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ORIGINAL ARTICLE

The Effect of Task Modifications on the Fundamental Motor Skills of Boys on the Autism Spectrum: A Pilot Study

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Abstract

A growing body of research has shown children on the autism spectrum are behind their peers developmentally in regard to their gross motor skill development. Given the increased risk for obesity and other health related co-occurring conditions associated with autism spectrum disorder, building foundational gross motor skills is vitally important so that individuals grow into physically active adults. However, the research on motor skill interventions for children on the autism spectrum is limited. Therefore, a multi-element multiple baseline across behaviors single subject design was employed to test the effectiveness of a motor intervention based on task modifications developed based on Dynamic Systems Theory. Using a purposive sample of two boys, aged 7 and 8 years, on the autism spectrum, task modifications were evaluated to understand the impact on the child's motor performance and their performance's persistence across two skills (i.e., horizontal jump and two-hand strike; $P1_{jump\text{-}pre} = 3$; $P1_{strike\text{-}pre} = 4$; $P2_{jump\text{-}pre} = 2$; $P2_{strike\text{-}pre} = 2$). As a result of the task modifications, both boys scores increased according to developed skill criterion and the raw scores of the Test of Gross Motor Development, 3rd Edition (Ulrich 2018; $P1_{jump\text{-}post} = 6$; $P1_{strike\text{-}post} = 6$; $P2_{jump\text{-}post} = 6$; $P2_{strike\text{-}post} = 8$). Once the modifications were faded, both boy's two-hand strike performance persisted; however, one boy's horizontal jump performance returned to baseline levels. Yet, for this still there remained a high level of non-overlap (90.5%). This study demonstrates the potential impact that an intervention designed around task modifications can have; however, it also shows that interventions may need to be designed at an individual level and contain the flexibility to adjust to the needs of the child.

Keywords Gross motor development · Autism spectrum disorder · Dynamic systems theory · Constraint-based approach · Fundamental motor skills

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In recent years there has been a growing body of research that indicates many, if not the vast majority, of children on the autism spectrum display differences in their gross motor skill development (Fournier et al. 2010; Liu et al. 2014; Staples and Reid 2010). These motor skill delays start at a very early age (Ketcheson et al. 2018; Lloyd et al. 2013) and, when compared to typically developing peers, increase throughout adolescence (Liu et al. 2014). Differences in motor skill development begin so early for children on the autism spectrum that delays are often present before core behaviors of autism spectrum disorder (ASD), such as social communication deficits or repetitive behaviors, are noticeable or diagnosable; leading some researchers to suggest that motor skills be included as a part of the diagnostic criteria (Teitelbaum et al. 1998) or at minimum a part of screening criteria (Liu 2012).

Further, demonstrated delays in gross motor development are in combination with higher rates of physical inactivity (MacDonald et al. 2014; Stanish et al. 2017) despite evidence showing the numerous behavioral benefits of physical activity (PA) for children on the autism spectrum (Bremer et al. 2016; Lang et al. 2010; Liu et al. 2015), potential for increased social opportunities (MacDonald et al. 2011; Healy et al. 2018b), and potential increase in quality of life (Stacey et al. 2018). Moreover, despite demonstrated enjoyment (Stanish et al. 2015) and desire to participate (Blagrave 2017), children on the autism spectrum and their families face numerous barriers to physical activity (Must et al. 2015; Obrusnikova and Miccinello 2012).

Arguably, fundamental motor skills are vitally important to the participation in physical activity (Haubenstricker and Seefeldt 1986). Stodden et al. (2008, 2014) argue that there is a synergetic relationship between motor skills ability, or motor competence, and PA; i.e. that one begets the other. In young children, physical activity allows for the development of motor skills and competence (Stodden et al. 2008). As children age, fundamental motor skills become increasing important for PA and more complex movements. This theoretical understanding of the interplay of motor skills and PA suggests that building motor skills is vitally important to overall development. This is further reinforced by the demonstrated link between motor skills and language development (Bedford et al. 2016), social skills (MacDonald et al. 2013a), and adaptive behavior (MacDonald et al. 2013b) in populations on the autism spectrum. Yet, motor skills are often an over looked area in this population (Staples et al. 2012) and given higher rates of obesity present in adolescents on the autism spectrum (Healy et al. 2018a), ensuring an early successful foundation for later participation in physical activity is vitally important. Without the appropriate development of fundamental motor skills, participation in physical activities will be difficult later in life (Healy et al., 2018b; Stodden et al. 2008).

The recent, limited research on motor skill interventions for individuals on the autism spectrum suggest that, seemingly, any motor skill intervention may provide benefit for children on the autism spectrum. In two past studies (Bremer and Lloyd 2016; Bremer et al. 2014), the presented intervention method was similar to physical education teaching (e.g. once or twice per week for 45 min). By focusing on one skill per week, children on the autism spectrum were able to increase their motor skill performance from baseline; though due to limited sample size, statistical data was not reported. Ketcheson et al. (2016) demonstrated significant improvement in fundamental motor skills using an intervention designed with the principles of classroom pivotal response treatment (CPRT). CPRT, stemming from behavioral theory, is based on strategies to elicit behaviors (antecedents) and responses to the produced behaviors (consequences). However, the intervention was administered 20 h per week for 8 weeks and requires a high fidelity of implementation from the instructor; this high of a frequency and large dosage may not possible for all providers or situations demonstrating a necessity for alternative options that provide for similar increases without the necessary time commitments. Further, an adapted physical educator in Bremer and Lloyd' study (2016) stated: "[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). Highlighting the need for an intervention method that does not focus solely on verbal or physical prompts.

Dynamic systems theory (DST; Newell 1986; Newell and Jordan 2007) may provide the necessary framework for such an intervention. DST, according to Newell, suggests that behavior is the result of individual (e.g., a person's strength or coordination), task (e.g., the step or rules necessary for an activity or movement), and environmental (e.g., the playing surface) constraints that self-organize within the individual. Constraints in this theory are not negative, but neutral; having potential for either negative or positive effects. For example, a person walking on a carpeted surface will walk with a stable walking pattern; yet, if that person were to step on a patch of ice (i.e., a change in the environmental constraints, but the individual and task constraints remain the same), their pattern would shift to ensure they stayed upright and would walk with a new walking pattern.

According to a recent review (Colombo-Dougovito 2017), studies that have used DST as a foundation for understanding movement have provided strong evidence for the theory, yet little empirical evidence exists testing if the modifications of the constraints could improve movement; most studies focused on solely on the effect—good or bad—of modifying a specific constraints on movement. Yet, as the theory is presented, any change in constraints—intentional or not—will cause a change in the movement pattern. In only one example has constraints been modified with the intention of improving movement. Vernadakis et al. (2015) manipulated task constraints in an intervention comparing direct instruction to exergaming. In this example, both intervention methods manipulated motor skill tasks to influence more mature movement patterns and showed an increase from pre- to post-assessment. Further, DST may prove a more optimal mode of instruction because, unlike other motor development theories, the characteristics of a child's ASD does not act as a barrier to overcome or disadvantage, but acts as another constraint that can either limit or influence certain behaviors, like movement, in different situations. However, as only one study was found that used DST as an intervention method, further inquiry must be made as to how DST might be used to influence the development of fundamental motor skills.

Purpose

The purpose of this study was to determine if purposeful changes to task constraints, heretofore referred to as *task modifications*, could improve the development of motor skills in children on the autism spectrum. Additionally, can improvements persistent in the absence of the absence of the task modifications. Using a multi-element multiple baseline across behaviors single-subject research design, this study was guided by three main research questions:

1. How do task modifications influence the motor performance of children with ASD?
2. Do changes in motor performance persist in the absence of task modification?
3. How much time is required to effectively fade a task modification for a child with ASD?

The authors hypothesized that changes in performance would occur with the addition of the task modification and persist in it's absence.

Methods

Prior to collecting data, approval for this study was obtained from the Institutional Review Board (IRB) at a mid-Atlantic research university. The study (protocol #2016–0034, approved 02/25/2016) was deemed exempt from review because it posed minimal risk to participants. As this study focuses on a vulnerable population, a consent/assent procedure was employed. Parents and legal guardians of children known to have a diagnosis of ASD were contacted with information regarding the study and asked to provide consent. 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 during 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 dissenting participation and was withdrawn from the study. All consented children that were included in the intervention phases completed each session without increased duress.

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 the child. From a total of 6 consented participants, a purposive sample of two participants were selected for this study. Selected participants needed to have a formal diagnosis of autism or ASD. This was verified through parent report on the Social Communication Questionnaire (SCQ; Rutter et al. 2003). Additionally, participants needed to demonstrate one skill component of one manipulative and one locomotor skill, as measured by the Test of Gross Motor Development, 3rd Edition (TGMD-3; Ulrich 2018). By requiring that participants have one component, research can assure that, at minimum, participants are developmentally read for that skill. If a participant demonstrated no components of a skill, it could be assumed that they are not developmental ready for that skill and may not benefit from an intervention no matter how impactful; conversely, if a participant had more components of a skill, it would be difficult to determine if growth was due to the intervention or simple maturation. Lastly, participants had to demonstrate the ability to receive prompts verbally or visually.

Participant 1 was as an 8-year-old boy with a diagnosis of autism from his developmental pediatrician. His SCQ score was 31, above the cut-off of 15. He had a body mass index (BMI) of 20.1. He had no reported co-morbidities. He was non-verbal, though very responsive to verbal commands and could communicate with an iPad. His overall initial raw score on the TGMD-3 was 22/100. He scored a 12/46 on the locomotor subtest and 10/54 on the object control subtest.

Participant 2 was a 7 year-old-boy with a diagnosis of autism from his developmental pediatrician. His SCQ score was 19, above the cut-off of 15. He had a BMI of 15.3. He had additional diagnoses of microcephaly, epilepsy, and ADHD. He was non-verbal, but responded to verbal commands, and communicated using an iPad. His overall initial raw score on the TGMD-3 was 27/100. He scored a 8/46 on the locomotor subtest and 19/54 on the object control subtest.

Setting

The intervention was provided one-on-one by each participant's APE instructor in a multipurpose room at the participant's home institution. The primary investigator (PI) was present, as was the participant's "teacher's aide (TA)." 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 in the multipurpose room of the participant's school. Distraction events were documented within the data and analyzed to determine whether any effect on performance was potentially due to a less than ideal environment. Overall, the intervention did not appear to be adversely affected by the distractions, as the children received APE services in this environment regularly and was use to the occasional distraction. Sessions were video recorded for later assessment and reassessment. The majority of sessions were done with only the three adults and child participant in the room. This study was completed twice per week over 11 weeks for a total of 21 individual sessions.

Instructor Training Each of the child's APE teachers was trained in how to administer prompts and prompting procedures. Instructions were given over two 1-h training modules. After each session of administering the intervention, the APE teacher was asked to self-report on their performance for that session using a 5-pt. Likert scale (5 being highest/most agreement). Additionally, the primary investigator attended every session for both children to observe the intervention; three of these sessions were randomly chosen by the primary investigator to evaluate each instructor's adherence to prompting procedures based on a predesigned checklist. Overall, the instructors self-reported strong adherence to study protocol (M = 4.33, SD = .65), which was confirmed by the primary investigator's observation.

Procedure

After an initial assessment using the TGMD-3, participants began the baseline phase for the intervention on the identified skills of horizontal jump and two-hand horizontal swing. The horizontal jump, is also referred to as the standing long jump; this skill consists of an individual starting on two evenly spaced feet, swinging arms backward, then forwards propelling the individual forward, leaving and landing on two feet. The two-hand strike is commonly used in baseball and tennis; this skill consists of an individual standing parallel to a stationary ball with two hand on a striking implement (e.g., a tennis racket or baseball bat), stepping toward the intended target, swinging and hitting the ball in the direction of the step. For a great breakdown of the skill criteria for each skill see Table 1. The study used a multi-element multiple baseline across behaviors single-subject research design and the intervention was completed 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 or tasks receive the intervention and others do not (Kazdin 2011). Since the intervention involves instruction, a reversal design was deemed to be inappropriate, as the subsequent A phase would be inherently different from the previous A phase at baseline. 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 faded prompting procedures, and C is performance without prompting.

The first phase of the intervention was the baseline (denoted A). During this phase, participants were given a verbal and visual prompt to perform 20 trials of each of the chosen skills. The skills were assessed based on a set of criteria (see Table 1) developed from the combined criteria of the TGMD-3 and the *Everyone Can!* skill assessment items (Kelly et al. 2010). Both the TGMD-3 and *Everyone Can!* were developed from the *I Can—Achievement-Based Curriculum (ABC)* project (Kelly and 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

Table 1 Skill criteria for horizontal jump and two-hand strike

Horizontal Jump		Two-hand Strike	
1	Stand with knees flexed with forward body lean**	1	Grip bat with hands together with preferred hand above non-preferred**
2	Arms extended behind body^	2	Stand sideways with non-preferred shoulder toward target**
3	Arms extend forcefully forward and reach above the head*	3	Hands start at shoulder level^
4	Two-feet takeoff, leaving the ground together***	4	Swing bat forward in horizontal plane at waist level**
5	Both feet contact ground ahead of body mass at landing**	5	Trunk rotation and derotation during swing*
6	Both arms are forced downward during landing*	6	Step toward target with non-preferred foot*
		7	Strikes the ball sending it straight ahead*
		8	Follow through beyond contact with the ball**

* = Test of Gross Motor Development, 3rd Edition (TGMD-3; Ulrich 2018); ** = *Everyone Can!* (*EC!*; Kelly et al. 2010); *** = Combination of TGMD-3 & *EC!*; ^ = Additional/unique criteria

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 and Wessel 1991). In total, each new set of skill criteria has 5 to 8 criteria points, which will be referred to as "skill criteria" or "SC" hereafter. The focal skills for this study, the horizontal jump and two-hand strike, had 6 SC and 8 SC respectively.

These SC were 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 24 points (6 SC × 4) for locomotor skills and 32 points (8 SC × 4) for ball control skills 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 third SC of the horizontal jump (i.e., "arms extend forcefully forward and reach above the head"), if a participant has his/her arms swing forward at different heights or not in unison, 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 jumping example, participants would earn a 2 if his/her swung forward in unison but stop prior to chest height. To earn a score of *nearly present* (3), the participant's movements must be close to the mature pattern but may still look rigid or jerky. For example, continuing with the SC from above, a participant's arms may swing in unison, but stop at shoulder height, not reaching above the head. During the baseline, a child's performance determined which criteria point was the focus of the intervention. For example, if the participant could perform the first SC, the intervention focused on development of the second criterion point.

The SC and attributable task modifications, as well as levels of performance, were reviewed, analyzed, and revised through two rounds of feedback from experts in the fields of child development, motor development, and/or autism. Experts were provided both the new skill breakdown and accompanying task modification. Each SC and task modification were rated on a 5-point Likert type scale; responses were averaged and scores above 4 were accepted. Each SC and task modification received a rating above 4. The task modification (i.e., a purposeful change in a task constraint) was chosen based on its ability to influence an individual into the appropriate movement behavior for each SC.

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 multi-element multiple baseline design over two skills (i.e., behaviors), each participant started the intervention for the horizontal jump, while continuing at baseline for the two-hand strike. By delaying the intervention for the second skill, the ability to detect changes that can be attributed to the active intervention was enhanced. During the intervention phase, participants received a prompt using predetermined task modifications (see Table 2). 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 two-hand strike, one modification was to apply tape to the handle in order to signal where each hand was placed; in the B phase, the

Table 2 Modifications for horizontal jump and two-hand strike

Horizontal Jump	Two-hand Strike
1 Chair or low bench placed behind; prompt to sit	1 Two dots on bat handle where hands go (red preferred, green non-preferred)
2 Place in front of wall; prompt to touch wall with hands	2 Two spots on ground positioned perpendicular to the target (red preferred, green non-preferred)
3 Instructor holds noodle for child to touch with hands	3 Position by wall; tap [spot] on wall behind preferred shoulder
4 Two spots to start on; two spots to land on.	4 Set up limbo bar slightly above waist. Prompt to swing under
5 Low hurdle or rolled towel to jump over.	5 Place pin near rear foot for the individual to knock over with the outside of his/her heel.
6 Two cones to touch on either side of landing zone for child to touch with hands after landing.	6 Additional spot (blue) on floor, in front of green spot
	7 Target on wall
	8 Position by wall; tap [spot] on wall behind non-preferred shoulder

Note: Each modification is matched to the skill criteria of the same number from Table 1

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. For the horizontal jump, participants were prompted to sit on a chair to influence adherence to the first criteria of jumping (i.e., "stand with knees flexed with forward body lean"). During the B′ phase, this was changed to a low bench, then a small hurdle (e.g., two cones with a pool noodle spanning the distance from the top of each cone at slightly above knee height for each child) in the B″ phase. The small hurdle would not allow for the child to rest any weight and only acted as a guide for how low to go.

Data Analysis

Data were graphed and analyzed visually (Lane and Gast 2014) to understand the effect of task modifications on the motor performance of participants. The PI assessed each child and scored the performances at each time point. Using a random number generator, intrarater reliability (IRR) was calculated on 3 random cases per child to insure reliability of coding performance. The primary investigator ensured that at least one case was chosen from each phase (i.e., A, B, or C) and from each measured behavior (i.e., one selected from one skill and one from another). These cases were re-coded two weeks after the initial coding. IRR was calculated at 92.8%, which was above the criterion goal of 80%. Further, the intervention for each participant was documented (Fig. 2), containing a minimum of three data points and four phase changes for each skill (Kratochwill et al. 2013). Non-overlap lines and effect sizes were calculated to further understand the task modifications impact on the motor performance of the participants (Parker et al. 2011).

Results

Figure 2 demonstrates the change in skill performance across the intervention for both participants. The graphs demonstrate an increase in the gross motor scores of each sub-test skill at the introduction of the task modification (B Phase). Across each trial during the baseline phase for the locomotor skill of jumping, participant 1 averaged 7.3 (SD = .74) and participant 2 averaged 6.6 (SD = 1.0). After the addition of the task modification, average scores were 14.7 (SD = 1.54) and 16.9 (SD = 2.0) for participant 1 and 2, respectively. These scores persisted as the task modification was faded, however, improvements only persisted in one participant after the task modification was removed. Specifically, participant 1's score stayed consistent (M = 18.2, SD = .76), while participant 2's score reverted to a score similar to baseline levels (M = 7.0, SD = 3.2).

This pattern of change was seen similarly during the two-hand strike. During the baseline phase, average scores for two-hand strike was 6.4 (SD = .75) and 8.6 (SD = .7), respectively. These scores increased to 20.7 (SD = 1.4) and 21.7 (SD = 2.2), respectively, after the addition of the task modification. Scores persisted in each subsequent phase when the prompt was faded. However, unlike with the horizontal jump performance, both participant's two-hand strike performance persisted in the absence of the task modification during the C phase; 18.2 (SD = .7) and 21.2 (SD = 1.1), respectively. When considering the non-overlap lines, all but one graph in Fig. 1 had no overlap; in the one example of horizontal jump in Participant 2, there was still 90.5% non-overlap.

Lastly, the calculated overall effect size, across both measured skills, 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 motor skills in children with ASD that have the potential to be sustained in the absence of the task modification. Individual sub-skill effect sizes were calculated for both the horizontal jump ($d = 3.96$) and two-hand strike ($d = 15.01$) performances were calculated; though due to the limited number of participants and large effect sizes for the individual skills, the practical implications of these values is limited. Yet, given the starting points of both participants, overall across both skills participants demonstrated a 118% increase in SC. Specifically, participants demonstrated an 80% increase in horizontal jump SC and a 183% increase in two-hand strike SC over the course of the study.

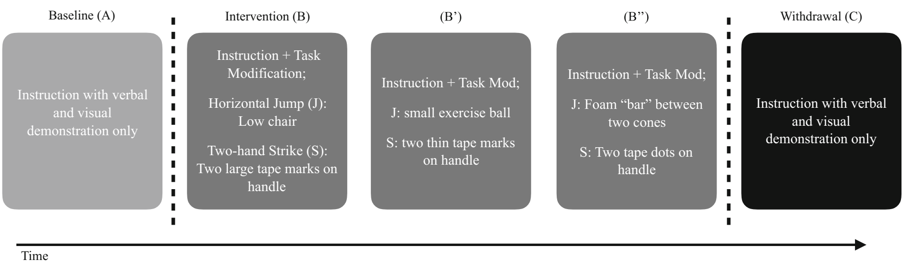
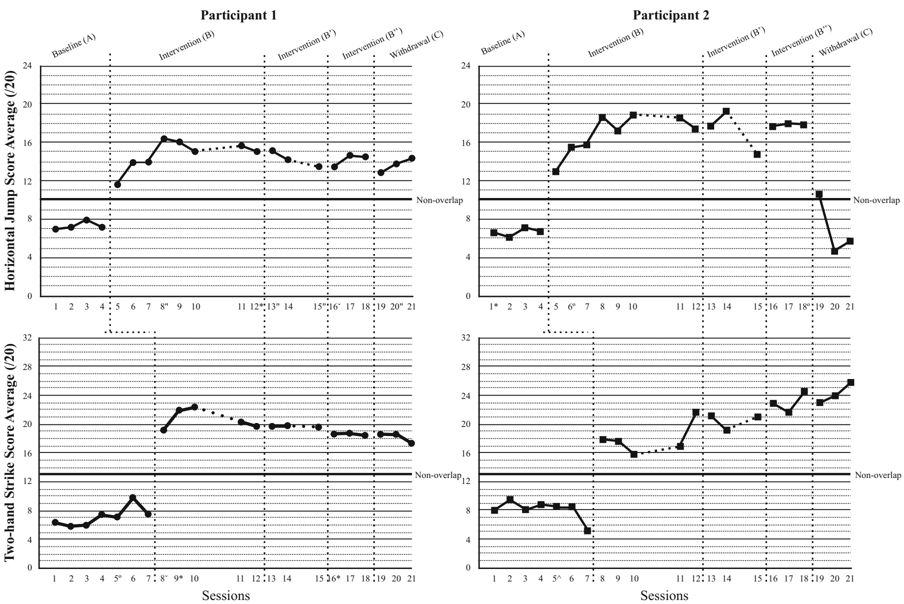


Fig. 1 Visual breakdown of prompting procedure

Discussion

The focus of this study was to understanding how task modifications (i.e. task constraints) could be used purposefully to improve the motor performance of children on the autism spectrum. Overall, results 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 on the autism spectrum. As shown in Fig. 2 (above), the addition of a task modification marked a noticeable improvement in the motor performance of each participant within 1 training session, as Newell's DST (Newell 1986) would suggest. Furthermore, the continued trend seen in the two-hand strike performance, while the horizontal jump skill received the task modification shows that the improvement was not due to exposure or maturation, but by the task modification specifically. Furthermore, the persistence of improved motor performance demonstrates the strong influence that task modifications can have on motor performance in children on the autism spectrum. For example, with the two-hand strike, both participants demonstrated higher levels of motor performance after the removal of the task modifications. Lastly, the improvement in motor performance demonstrates the potential of task modifications to perturb a stable motor pattern into a more mature pattern within populations on the autism spectrum.

Similar to previous research (Liu et al. 2014; Staples and Reid 2010), both participants showed very delayed motor skills, demonstrating fewer than 30% of the possible skill criterion on the TGMD-3–not the expectation for a typically developing 7 or 8-year-old child. This delay was further seen in the SC of the two focus skills, horizontal jump and two-hand strike, for this study. Despite both visual and verbal directions, both



Note: ° = 18 trials; * = 19 trials; " = 21 trials; ˇ = 22 trials; ^ = 23 trials; "…" = indicate a break in the school (i.e., scheduled holiday) that fell during data collection; Non-overlap line (Horizontal Jump) = 10; Non-overlap line (Two-hand Strike) = 13.

Fig. 2 Graphs of Motor Skill Performance by Participant. Note: ° = 18 trials; * = 19 trials; " = 21 trials; ˇ = 22 trials; ^ = 23 trials; "…" = indicate a break in the school (i.e., scheduled holiday) that fell during data collection; Non-overlap line (Horizontal Jump) = 10; Non-overlap line (Two-hand Strike) = 13 participants performed only one of the criteria in the focal skills consistently during the pre-assessment. In the baseline phases, participants often focused on only one or two components of the skill, such as moving from A to B. This selective focus has been documented in previous research (Berkeley et al. 2001; Staples and Reid 2010) and has implications for the validity of standardized assessments in this population. Specifically, it is difficult to discern if the limited performance of motor tasks found in minimally or non-verbal children on the autism spectrum is due to a misunderstanding or limited understanding of the task, a selective focus on one aspect of the task during the demonstration, or an actual delay in motor skill ability. Yet, the addition of task modifications in this study shows the potential for its use as an intervention regardless of the origin or severity of delay. During the B phases of the intervention, both participants scores improved greatly from the baseline phase. Some improvement from baseline to the initial intervention phase was to be expected, as the task modification (if done correctly) would ensure that the participant completed an additional SC; yet, both participants nearly doubled their scores, on average, in both skills within one session of adding the task modification. Meaning that improvements were seen not only in the focus SC, but in subsequent criteria as well. These improvements persisted, and in one case continued improving, during the fading of the prompt and, in the case of the two-hand strike skill, persisted in the absence of the task modification. This is clearly demonstrated in the limited amount of overlap between baseline and intervention measurements.

The improvements were not consistent, however, in the horizontal jump for one of the two participants, demonstrating that the task modification and the length at which they are administered may need to be implemented on an individual level. As seen in Fig. 1, participant 2 demonstrates a decrease in performance in Phase C in the horizontal jump, but not in the two-hand strike. This result suggests—and is supported by DST (Newell 1986; Thelen 1995)—that for the horizontal jump the skill with the modification was not performed long enough or in a strong enough way for the new motor pattern to stabilize. While not unexpected, this suggests that task modifications may not act universally between individuals and that individualized instruction needs to be considered for any intervention using this approach. Further, the PI noticed a change in behavior within participant 2 during completion of the horizontal jump during the withdrawl (C) phase: (1) having to go barefoot, because of poor footwear (not done in previous sessions); (2) more jocular behavior (i.e. playing when performing the task) toward the PI, instructor, and teacher's aide; and (3) less focus during the demonstration. During this phase, participant 2 jumped using the practiced SC; however, he did not use the others SC, such as appropriate arm swing or landing on two feet, that were used during the intervention phases. Any one of these factors could have influenced the child's performance, demonstrating a potential bias in these findings. The jocular behavior demonstrates the potential for enjoyment during the practice of skills that can happen with task modifications, as well as the comfort level with the instructor and researcher. However, the limited focus also demonstrates the potential for monotony in practice during single-subject studies. Yet, these results—despite the lower scores for participant 2 in the horizontal jump—demonstrate that changes in motor performance can occur in a very short amount of time (< 20 trials) and how much improvement can be made out of the total amount of time (< 16 sessions).

However, what was not expected was how much of an increase occurred due to the introduction of the task modifications. The task modifications during the intervention phases focused on improving one SC, yet influenced another SC. This suggests that while certain skill tasks may need dedicated task modifications, some skills may benefit from only one or two. This premise is seen in previous research using DST to manipulate treadmill walking patterns in infants with Down's syndrome (Ulrich et al. 1998) and further strengthens the evidence for the explanation of how motor behaviors occur provided by DST (Newell 1986; Newell and Jordan 2007). For example, in the present study, during the horizontal jump participants were asked to sit, reach back, then jump. While this focus on very beginning SC for the jump, when participants jumped they completed several later stage criteria, such as "swinging arms above the head". Further, an intervention incorporating task modifications could continue growth by focusing on subsequent SC. Results of this study demonstrate that using appropriate task modifications can cause quick improvements that persist; future research should investigate whether subsequent modifications can be used, and if fading prompts are necessary.

Lastly, the large effect sizes ($d = 1.945$) demonstrated for each skill showed how potentially powerful task modifications can be on the motor performance of individuals and 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 at the introduction of the task modification to each skill, the resulting increases 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 remained high as the participants started to move into a more stable, mature motor pattern. At the withdrawal phase (C), the motor skill persisted in most cases in the absence of the task modification. This further suggests that motor skills can be influenced positively in populations on the autism spectrum in a relatively short intervention (i.e., 40 trials per week per skill over less than 11 weeks); this is significantly less than that previous recommendations (i.e., greater than 18 weeks; Ketcheson et al. 2016) and may be more easily transferred to different settings with higher levels of time constraints.

Limitations

Given the quick increase of skill performance provided by the task modifications, this technique may provide a reasonable method for improving motor skills in a short amount of time. Yet, these results should be taken with caution, as replication is needed. These findings provide initial, strong evidence—long needed—for the application of DST to motor intervention and a first step toward a dedicated motor intervention for children on the autism spectrum. However, given the small sample size, generalization is limited. Further limiting generalization, is the lack of female participants on the autism spectrum. This study sought to recruit female participants; however, of those that parents consented ($N = 2$), one had no motor delay and thus may not have benefited from the intervention. The other had such as significant motor delay that a single motor skill with one consistently demonstrated skill criteria was not found. Future research should make a concerted effort to recruit female participants to understand how motor performance and the application of task modifications may differ.

Further, the task modifications and intervention for this study focused on only two motor skills, the horizontal jump and two-hand strike. While strong evidence was shown for DST's application in these two instances, it is reasonable to consider that this might not be the case with other motor skills. Research should look to replicate these findings during other motor tasks, even beyond the skills included in the TGMD-3, such as unique motor tasks like frisbee throwing. Last, while evidence suggests that motor performance was persistent in the absence of task modifications, this study lacked a true retention assessment. Future research should look at the impact task modifications have after a longer lapse in time to better understand if the motor skill patterns were truly perturbed into a new pattern or if ultimately individuals return to the previous pattern.

Conclusion

Given the mounting evidence (Lloyd et al. 2013; Liu et al. 2014; Staples and Reid 2010) of motor delays in children on the autism spectrum, the limited evidence for motor interventions in this population, and the potential benefits (Bremer et al. 2016), a clear motor intervention is desperately needed. DST provides a beneficial framework that, in these findings and that of previous research (Colombo-Dougovito 2017), shows a great potential for improving the motor performance of individuals on the autism spectrum quickly and in a relatively short period of time. However, these procedures need further replication in broader samples to better understand exactly how to provide task modification in the most effective and efficient way, especially for unique, non-linear tasks.

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Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Study protocols were reviewed and approved by a university internal review board prior to participant recruitment.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest Andrew Colombo-Dougovito declares that he has no conflict of interest. Luke Kelly declare that he has no conflict of interest. Martin Block declares that he has no conflict of interest.

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