What knowledge, strategies, or supports do you think that you need in order to best assist your child in building gross motor skills or to be physically active?
- *Over the course of the study, parents have mentioned a variety of barriers to physical activity, including acceptance, time, support, and unstructured time or holidays.* What barriers play the largest role in your life, in regards to physical activity?
- Additionally, are there any other barriers that we have not talked about that you think play a significant role?
- What are your biggest hopes and dreams for your child?
- Is there anything else that we have not talked about, that you think is important?

Appendix J: Example of Token Board



Appendix K: Parent Survey of Child and Family Activity

Activity Survey

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Is your child physically active (yes/no)? ___________________

About how many days per week is your child active? ___________________

What are your child's favorite activities?

Are you physically active as a family (yes/no)? ___________________

About how many days per week? ___________________

What are your family's favorite activities?

____

Does your child play any sports team (yes/no)? ___________________

About how many days per week does your child participate in this sport? _____________

What sports is your child involved in?

____

Does your child have any activities (e.g.) hobbies that wouldn't be considered physically active or sports related (yes/no)? ___________________

About how many days per week? ___________________

What are your child's favorites?

____