EFFECTS OF A VIRTUAL REALITY INTERVENTION ON POSTURAL ADAPTATION OF CHILDREN WITH MOVEMENT AND BALANCE PROBLEMS

A Thesis Presented to the
School of Kinesiology
Lakehead University

Submitted in partial fulfillment of the requirements for the
degree of Master of Science in Kinesiology

by

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January 2012

Abstract

The purpose of this study was to examine the effects of a 20-session Wii Fit intervention on postural adaptation of 10 children with movement and balance problems (*M* = 8.50 years; *SD* = 1.27 years). The children's balance was assessed at pre-, post-, and after a 7-week wash-out period, with the Total Balance Score (TBS) of the Movement Assessment Battery for Children (MABC) (Henderson & Sugden, 1992) and anterior-posterior (AP) sway, medial-lateral (ML) sway, area (Ao) of sway, and path length (L) measures of the balance space (BS) task (adapted from Geuze, de Jong, & Taylor, 1999), when the Wii board was placed on an Advanced Mechanical Technology Incorporation (AMTI) force plate (Krasniuk & Taylor, 2010). A series of repeated measures ANOVAs with Bonferroni corrections and effect sizes were used to examine and evaluate the effects of the Wii Fit intervention on the children's balance. Subsequent dependent samples *t*-tests and effect sizes were computed to further investigate the effects of the intervention on TBSs, TISs, and path length measures. The children met the criteria (adapted from Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010) and showed between 55.7 and 200% improvement on the Wii Fit simulations throughout the intervention period. There was a significant improvement in TBSs with large effects (F (2, 18) = 9.57, p = .001, ηp^2 = .52) shown at the post-test (t (9) = 3.49, p = .007, d = 1.10). It was speculated that the intervention had some effects on the children's TISs (t (9) = 4.60, p = .001, d = 1.46) and path length measures (t (9) = 2.19, p = .057, d = .69) at post-test, however, path length measures showed decreases in sway, which was opposite to what was anticipated. There were no significant differences and small effect sizes shown in area, ML, and AP sway measures. AP sway was the only measure to show an increasing trend at post-test as predicted. It was conjectured from the qualitative inspection of individual data that a developmental pattern

emerged, as three older boys increased sway at the post-test, while the others decreased sway. Based on the equivocal results from this study, future research should investigate the effects of Wii Fit interventions on postural adaptation of children with movement and balance problems using different age groups.

Acknowledgements

This research project was a major stepping stone in my life. First, I would like to express my appreciation to my supervisor, Dr. Jane Taylor. Her assistance, guidance, and encouragement helped me develop more independence and competence, and become more analytical in my endeavors. Throughout my time as a master's student, she has provided me with countless opportunities to explore my interests and connect with others from all over the world, to share common goals in life.

I would also like to thank my committee members, Dr. Eryk Przysucha and Professor Carlos Zerpa, for providing me with their time and advice, and supporting me with this project. I thank Dr. Eryk Przysucha for his passion and knowledge in research, which inspires me to become a more proficient researcher. I thank Professor Carlos Zerpa for his assistance and interpretation with the statistics in this project, which enhanced my understanding and skill in statistics.

Last but not least, I would like to express my gratitude to the participants and parents of this study who put forth full effort and dedication into the Wii Fit program. This project could not have been done without them. The participants brought youthfulness and high spirits to every session, and were truly motivated to perform. The children provided me with more experience in teaching and helping them perform tasks with which they have difficulty. The parents opened up time in their busy schedules, as well as their children's, to bring them to the program, which truly showed how devoted they were to help their children become the best they can be.

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Introduction

In a typical classroom, between 6 and 22% of the population comprise children with movement coordination problems, commonly known as developmental coordination disorder (DCD) (Cermak, Gubbay, & Larkin, 2002, p. 14). Children with DCD have difficulties performing activities of daily living (ADL) such as dressing, feeding, writing, grasping, and balancing, and these limitations can also interfere with academic achievement (American Psychiatric Association [APA], 2000). A major area of concern for children with DCD is the development of balance (Deconinck, De Clercq, Van Coster, Oostra, Dewitte, Savelsbergh,...Lenoir, 2008; Geuze, 2005), and poor balance skills have been consistently reported as characteristics of a subtype among children with DCD (Dewey & Kaplan, 1994; Hoare, 1994; Macnab, Miller, & Polatajko, 2001; Miyahara, 1994; Wright & Sugden, 1996). Since balance is a component required in the performance of most functional skills an intervention program that improves balance skills in children with DCD is warranted.

Balance is a person's ability to maintain his or her centre of mass within the base of support (Shumway-Cook & Woollacott, 2012, p. 162). To maintain balance, the individual uses postural control. This control mechanism utilizes systems in the body to maintain an individual's posture and stability in a task and environment (Shumway-Cook & Woollacott, 2012, p. 165). For example, the musculoskeletal system is used in postural control to create biomechanical relationships, or synergies, among linked body segments. Whereas, perceptual-motor processes are used to organize and integrate multiple sensory systems such as proprioception and kinesthesis (interoception), as well as vision, smell, and audition (exteroception) to maintain an individual's posture and stability in the task and environment (Schmidt & Wrisberg, 2004, p. 92-94).

A person uses balance control to maintain and orient his or her posture and stability within the base of support. Meanwhile, an individual uses postural adaptation to maintain and control his or her posture and stability while willingly moving toward the stability limits. Stability limits are the maximum distances an individual can move before a loss of balance that results in a change of position (Shumway-Cook & Woollacott, 2012, p. 166). Using an ankle pendulum-like strategy, the plantar- and dorsi-flexors control movement in the anterior-posterior (AP) directions, while the evertors and invertors control movement in the medial-lateral (ML) directions (Winter, 1995). Along with ankle strategies, the hip abductors and adductors control movement in the ML directions.

In quiet standing tasks, balance control is represented by the person's ability to maintain an upright posture while making minimal deviations, while standing as still as possible (Geuze, 2003). An adult-like level of balance control is achieved in healthy children by 7 to 12 years of age (Deconinck, De Clercq, Van Coster, Oostra, Dewitte, Savelsbergh,…Lenoir, 2008; Geuze, 2003; Woollacott & Shumway-Cook, 1990). When compared to typically developing peers, children aged 7 to 12 with DCD and balance problems show less than optimal levels of balance control during quiet standing tasks by swaying more within the stability region and toward the stability limits (Przysucha & Taylor, 2004).

In contrast to balance control, postural adaptation is represented by the person's ability to control a voluntary goal-directed movement, in this case, leaning as far as possible in the AP and ML directions (Geuze, de Jong, & Taylor, 1999). This movement has been termed the balance space task and has been investigated in typically developing children (Blaszczyk, Hansen, & Lowe, 1993) and also in children with DCD (Przysucha, Taylor, & Weber, 2008). As with balance control, adult-like postural adaptation is achieved in healthy children by 7 to 12 years

(Riach & Starkes, 1993; Schmid, Conforto, Lopez, Renzi, & D'Alession, 2005; Usui, Maekawa, & Hirasawa, 1995). On the other hand, children with DCD and balance problems show less than optimal levels of postural adaptation during the balance space task by not leaning as far in the AP directions as age-matched typically developing children (Przysucha et al., 2008). Since postural control is used in performing almost all ADL, it is problematic that children with DCD show lower levels of both balance control and postural adaptation, and so it would seem that intervention is warranted.

The literature on intervention for children with DCD concludes that intervention is beneficial, with no particular approach being more effective, and inspires further investigation to examine if there is any approach better than others (Hillier, 2007; Polatajko & Cantin, 2010). Since the release of Nintendo's Wii Fit, it has become a beneficial tool for rehabilitation in persons with balance problems, including children with movement problems (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010). The Wii Fit's balance board uses four electromagnetic sensors to track the performer's movement, and the hardware console uses wireless technology to display those movements on the screen through the use of the avatar (Burke, McNeill, Charles, Morrow, Crosbie, & McDonough, 2009; Nintendo, 2010). These features have only been used in intervention for three boys with movement and balance problems, and so the majority of children with DCD or movement problems have not experienced this type of treatment. It is suggested, however, that by the children seeing and perceiving their movement and feedback through their avatar, they will become motivated to perform and improve on the tasks in the simulations, which aim at improving balance. Thus, this *visual-perceptual* intervention approach might be very effective for children with DCD.

In addition to these features, the software incorporates a fitness training program that has over 50 different games, or simulations, in four main categories: yoga, strength training, aerobics, and balance training (Burke et al., 2009). Beginner, advanced, and expert challenge levels are provided in each simulation to permit individuals with different levels of experience, including children with DCD, to participate. The task difficulty also allows performers to increase their challenge levels so that progress is possible, recorded, and rewarded, and so individuals do not become bored. Through feedback and task difficulty provided by the simulations, the Wii Fit used in intervention may provide an opportunity for balance improvement in children with movement and balance difficulties.

Virtual rehabilitation is the provision of therapy using virtual reality hardware and simulations (Burdea, 2003). As previously mentioned, an example of virtual reality hardware is the Wii console, while simulations are the games in the Wii Fit training program. As with most interventions that use a particular approach in order to accomplish set goals, virtual rehabilitation also utilizes a programmed approach to goal attainment. The most common approach in virtual rehabilitation is a *virtual reality-based* approach. This method requires the individual to perform only the tasks in the simulations (Burdea, 2003; Pasch, Berthouze, van Dijk, & Nijholt, 2008). While performing these tasks a person obtains information by utilizing his or her interoceptive and exteroceptive systems, which creates an interaction between the individual and the simulations (Holden, 2005; Pasch, et al., 2008). The consequence of this interaction is called *presence,* or a feeling of being in the game, as a real and three-dimensional environment (Holden, 2005). The level of *presence* that the individual gains while performing simulations may provide another benefit of Wii Fit interventions for persons with balance problems.

The Wii Fit has numerous advantages when it is used for rehabilitation. When it is compared to traditional intervention, the Wii Fit is relatively affordable and this allows many more individuals to take part. As with the Wii Fit's affordability, it also offers a variety of exercises through the simulations, which provides an opportunity for a wide diversity of individuals to participate. Data from the simulations are automatically gathered and stored without any actions required by the instructor or therapist (Burdea, 2003). The Wii Fit allows the instructor to more easily guide the individual through the simulations, and the program offers more accessibility to the person to perform the tasks to the best of his or her ability.

The numerous advantages that are provided by Wii Fit interventions, as well as the limited but positive findings that Wii Fit rehabilitations have shown in persons with balance problems have inspired further investigation. Recently, Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010) examined the effects of the Wii Fit balance simulations on postural adaptation and balance control in three boys with movement and balance problems. They reported increased area of sway and AP sway during the balance space task, increased ML sway during quiet standing eyes open, and increased area of sway during eyes closed. Although increased sway in quiet standing tasks appears counterintuitive to balance control, this increase in sway has been interpreted as an increased tolerance of or ability to manage sway due to the requirements of the specific intervention tasks (Allen & Taylor, 2001; Wolf, Barnhart, Ellison, & Coogler, 1997). Krasniuk and colleagues concluded that there is promise for success in Wii Fit balance interventions that is pertinent to this study; however, more research is needed with more controlled designs and well-defined, homogeneous samples and subtypes.

The current study used *visual-perceptual* and *virtual-reality based* approaches to intervention. Also, it was the first in the literature to use a more controlled research design and have a larger sample size, of 10 children with movement and balance problems, aged 7 to 10 years. The rationale of this study was that if the children showed improved on postural adaptation after the intervention, the Wii Fit could be used alternatively to traditional intervention, as it offers exciting and motivating methods. As well, if the participants experienced more difficulty at the wash-out test, then intervention would be necessary in their lifestyle to maintain any gains from the intervention.

Purpose Statement

The purpose of this study was to examine the effects of a 20-session Wii Fit balance intervention on postural adaptation of children with movement and balance problems as measured by AP sway, ML sway, area of sway, and path length from an Advanced Mechanical Technology Incorporation (AMTI) force plate, and Total Balance Score (TBS) and Total Impairment Score (TIS) from the Movement Assessment Battery for Children (MABC).

Research Hypotheses

1. Throughout the intervention period, the children with movement and balance problems will improve their scores and make first and second level advancements in the Wii Fit simulations, according to the criteria adapted by Krasniuk, Macleod, Matthews, Twahir, and Taylor (2010).

2. At the post-test, the extent of the effects of a Wii Fit balance intervention on postural adaptation of children with movement and balance problems will show significant improvement in the TBS and TIS. At the wash-out test, the participants' TBS and TIS will show that intervention is necessary to maintain gains.

3. At the post-test, the extent of a Wii Fit balance intervention on postural adaptation of children with movement and balance problems will show significant increases in AP sway, ML sway, area of sway, and path length. At the wash-out test, the children's sway measures will show that intervention is necessary to maintain gains.

Review of Literature

Children with Developmental Coordination Disorder (DCD)

The fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) defines DCD as a marked impairment in the performance of children's motor skills, according to four criteria (APA, 2000). Criteria A states that children with DCD experience lifelong movement difficulties performing gross and/or fine motor skills, and criteria B describes those movement difficulties as negatively affecting ADLs and/or academic achievement. Criteria C stipulates that the motor difficulties children with DCD experience are not due to a general medical condition (e.g., cerebral palsy, hemiplegia, muscular dystrophy) and do not meet the criteria for a pervasive developmental disorder (PDD). Criteria D elucidates that if an intellectual disability (ID) is present (e.g., IQ score <70) the motor difficulties tend to be more severe than would be expected from a person with ID.

Although the DSM-IV provides specific characteristics of DCD, the etiology of DCD is not well understood. One explanation of its underlying cause is that the deficit is related to central nervous system pathology which may include abnormality in the cerebellum, parietal lobe, corpus callosum, or basal ganglia (APA, 2000; Zwicker, Missiuna, & Boyd, 2009; Zwicker, Missiuna, Harris, & Boyd, 2010). Although no hard neurological signs are present in children with DCD, soft signs (e.g., abnormal reflexes, mild hypotonia, and dysmetria) have been shown in some of them (Kaplan, Wilson, Dewey, & Crawford, 1998). However, due to the heterogeneity of the population of DCD and the lack of agreement among researchers that this explanation is the underlying cause of the disorder, this explanation cannot be confirmed.

Assessment of DCD. The Movement Assessment Battery for Children (MABC) (see Appendix A) (Henderson & Sugden, 1992) is a commonly used formal test to evaluate and identify movement coordination problems, including developmental coordination disorder, in children between the ages of 4 and 12 years (Wilson, 2005). The assessment battery encompasses eight tests that are categorized into three subsections including static and dynamic balance, ball skills, and fine motor skills. The sum of the eight tests makes up the Total Impairment Score (TIS) which is used to identify motor difficulties in children. The TIS has high reliability (*ICC* = .88) (Van Waelvelde, Peersman, Lenoir, & Smits Engelsman, 2007). A TIS $\leq 15^{th}$ percentile signifies that a child may have a motor impairment, while a TIS $\leq 5^{th}$ percentile indicates that a child has a definite motor deficit (Henderson & Sugden, 1992). To measure a child's balance status, the sum of the static and dynamic balance subsection, termed the Total Balance Score (TBS) is examined. As with the TIS, the TBS has reasonably high reliability (*ICC* = .82) (Van Waelvelde, De Weerdt, De Cock, & Smits-Engelsman, 2004). A TBS $\leq 15^{th}$ percentile implies that a child may have difficulties with balance, while a TBS $\leq 5^{th}$ percentile indicates that a child has a definite balance problem (Henderson & Sugden, 1992).

The MABC provides the instructor or practitioner with a thorough process to identify and evaluate whether children have motor coordination problems, but a limitation to this test is that it covers only one of the four criteria of the DSM-IV for DCD. The remaining three criteria can be inferred with information about the children's developmental history (see Appendix B). A set of questions is presented to the parents of the child in an interview format asking them whether the child has movement difficulties that affect ADLs and/or academic achievement. The answers to these questions also determine whether the movement difficulty is due to another general medical condition or intellectual disability.

Concomitants and subtypes of DCD. As previously discussed, there are numerous descriptions of DCD but no confirmed underlying causes, so it is necessary to acknowledge that the population of children with DCD is heterogeneous. There is evidence of concomitant disorders, as well as specific subtypes within DCD. Approximately 50% of children with DCD have at least one other disorder such as attention deficit hyperactivity disorder (ADHD), speech or articulation difficulties, and learning disabilities (Missiuna, Rivard, & Pollock, 2004; Visser, 2003). These co-occurring disorders suggest a shared etiology with the cerebellum being the common source of neuropathology (Zwicker, Missiuna, & Boyd, 2009).

In addition to concomitant disorders, the heterogeneity within the population of children with DCD has prompted subtype classification. One subtype that has been consistently reported includes poor balance skills (Dewey & Kaplan, 1994; Hoare, 1994; Macnab, Miller, & Polatajko, 2001; Miyahara, 1994; Wright & Sugden, 1996). Hoare (1994) identified a subtype of 20 children with DCD who exhibited difficulties in static balance, as well as kinesthetic acuity, manual dexterity, and running. As with Hoare's findings, Macnab, Miller, and Polatajko (2001) categorized a subtype of children with DCD and motor impairments that displayed weaknesses in balance skills, kinesthetic acuity, and fine motor skills, but who showed strengths in upper limb speed and dexterity measures. In both reports, the children were assessed using the same six perceptual motor tasks, which may be an explanation for the similar findings. Children with weaknesses in balance skills and strengths in ball skills have been reported by Miyahara (1994) and Wright and Sugden (1996). Miyahara also identified another subtype of children with poor balance, coordination, bilateral coordination, running, and ball skills. Although similar findings were revealed by these researchers their samples were different. Miyahara only examined children with learning problems, while Wright and Sugden investigated both children with DCD and also those identified as having movement problems. The different samples used in these studies might also explain why different subtypes were discovered. Comparable to Wright and Sugden's results, Dewey and Kaplan (1994) found two subtypes in children with motor skill deficits. One of the groups presented severe deficits in all areas measured which included balance, bilateral coordination, upper limb coordination, transitive gesture, and motor sequencing. The other group illustrated deficits in balance, coordination, and gestural performance (Dewey & Kaplan, 1994).

Although poor balance skills have been consistently reported as a subtype in children with DCD, the subtypes discovered in these five studies show different attributes for a number of reasons. Different populations were used in the research: Dewey and Kaplan (1994) examined children with motor skill deficits; Hoare (1994), Macnab, Miller, and Polatajko (2001); Wright and Sugden (1996) investigated both children with DCD and with movement problems; and Miyahara (1994) evaluated children with learning problems. Different sample sizes of 62 to 138 children were also used in the research which may also have affected the outcomes. Lastly, a variety of assessment tools with different recruitment criteria were used across the five studies. The different populations, sample sizes, assessment tools, and recruitment criteria that were employed by these researchers demonstrate that there is a need for the development of a gold standard to assess balance in children with DCD.

Measuring Balance on an AMTI Force Plate

The force plate is the gold-standard assessment tool for measurement and analysis of balance control and postural adaptation. The AMTI force plate is a single plate that records and calculates measures of centre of pressure (COP) while individuals perform tasks that reflect balance control and postural adaptation. The COP is “the centre of the distribution of the total force (e.g., body) applied to the supporting surface” (Shumway-Cook & Woollacott, 2012, p. 162). While using an ankle pendulum-like strategy, COP measures indicate the excursions the body makes from the vertical (Winter, Patla, & Frank, 1990).

A person’s level of balance control can be assessed by measuring and analyzing quiet standing with eyes open and closed. In both tasks, the individual is required to make only minimal deviations from the vertical (Winter, 1995). To perform these tasks, the individual stands as still as possible with arms crossed over the chest with eyes open or closed. When comparing quiet standing in both conditions, Deconinck, De Clercq, Van Coster, Oostra, Dewitte, Savelsbergh,… and Lenoir (2008) showed that children with DCD display larger COP sway measures in eyes closed than in eyes open, suggesting that they rely more on vision to maintain balance than their typically developing peers. However, Geuze (2003) and Przysucha and Taylor (2004) showed that there are no significant differences between the two groups across the two conditions.

In contrast to assessing balance control, a person’s level of postural adaptation can be assessed by measuring and examining the balance space task, which requires the individual to lean a maximum voluntary distance in the AP and ML directions (Blaszczyk, Hansen, & Lowe, 1993; Przysucha, Taylor, & Weber, 2008). To perform this task the individual crosses arms over the chest and preserves his or her stance while leaning forward, backward, to the right and left, and back to the centre.

Postural Adaptation Difficulties in Children with DCD

The literature on the difficulties children with DCD experience in postural adaptation is limited. Przysucha, Taylor, and Weber (2008) are the primary researchers who used the balance space task to investigate postural adaptation in children with DCD. These researchers compared postural adaptation of 7 and 11 year old boys with and without DCD when performing the balance space task. Also, spectral analysis was used to delineate the nature of control tendencies exhibited by both groups. Results indicated that during the balance space task, the typically developing boys swayed further than those with DCD in both AP and area of sway. In terms of identifying control, children with DCD spent less time in the corrective phase of the movement than the typically developing boys. These results suggest that the boys with DCD used more open loop control shown by their quick and jerky movements than the smooth and controlled movements of the typically developing boys in the control group.

Intervention for DCD

As previously discussed, intervention is necessary for children with DCD and poor balance. The literature on intervention for DCD has been based on competing approaches, with no specific research design used over others. Thus, in many cases, larger sample sizes are needed and generalizations are questionable, so researchers tend to rely on their own clinical judgments to which approach is best (Mandich, Polatajko, Macnab, & Miller, 2001).

The most common research approaches used in intervention for DCD are performance-oriented and impairment-oriented. Performance-oriented approaches aim at teaching specific skills by breaking the skills down into their parts and encouraging practice of each part (Sugden & Chambers, 1998). These approaches are relatively new, and thus, are reported less in the literature. On the other hand, impairment-oriented approaches aim to improve motor performance by correcting, reducing, or remediating underlying impairments in body function or structure (Polatajko & Cantin, 2010).

A visual-perceptual approach applied to a Wii Fit balance intervention is considered an impairment-oriented approach. The goal of the intervention is to improve the children's balance through viewing and perceiving the simulations and then performing the tasks in the simulations correctly. By performing the tasks in the simulations, it is suggested that the children will learn to maintain and control their posture while they are moving. A Wii Fit intervention on balance control and postural adaptation, however, has only been applied once thus far, for three boys with movement and balance problems, and consequently more research is needed.

Problems of intervention for children with DCD. It is somewhat problematic that interventions that are well designed for children with DCD show little evidence that one approach is more effective than any other (Ayyash & Preece, 2003). Hillier (2007) performed a systematic review of 31 interventions with the impairment-oriented approaches being the most commonly used, concluding that intervention for children with DCD is better than no intervention, and what the children are training are what they are improving. More recently, Polatajko and Cantin (2010) performed a systematic review of 20 interventions which consisted of nine populations including DCD. They concluded that children who have difficulty processing and integrating sensory information can benefit from intervention, and performance-oriented approaches hold promise, especially for those with motor coordination problems.

The persistent conclusion that any intervention approach is beneficial for children with DCD or motor difficulties may be due to a number of factors. First of all, there is limited research on intervention for children with DCD. The etiology of the disorder is not well understood which makes it difficult for researchers to know what needs to be trained. Also, the heterogeneity in the population of children with DCD makes it difficult for research because the children have different strengths and weaknesses. In addition, there is no universal intervention period, session length, or assessment tool that is used over others. To help control these factors, researchers should use well-defined, more homogeneous samples and subtypes, and provide clarification of all details of the intervention. Perhaps the most effective intervention approach for children with DCD has not been used yet, which is a challenge, but also an inspiration for researchers to find one that is most effective. Or, it may be possible that a visual-perceptual approach applied to a Wii Fit balance intervention may be the most effective for children with movement and balance problems.

Balance Intervention for Children with DCD

As mentioned, intervention for children with DCD is limited, thus, specific balance training is even more limited. Balance intervention is designed to enhance balance control and postural adaptation (Wescott & Burtner, 2004). To achieve these goals, the intervention consists of performing tasks that focus on the practice of the body maintaining positions or controlling movements that are functional and meaningful to the children. Some of these tasks involve reaching the stability limits, moving quickly in one direction while maintaining stability, and modifying ankle and hip strategies (Wescott & Burtner, 2004). In the majority of these tasks the performer is voluntarily moving toward a goal, thus, these balance interventions generally result in improved postural adaptation (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010; Yang & Taylor, 2010).

In contrast to these balance interventions, Inder and Sullivan (2005) conducted one of the few balance interventions for children with DCD using the Sensory Organization Test (SOT) (Shumway-Cook, Horak, & Black, 1987). This test consisted of six conditions of quiet standing which included: (1) eyes open, (2) eyes closed, (3) sway-referenced visual surround, (4) sway-referenced surface, (5) eyes closed and sway-referenced surface, and (6) sway-referenced visual surround and surface.

Four children with DCD, aged 9 to 12 years, performed the SOT during the intervention period which was three to six sessions of 20 to 40 minutes duration. Descriptive statistics (means, standard deviations, and ranges) of the SOT measures indicated considerable inter- and intra-subject variability in performance of all sensory conditions, with an increase in sway and falls in conditions three and four. Balance was more challenged in the most complex conditions. A qualitative visual representation of each participant's measures, compared with typically developing peer age scores showed that the participants demonstrated severe difficulty performing the tasks. For the most part, two participants scored two standard deviations below their peers' mean scores, while the other two scored below the first standard deviation. Sensory ratio scores for the somatosensory, visual, and vestibular systems suggested that the participants displayed deficits in visual and vestibular systems. Results were equivocal between participants which may have been due to the small heterogeneous sample and the short intervention period

Why use a Wii Fit Intervention?

The literature on intervention for children with DCD encourages researchers to examine which type of intervention is most effective for which subtype of interest. As previously discussed, a Wii Fit intervention was shown to be successful on postural adaptation of three boys with movement and balance difficulties (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010). Not only has a Wii Fit intervention been successful on balance for children with movement and balance problems, it has also been an effective means of improvement for persons with balance difficulties due to cerebral palsy (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008), stroke (Deutsch, Robbins, Morrison, & Bowlby, 2009; Sugarman, Burstin, Weisel-Eichler, & Brown, 2009), and inactivity (Nitz, Kuys, Isles, & Fu, 2010).

Deutsch, Borbely, Filler, Huhn, and Guarrera-Bowlby (2008) were the first researchers to use Nintendo's Wii Sports to examine their effects on the balance control of a 13 year old male adolescent with cerebral palsy. In 4 weeks, the participant performed 11 sessions of 60 to 90 minutes on the Wii comprising boxing, tennis, bowling, and golf. Balance control was measured by postural sway and weight distribution when the participant performed quiet standing eyes open and closed on a Posture Scale Analyzer force plate. Post-test results illustrated improvement in balance control due to the intervention. The COP sway decreased by 60% in both eyes open and eyes closed. Weight distribution became more symmetrical in ML directions in eyes closed and in AP directions in eyes open (Deutsch et al., 2008). Although practicing Wii Sports caused improvement in balance control in a male adolescent with cerebral palsy, replication with larger and different samples would be beneficial for the literature.

Shortly after Nintendo's Wii Sports was shown to improve balance control in an adolescent with cerebral palsy (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008), Deutsch, Robbins, Morrison, and Bowlby (2009) investigated the effects of Nintendo's Wii Sports and Wii Fit on the dynamic balance of two adults who had experienced a stroke. At the time of the study, participants were 34 and 48 years old and both had experienced a stroke 5 or more years previously. A standard balance and mobility rehabilitation program was compared to the Wii-based intervention, with participants allocated to one of the two interventions. Both interventions were three sessions of 1 hour each for 4 weeks. Tasks in the Wii-based intervention comprised the boxing, bowling, baseball, ski jump, ski slalom, tightrope walking, lunges, and park strolls simulations; meanwhile, tasks in the standard intervention included sitting, standing, and stepping to a metronome while the participant was visually distracted, standing on different surfaces, and going through obstacle courses.

Results confirmed improvement in both participants' gait speed and endurance on the six-meter walk test, dynamic balance on the dynamic gait index, and self-confidence on the activities-specific balance confidence scale, with greater improvement shown in the Wii-based intervention. After 3 months, a wash-out test showed that intervention was needed for both participants to maintain their gains. In contrast to research by Deutsch and colleagues (2008) where balance control in quiet standing was used, here different dynamic balance tasks were analyzed to examine the effects of the intervention. This study added to the literature by incorporating a control condition and a wash-out test.

Another study was carried out by Sugarman, Burstin, Weisel-Eichler, and Brown (2009). They examined the effects of the Wii Fit on balance of an 86 year old female who had experienced a stroke 5 weeks prior to the time of study. In addition to standard therapy, the participant received four consecutive 45-minute daily training sessions with the Wii Fit. During the first three sessions, the participant practiced table tilt, balance bubble, tightrope walking, and torso twists, with three trials for each simulation, and during the last session she practiced each simulation once. Results revealed improved balance control, with weight distribution being more symmetrical in AP directions, and in dynamic balance agility, with a 10-second improvement on the Timed-Up-and-Go test.

Examining a different population altogether, Nitz, Kuys, Isles, and Fu (2010) performed an intervention using the Wii Fit with eight women with a mean age of 46.6 years (*SD* = 9.9 years). The intervention involved two 30-minute sessions per week for 10 weeks, with participants performing their choice of the Wii Fit simulations. The choices the women had included activities from all yoga, balance training, aerobics, and strength training. Results showed significant improvement in balance control measured by unilateral stance of both limbs and in lower limb strength measured by a spring gauge.

In all of these interventions, the sample size is extremely small, with the majority of studies having only two participants. Also, different populations and assessment tools are used in each study, providing little evidence for generalization. Another limitation, but also an inspiration to continue research in this area, is that these Wii Fit interventions are the first to examine the effects on balance in these populations.

Motor learning in a Wii Fit balance intervention. Another rationale for the success of the Wii Fit balance intervention is that the training program encompasses some concepts of motor learning. Motor learning occurs when there are relatively permanent changes in an individual's capability to perform a motor task, shown as a result of practice (Magill, 2004, p. 193-200). The changes that occur in the individual are internal and thus cannot be seen directly by the observer. Instead, the changes can be shown by observing an individual's motor performance over a period of time and examining if the performance improves, and has become more consistent, persistent, and adaptable. Learning can be assessed in a Wii Fit intervention for children with DCD by observing their performance, and recording and graphing the scores attained throughout the entire training period.

In addition, transfer tests are used to infer learning by introducing the performers to a novel situation, so they adapt the tasks that were practiced in training to the characteristics of the new situation (Magill, 2004, p. 200). The balance space task and the balance tasks of the MABC can be used as transfer tests to evaluate learning because they resemble similar characteristics of the tasks in the Wii Fit simulations, but without the augmented feedback the Wii Fit program provides. Learning can be inferred by assessing performance in those transfer tests before and after the intervention to examine if there were any changes in performance from the baseline measurement.

A wash-out test was used in this study because it was believed that the children had deficits in motor coordination and balance. The literature has shown that children with DCD do not grow out of the disorder, as difficulties are still experienced in adolescence (Cantell, Smyth, & Ahonen, 1994; Geuze & Börger, 1993) and adulthood (Kirby, Sugden, Beveridge, & Edwards, 2008; Missiuna, Moll, King, Stewart, & Macdonald, 2008). With this finding mentioned, for the children to maintain any improvement gained from training, they need to implement training into their lifestyle. Intuitively, a wash-out period, where the children do not practice the Wii Fit simulations or any similar form of balance training, should be the same length as the intervention period. After a 7-week wash-out period, assessing the performance of the balance space task and the balance tasks of the MABC would indicate if intervention was needed in the children's lifestyle to maintain any gains.

Task constraints in the Wii Fit. The Wii Fit program revolves around task constraints, or the boundaries that limit the movement performers can make during a task, in order to achieve the task's goals (Newell, 1986, p. 352-354; Newell & Jordan, 2007, p. 12-13). The Wii balance board for instance, is a tool that enables performers to stand on and move in response to stimuli from the simulations on the screen. In this case, in order for individuals to optimally perform the tasks in the simulations, they must be standing inside the rectangles outlined on the board with the screen in front of them.

The goals, objectives, and rules that constrain performers' movement are presented before starting the Wii Fit simulations by demonstration through the avatars and written description of what the individuals need to do. During the simulations, the goals, objectives, and rules are presented to the performers by demonstrating how to position the body on the Wii board and where to move the body in reaction to stimuli in the simulations. The Wii Fit program informs performers about the task constraints in the simulations through modeling, verbal instruction, cues, and augmented feedback.

Modeling in the Wii Fit. Modeling is one method used to help individuals learn how to perform a simulation (Magill, 2004, p. 249). For modeling to be successful, a person must observe a correctly performed demonstration of the tasks. From that demonstration, the individual will perceive the invariant features of the coordinated movement patterns that are required and perform with his or her own patterns to perform the skills. The Wii Fit program may assist children with DCD in performing the simulations through modeling with the avatar. For example, in before the simulation in soccer heading begins, the avatar moves left and right to demonstrate to the children what they have to do in order to head the balls (see Figure 1).

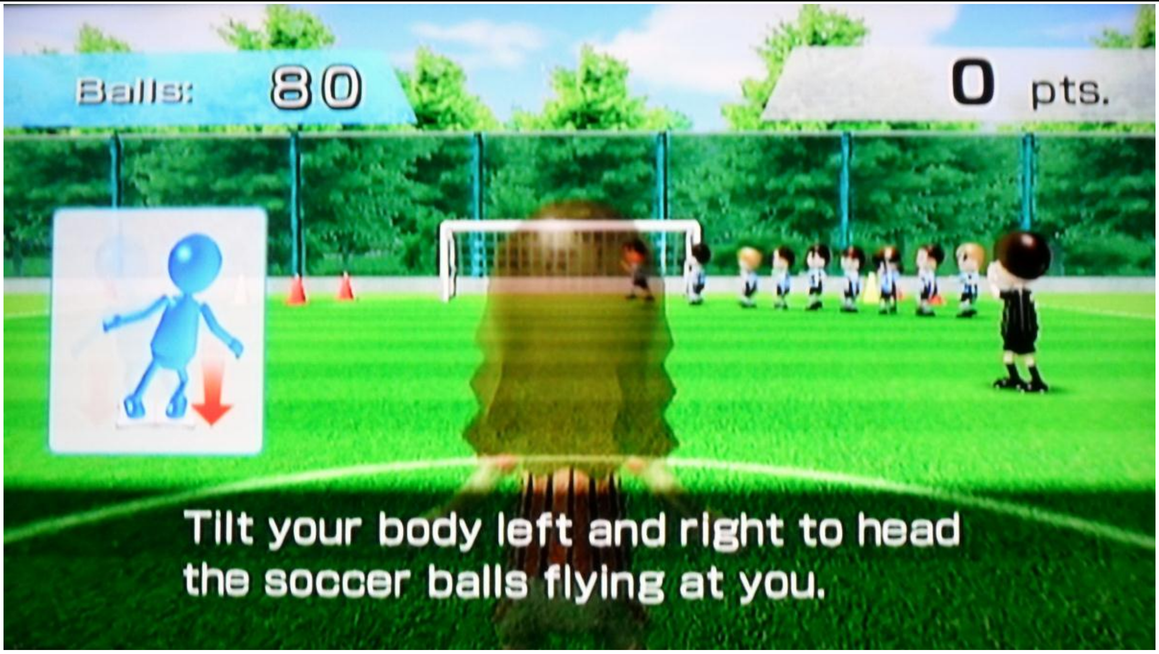


Figure 1. Modeling before soccer heading. Adapted from “Wii Fit,” by Nintendo, 2008. Copyright 2008 by author, Canada

The Wii Fit program may also guide children with DCD on how to perform the movements during the simulations. In Figure 2 the model for performing basic step, an aerobic simulation in the Wii Fit, is depicted. To achieve rhythm in the simulation, the individual must perform the particular tasks indicated in a specific amount of time. The red-filled foot signifies that the person must step on the Wii board with that foot. The faded red foot represents the person lifting his or her foot off the board. The arrow represents the performer placing the foot that was on the board onto the floor where the arrow was pointed. The outlined foot with no colour illustrates that the individual’s foot should not be on the board, but on the floor. An “OK” or “PERFECT” will be displayed on the screen to show the performer that he or she completed the tasks in the simulation in the required amount of time or at the exact timing, respectively. Over a period of time, the cues, like when to lift a foot, for example, will help improve corresponding reaction time in performing the correct tasks in the simulations.

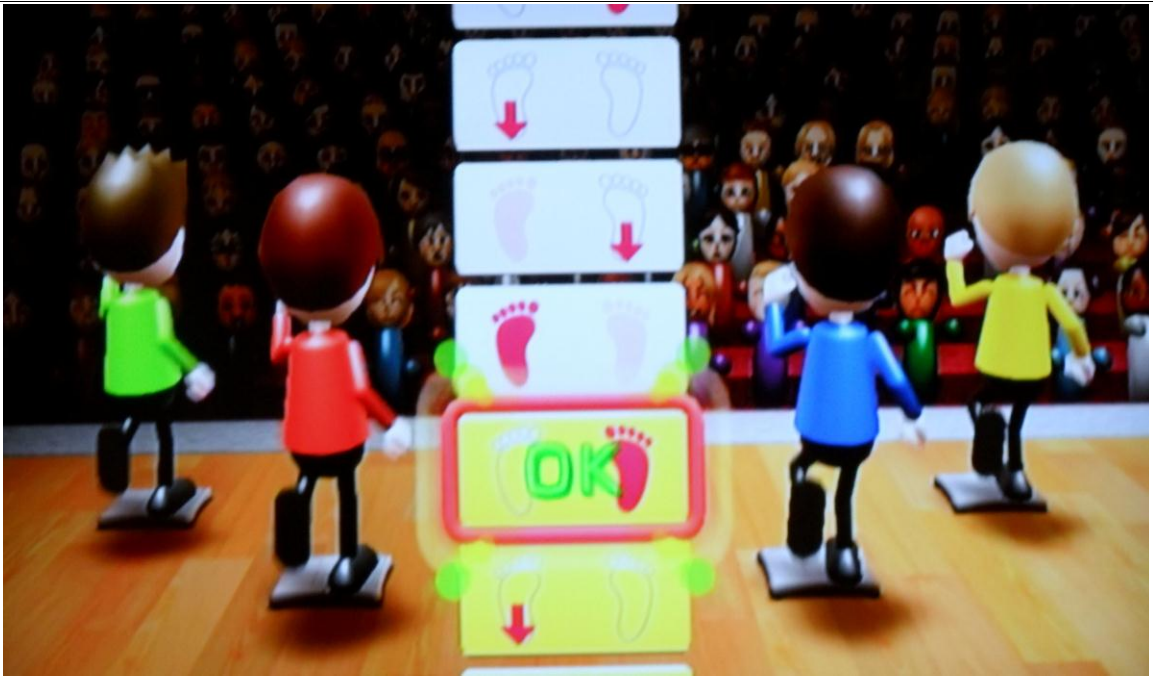


Figure 2. Modeling during basic step. Adapted from “Wii Fit,” by Nintendo, 2008. Copyright 2008 by author, Canada.

Verbal instructions and cues in the Wii Fit. Verbal instructions and cues can help a person learn how to perform a task by directing his or her attention to the features of the task or environmental context that will enhance or inform the motor performance (Magill, 2004, p. 259). The Wii Fit program presents verbal instructions on the screen that can be read by either the instructor or performer. The instructions may focus attention of the performer on the movement outcomes, and the environmental features that will prepare him or her for the movements needed in order to perform the simulations (see Figure 3). The instructions tell the children performing ski jump to “straighten their knees at the right moment to jump for glory.” These instructions inform the performer to direct his or her attention to the “right moment to jump.” In other words, where the red line is situated at the bottom of the slope indicates where the individual straightens his or her legs.

Figure 3.Verbal instructions for movement outcomes in ski jump. Adapted from “Wii Fit,” by Nintendo, 2008. Copyright 2008 by author, Canada.

Figure 4 demonstrates how verbal instructions in soccer heading can direct the participants’ attention to the essential cues to help them perform the simulation. The instructions “head the soccer balls as they get kicked at you, but dodge other flying objects” directs the performer’s attention to the regulatory conditions. Soccer balls are what the person wants to focus his or her attention on, and other flying objects such as shoes and panda heads are what he or she needs to avoid.

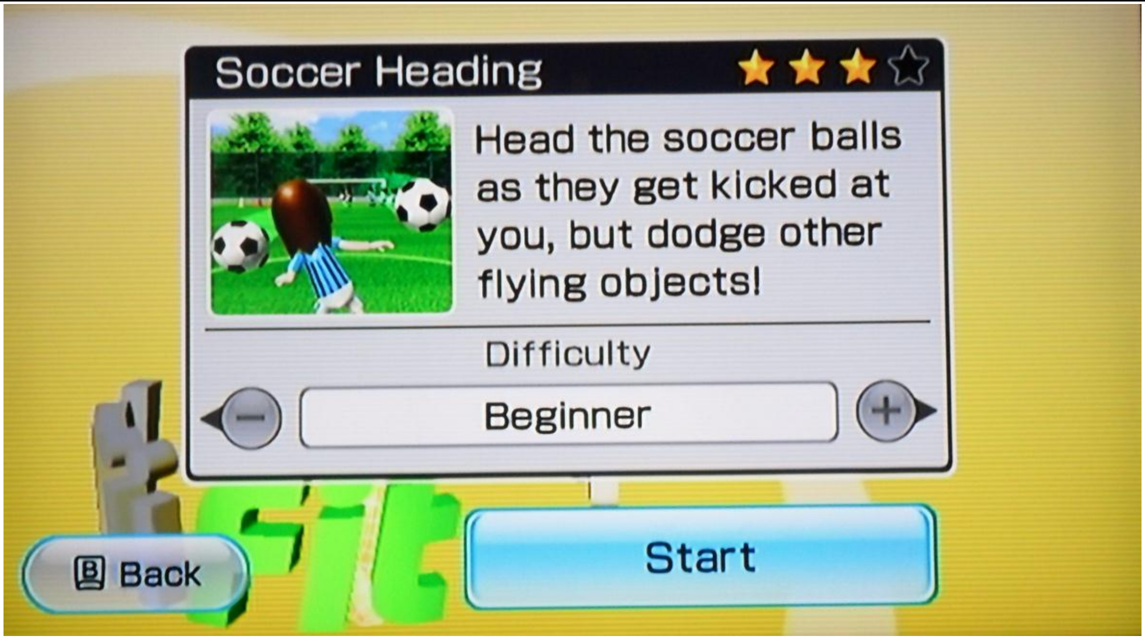


Figure 4. Verbal instructions for essential cues in soccer heading. Adapted from "Wii Fit," by Nintendo, 2008. Copyright 2008 by author, Canada.

Augmented feedback in the Wii Fit. Feedback is another method used to help an individual perform a motor skill by describing the elements of his or her performance during or after the action (Magill, 2004, p. 269). The feedback can be task-intrinsic or augmented. Task-intrinsic feedback provides the sensory-perceptual information that is a natural part of performing a skill, while augmented or external feedback illustrates additional information about performing a skill and comes from an external source. Augmented feedback facilitates achievement of the action goal of the task and it also motivates the performer to continue striving towards his or her goal. The Wii Fit simulations provide the individual with augmented feedback through knowledge of results (KR) and knowledge of performance (KP). KR provides information about an outcome of performing a task or about achieving the goal (Magill, 2004, p. 270). The Wii Fit simulations provide KR after each trial of a task in a simulation and also when the person has finished the simulations. Figure 5 shows how soccer heading presents KR after the individual performs trials of tasks in the simulation.

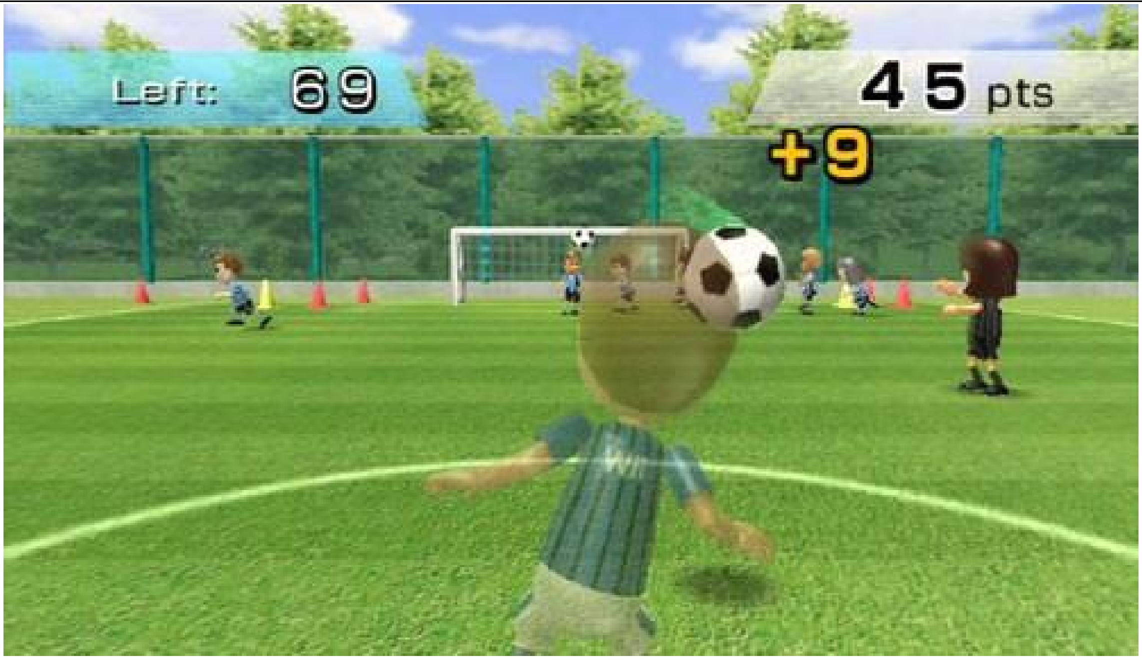


Figure 5. KR after a task in soccer heading. Adapted from “Wii Fit,” by Nintendo, 2008. Copyright 2008 by author, Canada.

At the time in the simulation, the number of balls that are left to come is presented in the top left corner, meanwhile, the number of points the performer has obtained is revealed in the top right corner. The yellow number (+9) states how many balls have been consecutively headed by the individual up to 10, and the number of points gained from that trial. It can be suggested that the KR presented in Figure 5, as well as KR presented in every simulation, motivates children with DCD to continue performing tasks in the simulations to gain higher scores overall.

Figure 6 illustrates how soccer heading presents KR at the end of the simulation. The first number (252) represents the total score the performer obtained in the simulation. Also, the individual’s overall performance is presented as a descriptor (e.g., professional). Underneath the person’s descriptor there are stars out of four that characterize their overall performance in the simulation. In this demonstration, the performer received three out of four stars, which is almost perfect. The description and number of stars the performer receives depends on the total scores obtained. For example, for a performer to receive two stars, he or she must obtain a score of at least 200.

Figure 6. KR at the end of a simulation. Adapted from "Wii Fit," by Nintendo, 2008. Copyright 2008 by author, Canada.

It is conjectured that KR presented at the end of a simulation motivates children with DCD to continue on performing when they receive a high score and make the top ten ranking list. On the other hand, this KR could be negative for children with DCD, when they receive low scores, as it may result in lowering the children's motivation to continue on performing the simulations.

In contrast to KR, KP is the other form of augmented feedback that provides the performer with information of the movement characteristics that lead to the performance outcomes (Magill, 2004, p. 271). KP is also shown during an individual's performance of the Wii Fit simulations. Figure 7 depicts how KP is shown while a person is performing ski slalom. KP is symbolized in the top right corner, with a red circle representing the individual performing ski slalom, a blue rectangular area being the most ideal area to occupy during the simulation, and a vertical and horizontal line distinguishing where the performer is situated on the balance board. In this illustration, the person is leaning forward in the ideal area when performing ski slalom. The horizontal and vertical lines related to the red circle show that the person is leaning to the left on the balance board. Intuitively, children with DCD tend to have difficulty acknowledging their KP. It is logical that this feature in the Wii Fit may help the children position their body parts and perform movements so that their performance is more optimal. If KP was not displayed in the simulations, children with DCD would most likely have difficulty knowing where to place their body and how to perform the movements.

It is necessary to know that both KR and KP presented in the Wii Fit simulations are delivered every time an individual performs which may be both positive and negative to the learning experience. Through observation, children with DCD tend to acknowledge their KR but not their KP. Providing standardized augmented feedback for every performance adds control in the intervention and may allow for quicker improvement in performance and optimal patterns of movement. It is speculated that since the Wii Fit provides a sufficient amount of augmented feedback, that children with DCD will only use the types of feedback that are necessary for them to perform the movement in the simulations. On the other hand, when the same feedback is provided too often, the performer may tend to either ignore the feedback or become completely dependent on it, and as a result not be able to generalize skills (Magill, 2004, p. 275-276).

Figure 7. KP in ski slalom. Adapted from "Wii Fit," by Nintendo, 2008. Copyright 2008 by author, Canada.

Achievement motivation in a Wii Fit intervention. Perhaps, the most critical factor in learning to perform a motor skill relates to the characteristics of the performer. Achievement motivation, the direction and intensity of a person's effort to reach a performance goal (Davis & Burton, 1991; Schmidt & Wrisberg, 2004, p. 191), may be the most important characteristic a person possesses to perform a task. Children with DCD have difficulty learning complex motor skills and in turn may show lower success, competence, and achievement motivation than typically developing children in performing these movements. As a result, children with DCD experience long-term decreased self-esteem issues and avoid performing motor skills altogether in order to avoid failure and the ridicule of their peers (Cantell & Kooistra, 2002, p. 29-32).

Children tend to rely on external sources of competence information (Missiuna & Mandich, 2002, p. 227), and so a Wii Fit intervention might suffice for children with DCD as it provides standardized augmented feedback with motivating methods. It is surmised that one contributing factor to a person’s motivation to perform the Wii Fit simulations is that he or she can always see and perceive his or her performance and feedback. This factor makes a Wii Fit intervention different from any other type of intervention for children with DCD. Through the avatar, the performer can perceive how he or she is missing the soccer balls, for example, and allows the individual to strategize his or her performance in order to be successful. In every simulation, KP is uniquely provided through modeling with the avatar, using cues that light up when children are in the correct position, and using verbal instructions that inform children what to do in the simulation. Together, this feedback may teach in an engaging and positive way how to perform the tasks in the simulations.

In addition, KR is visually shown at the end of the simulation in a top ten highest scores list. Children with DCD may become motivated to perform the simulation when they appear on the list because it shows that they have scored high overall. By observation, when children are on the list, they want to place on it more than once. For example, they want to place first, second, and third. The children might also be motivated to compete with their peers to be first place or a higher rank. KR is provided after a task where the score either increases or decreases depending on the participant’s success in performing that task. This KR may motivate children with DCD to either continue on increasing their score or to re-attain their previous scores.

The modeling, verbal instructions and cues, and augmented feedback provided by the Wii Fit may assist children with DCD in performing the tasks in the simulations. One supposition is that understanding KP may be more beneficial for children with DCD than the KR because some of the children may have such low self-esteem that they do not believe that they have succeeded at performing a skill even when KR informs them. So, instead, when children with DCD are informed with KP they can concentrate on the movement characteristics of the performance. A

Wii Fit intervention on balance control and postural adaptation has shown to be beneficial for three boys with movement and balance problems (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010). The concepts of motor learning provided in the program that accentuate motivation may be one reason why the boys were successful. The effects of this Wii Fit intervention on postural adaptation of children with movement and balance problems will enhance the research literature.

Fitts and Posner's stages of learning. The stage of learning a performer presents is another critical characteristic that interacts when a performer is learning a skill. Fitts and Posner (1967) proposed a three-stage model of learning. In the first stage, *cognitive*, an individual employs most of his or her time problem-solving to determine the task demands and components involved. The individual's performance is variable and inconsistent, the person makes several errors, and there is a large amount of improvement that can be made in the skill. Since children with DCD have movement difficulties, it is assumed that when they initially perform the Wii Fit simulations, they will be in this stage of learning.

In the second or *associative* stage, a person reduces the amount of cognitive activity involved in performing a simulation and learns to produce the correct response pattern to a given situation to increase performance success and consistency (Fitts & Posner, 1967). There are fewer errors made that are detrimental to the individual's performance, the person's performance becomes more consistent, and the performer can detect his or her own performance errors. In a Wii Fit intervention, children with DCD would be classified in this stage when their KR of the simulations becomes more consistent. In addition, their performance would illustrate more consistency of movement patterns.

In the final stage of learning or *autonomous* stage, the person performs the task skillfully with little conscious attention directed to the movements (Fitts & Posner, 1967). The performer can do more than one skill at a time, has maximal consistency, and the individual can detect his or her errors and correct them. Children with DCD would be categorized in this stage of learning when their KR displays strong consistency, with very little variation in results, and strong consistency in their movement patterns.

Applying a Wii Fit Balance Intervention on Postural Adaptation of Children with Movement and Balance Problems

Thus far, Wii Fit interventions have generally been pilot or feasibility studies, using very small samples. Currently, there have not been any Wii Fit interventions that have used more controlled research designs for children with movement and balance problems. This study used *virtual-reality based* and *visual-perceptual* approaches to intervention that required ten children with movement and balance problems, aged 7 to 10 years, to interpret the Wii Fit simulations. If postural adaptation showed improvement in the participants, Wii Fit balance interventions could be implemented as exciting and motivating alternatives to intervention.

Method and Procedure

Comparison of COP Measures Obtained on the Wii Fit Balance Board and the AMTI Force Platform: A Pilot Study

Prior to conducting this research project, a pilot study was carried out to validate COP measures obtained on the Wii board when placed on an AMTI force plate (Krasniuk & Taylor, 2010). The rationale of this pilot study was that if COP measures were shown to be internally reliable and concurrently valid during the balance space task when the Wii board was placed on the force plate, then the protocol could be used in the main research study. This protocol (see Appendix C) would add control to the main study by minimizing variability in measurement tools and maximizing similarity in testing and training conditions.

The sample involved 10 healthy adults with a mean age of 24 years (*SD* = 2.06 years). Participants performed a force plate protocol which involved three trials of quiet standing tasks, with eyes open and then closed, and then the balance space task, while standing on the force plate. The balance space task required the participants to perform a maximum voluntary lean in the AP and ML directions (Blaszczyk, Hansen, & Lowe, 1993). Once the three tasks were completed, the participants immediately repeated the protocol once more, but while standing on the Wii board placed on the force plate. Outcome measures were AP sway, ML sway, and area of sway, path length, and velocity for the balance space task.

Using the Statistical Package for the Social Sciences 18, internal consistency analyses were computed using Cronbach's alpha (α) for the five COP measures obtained during the balance space task on the force plate and also on the Wii board placed on the plate. Cronbach's alpha coefficients displayed very high internal reliability for all five measures of each standing condition (see Table 1).

Concurrent validity analyses were computed using Pearson's product-moment correlations (*r*) for the five COP measures obtained during the three trials of the balance space task on the force plate and also on the Wii board placed on the plate. Pearson product-moment coefficients displayed very high, significant concurrent validity of AP sway ($r = .97$), ML sway ($r = .82$), area of sway ($r = .93$), path length ($r = .89$), and velocity ($r = .89$) (see Figure 8 for scatter plots of each COP measure).

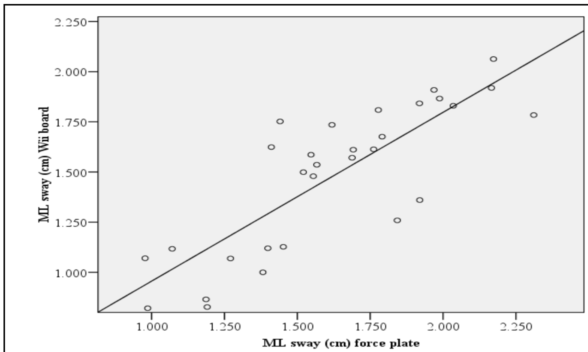
Table 1

Internal reliability of balance space task when standing on the force plate, and when standing on the Wii board placed on the force plate

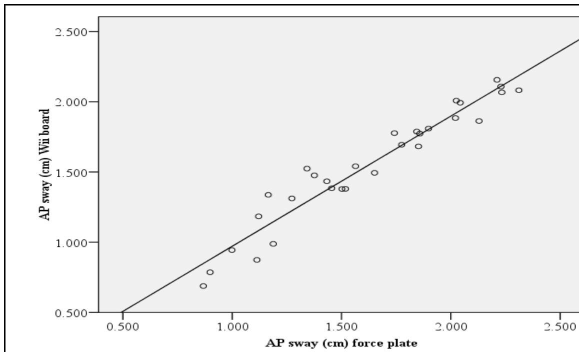
DV	Cronbach alpha coefficients (*a* =) while on force plate	Cronbach alpha coefficients (*a* =) while on Wii board
AP (cm)	.98	.98
ML (cm)	.96	.98
Ao (cm^2)	.98	.99
L (cm)	.97	.99
V (cm/s)	.97	.99

Note. AP = anterior-posterior sway; ML = medial-lateral sway; Ao = area of sway, L = path length; V = velocity.

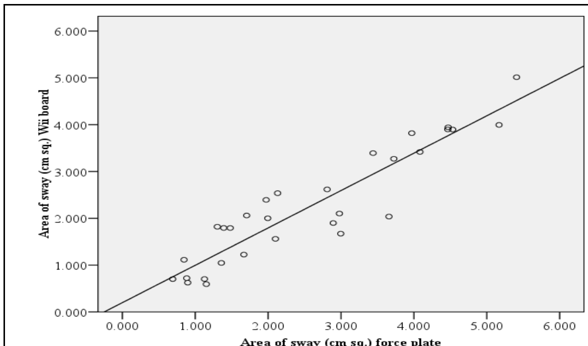
It was concluded that when typically developing adults perform the balance space task while the Wii board is placed on the force plate, very high internally reliable and concurrently valid measures of AP sway, ML sway, and area of sway, path length, and velocity are produced. These results justified our logic for incorporating the Wii board in the main study (Krasniuk & Taylor, 2010). Although, healthy adults were recruited for this pilot study, replicating the study employing children with movement and balance problems would further support the findings relevant to the main research project.



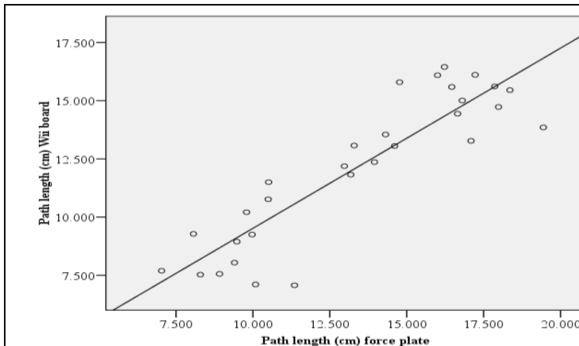
Validating ML sway (cm) of the BS task while the Wii board is on the force plate



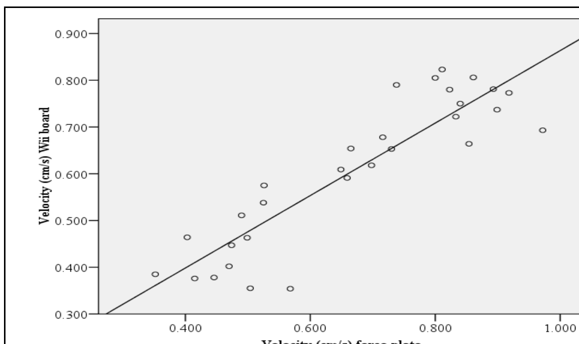
Validating AP sway (cm) of the BS task while the Wii board is on the force plate



Validating area of sway (cm^2) of the BS task while the Wii board is on the force plate



Validating path length (cm) of the BS task while the Wii board is on the force plate



Validating velocity (cm/s) of the BS task while the Wii board is on the force plate

Figure 8. Validating COP measures of the balance space (BS) task while the Wii board is on the AMTI force plate.

Participant Recruitment

Once ethical approval was granted by Lakehead University's Research Ethics board, purposive sampling was used to recruit participants. Participants were recruited from those children who had attended Lakehead University's Motor Development Clinic between 2007 and 2010. Referrals to the Motor Development Clinic were made by parents, teachers, pediatricians, and occupational therapists to Dr. Jane Taylor via telephone or email. Dr. Taylor invited past participants, who met the inclusion criteria, to take part in the research study via a letter (see Appendix D). Interested children and parents contacted the researchers via telephone.

Inclusion criteria. To participate in this study, the children had to meet all four criteria of the DSM-IV for DCD. They also had to have good or corrected vision, be free of medication that affected vision or balance, and could not have any ankle, knee, or hip injuries. Of the DSM-IV, criteria A and B state that children with DCD experience difficulties performing motor skills that adversely affect ADLs and/or academic achievement (APA, 2000). Screening with the MABC determined whether the participants had movement and balance problems. Participants obtained a TIS and a TBS $\leq 5^{th}$ percentile. The developmental history form used for intake to the School of Kinesiology Motor Development Clinic confirmed the existence of difficulties that affected ADLs and/or academic achievement. To comply with Criteria C and D, the motor difficulties experienced by the participants were not due to general medical conditions (e.g., cerebral palsy, hemiplegia, muscular dystrophy) and did not meet the criteria for PDD, or motor difficulty associated with intellectual disability (APA, 2000). The developmental history form confirmed that the participants did not have any general medical conditions or identified intellectual disabilities.

Information session. A total of 13 potential participants and parents were interested and contacted the researcher. They then attended an information session held in Lakehead University's Field House in the Motor Development lab, to discuss the details of the study. During the meeting, parents and participants received details of the study, read the study information letter (see Appendix E), and signed the consent form (see Appendix F). The researcher interviewed the parents with the developmental history form to confirm initial screening criteria for the study (Criteria B, C & D of the DSM-IV), and parents and participants completed the Wii Fit and physical activity questionnaire (see Appendix G). By reading the participant letter and signing the consent form, the participants fully acknowledged that they had the right to withdraw from the study at any time and that their data would be used for research purposes only. The Wii Fit and physical activity questionnaire determined the participants' level of experience with the Wii Fit, as well as their level of physical activity. Participants and parents were provided with detailed information of the MABC and force plate testing protocols and intervention (see Appendix H for Wii Fit balance intervention). The MABC was administered by the researcher to determine if the participants met criteria A of the DSM-IV, and also for collection of pre-testing measures. All participants were asked not to use the Wii Fit or participate in any other balance intervention during the time of this research project, but otherwise not to alter their daily physical activity pattern.

Participants. All 13 children met the inclusion criteria to be part of this study, however, before the force plate protocol and intervention commenced, two children dropped out, and another child dropped out after completing four sessions of the intervention. The final sample consisted of 10 children, eight males and two females, aged 7 to 10 years with movement and balance problems. Children with concomitant disorders such as ADHD, speech or articulation difficulties, or learning disabilities were included in the study, and all participants presented relevant symptoms to DCD, but they may not have been formally diagnosed with the disorder.

Intervention

Research design. The original research design was to be a two-factor repeated measures design, with a pre- and post-test, and a cross-over. There would be two groups with each comprising 10 children, aged 7 to 10 years, with movement and balance problems. The cross-over design would ensure that all participants receive the same number of treatments, and everyone would participate for the same period of time. In this experiment, the groups would be randomly assigned, with one group completing the intervention and the other group put on a waiting list for training, acting as a control. Once the intervention was completed, the children on the waiting list would begin training, and the other children would act as a control.

This research design was not applied because all participants were interested in performing the Wii Fit intervention and there were only 10 children interested in the study. So instead, a one-factor repeated measures design was applied with a pre- and post-test, and a 7-week wash-out period. The children were their own controls during the wash-out period (Jones & Kenward, 2003); they were asked not to perform the Wii Fit simulations or any similar type of balance training, but to carry on with their regular physical activity patterns.

Wii Fit training. The Wii Fit balance intervention took place in Lakehead University's Field House in the Motor Development lab. Supervised by the researcher, participants individually completed their training sessions two days per week on non-consecutive days. Ideally, the training sessions were three days apart and maintained for the entire 20 session period. Each session was 90 minutes in duration. The participants had three 5-minute breaks, one every 30 minutes, scheduled in each session, and were invited to take more breaks should they request it.

During training, the Wii console was placed on the television stand located approximately eight feet from the Wii board. The researcher directed the training sessions by holding onto the Wii remote. Participants performed the five pre-determined Wii Fit balance simulations, beginner soccer heading, ski slalom, ski jump, table tilt, and hula hoop, each five times in a row, while standing on the Wii board. To advance in each of these simulations (see Table 2), the participants had to score two stars, three times in one session, for two sessions in a row.

Table 2

Order of difficulty in the Wii Fit simulations

	No. of advancement (order of difficulty)			
Pre-determined simulations	1st	2nd	3rd	4th
soccer heading	adv. soccer heading	penguin slide		
ski slalom	adv. ski slalom	beg. snowboard slalom		
ski jump	beg. tight rope walking	adv. tight rope walking	exp. tight rope walking	
table tilt	beg. balance bubble	adv. balance bubble		
hula hoop	super hula hoop	rhythm boxing	basic step	adv. step

Note. beg. = beginner; adv. = advanced; exp. = expert. Adapted from "The effects of the Wii Fit balance games on static and dynamic balance of 9-11 year old boys with developmental coordination disorder," by S. M. Krasniuk, J. MacLeod, S. Matthews, J. Twahir, and M. J. Taylor, 2010, Paper presented at the North American Federation of Adapted Physical Activity Symposium, Riverside Valley, California.

This protocol required a 60% success rate before they advanced to more difficult simulations. In each session, the researcher presented the five simulations in a random order to the participants (see Appendix I).

Wash-out Assessment

Following the 20-session Wii Fit intervention, the children and their parents were were advised to refrain from participating in further Wii Fit interventions, home practice or new balance program during a 7-week period before being tested for a final time. This period was to allow time for a wash-out of effects due to the intervention. The researcher asked the participants and parents to read a letter and sign the consent form (see Appendix J), if they agreed to do the wash-out period and test, and record all details of programs that the children did start in this wash-out period, including using the Wii Fit at home.

Measures and Instrumentation

Participants were asked to wear comfortable clothes and running shoes to pre- and post-test and wash-out assessments. During the pre-test assessment, the children completed the MABC first. During the first session of the intervention, before starting the Wii Fit program, the participants performed the force plate protocol. However, during the post-test and wash-out assessments, the participants performed the force plate protocol first and then the MABC.

MABC. Individually, the participants performed the eight corresponding age band (e.g., 7 to 8 years or 9 to 10 years) tests of the MABC. The researcher, who was trained and had 3 years of experience conducting assessments with the MABC, administered the test to all participants. The MABC assessment took approximately 1 hour to complete. The TIS and TBS were calculated and recorded to examine movement and balance status before and after the intervention, and after the 7 week wash-out period.

Force plate protocol. The children's postural adaptation status was assessed using an Advanced Mechanical Technology, Inc. (AMTI) force plate. The force plate was connected to an

IBM compatible Pentium 166 MHz personal computer and the software, BioSoft-Beta version 1.0, translated and recorded the vertical force and AP and ML moments of force that were applied to the force plate. The postural sway measures, AP and ML sway, area of sway, and path length, were recorded during eyes open and closed tasks and the balance space task; however, the measures were only analyzed for the balance space task. This study investigated postural adaptation and so the logic for performing the eyes open and closed tasks before the balance space task was to follow the researchers' force plate protocol (Krasniuk & Taylor, 2010), in an attempt to replicate the very high internal consistency that was shown in the pilot study. AP and ML sway measured the total distance the participants travelled in those respective directions. Area of sway measured the 95% ellipse of surface area that the participants moved within. Path length measured the total distance the participants covered in the 20-second period. All measures were taken at a sampling frequency of 100 Hz with the gain set at 4000x, 5x, and the electronic filter set at 10.5 Hz.

Individually, the participants performed the force plate protocol (Krasniuk & Taylor, 2010). The protocol commenced with measuring and recording the participants' height, weight, and foot size (length and width). While barefoot, the participants stood on the Wii board placed on the force plate and performed one practice trial and then three formal 20-second trials of eyes open, eyes closed, and the balance space task. Each trial started on keystroke.

Quiet standing with eyes open required the participants to stand as still as possible with feet positioned side-by-side and arms crossed over the chest while looking at a yellow *X* target that was eye level and taped on a blue mat placed 4.2 meters from the force plate. Quiet standing with eyes closed required the participants to stand as still as possible with feet positioned side-by-side and arms crossed over the chest with eyes closed. The balance space task required the participants to lean as far as possible forward, backward, to the right, then left, and back to the centre, while keeping the trunk upright, knees and hips extended, feet positioned side-by-side, and without lifting the toes or heels. The force plate protocol took approximately 15 minutes to complete.

Social validation survey. Once the post-test assessments were completed, the participants were asked to complete a social validation survey (see Appendix K) which was adapted from Allen and Taylor (2001). This survey allowed the children to express their feelings about the Wii Fit intervention through a series of closed- and open- responses. Responses provided by the children described how the participants felt physically, mentally, and socially about Wii Fit as a form of balance training.

Data Analysis

All data analyses were conducted using Statistical Package for Social Sciences (SPSS) 18.0. All tests were conducted using an alpha level of $p \leq .05$, with a two-tailed level of significance. Descriptive statistics (means, standard deviations, and ranges) were calculated for the dependent measures, age (years), weight (kg), height (cm), foot measurements (cm), possible anterior and posterior sway calculations (cm), adapted from Usui, Maekawa, & Hirasawa (1995), TIS (z-scores), and TBS (z-scores), to compare the nature and variability of the participants' demographics. Descriptive statistics (means, standard deviations, and ranges) were computed for the participants' performance scores of each simulation, of every training session, to characterize their performance throughout the training period.

Internal consistency analyses using Cronbach's alpha (*a*) were calculated for the dependent measures, AP sway (cm), ML sway (cm), area of sway (cm^2), and path length (cm), to investigate if the three trials of the balance space task displayed internal reliability. Moderate to very high Cronbach coefficients ($\alpha = \geq .70$) showed that the three trials of the balance space task were internally consistent. Therefore, the mean of the three trials for each dependent measure was calculated and used for the following procedures. These analyses were repeated for the dependent measures at the post-test and wash-out assessment.

A series of repeated measures designs were used to examine the effects of the Wii Fit intervention on postural adaptation of children with movement and balance problems. One-factor repeated measures ANOVAs were calculated for dependent measures, TIS and TBS of the MABC, and then AP sway, ML sway, area of sway, and path length of the force plate protocol, to investigate if there were significant changes in scores under the independent measure, time: pre-test, post-test, and wash-out test. Bonferroni corrections were used to decrease the chance of committing a type one error. Effect sizes were analyzed using partial eta squared (ηp^2) to evaluate the strength of the relationship between the effects and the dependent variables. A value of 0.1 was a small effect; 0.25 a medium effect; 0.4 a large effect (Cohen, 1992).

If any of the repeated measures analyses revealed significance or had more than a small effect size, subsequent dependent-samples t-tests were computed to further investigate the differences or apparent differences in scores. Effect sizes were calculated using Cohen's *d*. Here, a value of 0.2 was a small effect; 0.5 a medium effect; 0.8 a large effect (Cohen, 1992).

Results

Participant Demographics

The sample met the requirement criteria for this study, which were the four criteria of the DSM-IV for DCD. Table 3 reports descriptive statistics of the 10 participants' demographics at the pre-test. Individual demographic data of each participant at the pre-test can be found in Appendix L.

Table 3

Means, standard deviations, and ranges of participant demographics at pre-test

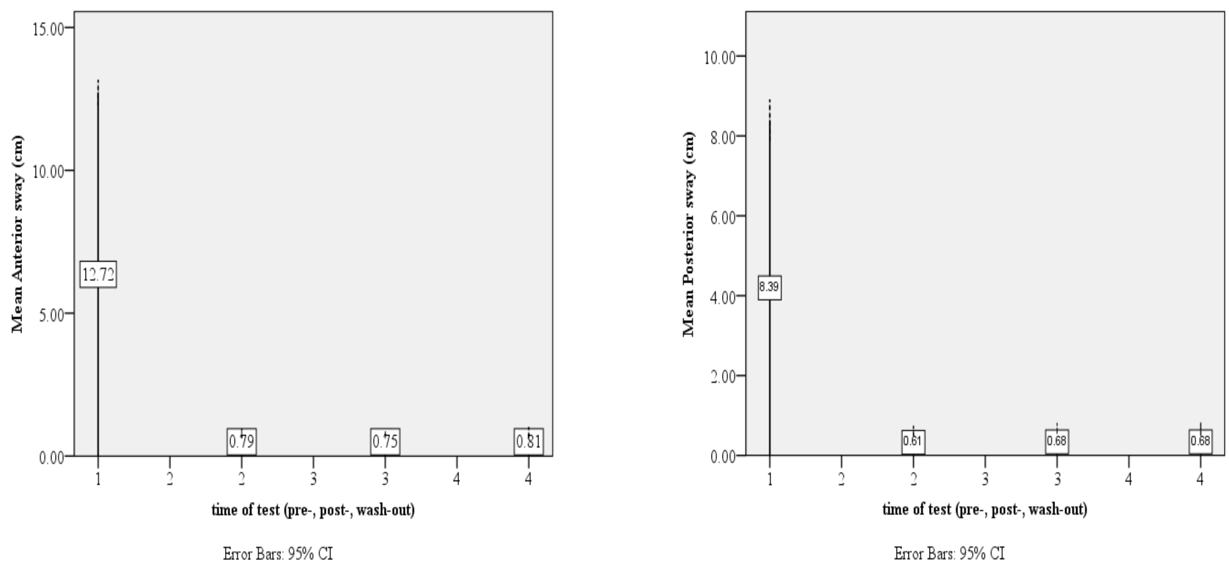
DV	*M*	*SD*	*Ranges*
Age (years)	8.50	1.27	7.00-10.00
Weight (kg)	34.80	6.79	27.50-47.10
Height (cm)	139.00	10.90	114.00-151.00
Foot length (cm)			
Right	21.10	1.27	19.00-22.90
Left	21.10	1.58	18.40-23.30
Foot width (cm)			
Right	8.30	.63	7.50-9.40
Left	8.19	.61	7.10-9.00
PAS (cm)	12.70	.61	11.80-13.50
PPS (cm)	8.39	.72	7.20-9.40
MABC			
TIS	21.90	4.27	16.50-31.50
(%)	(<1)		
TBS	7.50	2.74	3.50-12.00
(%)	(5)		
TMDS	10.60	2.97	6.50-15.00
(%)	(<5)		
Tball	3.80	2.41	1.00-9.00
(%)	(5-15)		

Note. TIS = Total Impairment Score; TBS = Total Balance Score; TMDS = Total Manual Dexterity Score; Tball = Total Ball Skills Score. PAS = possible anterior sway; PPS = possible posterior sway, calculations Adapted from "Development of the upright postural sway of children," by N. Usui, K. Maekawa, and Y. Hirasawa, 1995, *Developmental Medicine and Child Neurology, 37*, 985-996.

Criteria of DSM-IV for DCD. The participants' TIS on the MABC determined if they met criteria A of the DSM-IV for DCD; if the children had motor skill problems. Meanwhile, the TBS of the MABC established if the participants had balance problems. Prior to commencement of the intervention, the children obtained a mean TIS of 21.90. When compared to the normative data (Henderson & Sugden, 1992), this score placed the participants' motor skill performance at less than the 1st percentile. The range of TIS (16.50-31.50) indicated that these children had very severe motor difficulties; one child scored at the 2nd percentile; one at the 1st, and the remaining eight less than the 1st. This score established that the children met criteria A of the DSM-IV for DCD.

In addition, the participants acquired a mean TBS of 7.50 or at the 5th percentile when compared to the normative data (Henderson & Sugden, 1992). Similar to the mean TIS, the mean TBS confirmed that the majority of participants had balance problems. The range of TBS (3.50-12.00) indicated that according to normative data, some of the participants did not have severe balance problems. Three participants did not show severe balance difficulties, scoring above the 15th percentile, while one boy had a TBS between the 5th and 15th percentile, and the remaining six children scored a TBS less than the 5th percentile. When comparing the children's anterior and posterior sway to their possible anterior (PAS) and posterior sway (PPS) calculations (see Figure 9), adapted from Usui, Maekawa, and Hirasawa (1995), however, it was clear that the participants illustrated balance difficulties, as they did not come close to reaching their possible stability limits in either direction.

To establish if the participants met criteria B, C, and D, the researcher interviewed the participants' parents with the developmental history form. Criteria B requires that the motor skill difficulties experienced by the children also affected ADLs and/or academic achievement. Question three of the form “compared to other siblings and children of his or her age did you find his or her development different in any way?” helped examine if the children met criteria B. Parents stated that their children had difficulties in riding bicycles, dressing, tying shoe laces, catching balls, climbing stairs, and climbing playground equipment.



Mean PAS (1) compared to participants’ mean anterior sway at each assessment

Mean PPS (1) compared to participants’ mean posterior sway at each assessment

Figure 9. Participants’ mean possible anterior and posterior sway calculations (1) compared to their respective actual sway values at pre- (2), post- (3), and wash-out (4). *Note.* PAS = possible anterior sway; PPS = possible posterior sway, calculations Adapted from “Development of the upright postural sway of children,” by N. Usui, K. Maekawa, and Y. Hirasawa, 1995, *Developmental Medicine and Child Neurology, 37*, 985-996.

Question five of the form “has your child ever been assessed and diagnosed for developmental difficulties? If so, what type of remediation followed?” provided further assistance in determining if the children met criteria B of the DSM-IV for DCD. Parents specified that their children had been assessed in speech therapy for assessment and printing, and in occupational therapy for fine and gross motor development. Two of the participants were diagnosed with DCD, and the one boy diagnosed with ADHD was also assessed for obsessive compulsive disorder.

Lastly, question six of the form “how would you describe your child’s social life?” helped determine if the participants’ motor performance affected their ADLs and/or academic achievement. Parents stipulated that their children had little to no friends and mostly played with their siblings. When the children were out in the neighborhood, they watched other children play games and waited for an invitation to play with them. When tasks became difficult, the participants became frustrated, stopped doing the tasks, and walked away from them. In some cases, if tasks looked difficult for the children, they would not even try to do the tasks and avoided trying them altogether. The responses made from questions three, five, and six provided evidence that the participants’ motor skill performance affected ADLs and/or academic achievement.

Questions two and four of the developmental history form ensured that the motor difficulties the participants experienced met criteria C and D of the DSM-IV for DCD; the difficulties were not due to a general medical condition, did not meet the criteria for PDD, and did not meet the criteria for an intellectual disability. Question two inquired about potential birth complications experienced by the participants. Parents stated that there were no examinations made during their children’s birth or subsequently which identified a general medical condition, PDD, or intellectual disability. All of the children attended academic classes for typically developing children. Complications at birth most often included either premature or late delivery dates. Two participants had irregular breathing and were placed in the intensive care unit when they were born.

Question four of the form inquired if the participants had any serious health problems. There were very few responses made from the parents. When one participant was younger, his feet were small and turned inwards. He wore orthotics to correct this issue. Three participants were sensitive to touch or sound when they were younger, but not as much anymore. One girl had epilepsy and took clobazam to control the disorder. Parents showed that their children did not have any serious health problems, and the conditions mentioned were controlled.

Experience with the Wii Fit. The Wii Fit and physical activity questionnaire first examined the participants' experience level with the Wii Fit. The first question asked the participants if they enjoyed playing video games. Of the ten children, nine answered yes and one replied no. Nine of the ten participants owned a Wii console and five owned the Wii Fit program. Six participants began playing video games on the Wii or Wii Fit more than 12 months earlier. Meanwhile, one child started playing video games on the Wii or the Wii Fit 6 to 12 months before the study, two participants began 2 to 6 months previous, while another did not play games on either the Wii or Wii Fit.

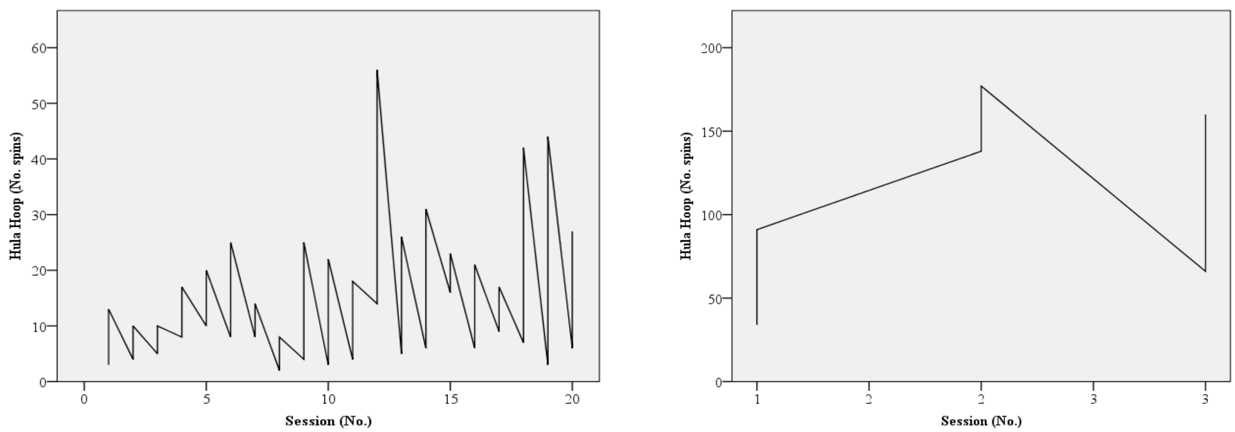
On the question "how often do you play video games on the Wii or Wii Fit?" five children replied two to five times a week. Another two participants answered less than once a week, and two more responded more than once a day. The last participant did not have a Wii or Wii Fit so he did not play any games.

The fifth question inquired about the types of games from the Wii or Wii Fit the children enjoyed playing. Cars, Mario cart, Simpsons, Rockband, Star Wars, Penguins of Madagascar, and Pet Puppy were the games mentioned from the Wii. Bowling was the only game listed from Wii Sports. Ski slalom, hula hoop, ski jump, table tilt, basic run, and bicycle were the games stated from the Wii Fit. Based on these responses made by the children, it appeared that the participants had plenty of experience playing video games on both the Wii and Wii Fit.

The second part of this questionnaire examined the participants' experience in physical activity. A positive response was that all ten children enjoyed participating in physical activity or sports. The seventh question asked the children to list the types of physical activities or sports they did and the length of time they spent doing them. Responses from the participants varied greatly (see Appendix M). The last question inquired about serious injuries resulting from their participation. Thankfully, none of the children had any serious injuries.

Performance in the Wii Fit Balance Intervention

All ten participants made considerable advancement, between 55.7 to 200%, in the Wii Fit balance simulations, by meeting the criteria (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010) and scoring between one and two stars (see Appendix N for descriptive statistics and visual representations of participants' performance results in each simulation). Participants' performance on the simulations was subject to individual strengths and weaknesses. Figure 10 shows an example of one participant who experienced difficulty performing hula hoop, compared to another participant who excelled on the simulation.



Participant two on hula hoop | Participant ten on hula hoop

Figure 10. Comparing participant two's performance results to participant ten's performance results on hula hoop.

There were three different trends shown when inspecting the visual representation of participants' performance on hula hoop (see Figure 11), beginner soccer heading (see Figure 12), and advanced ski slalom (see Figure 13).

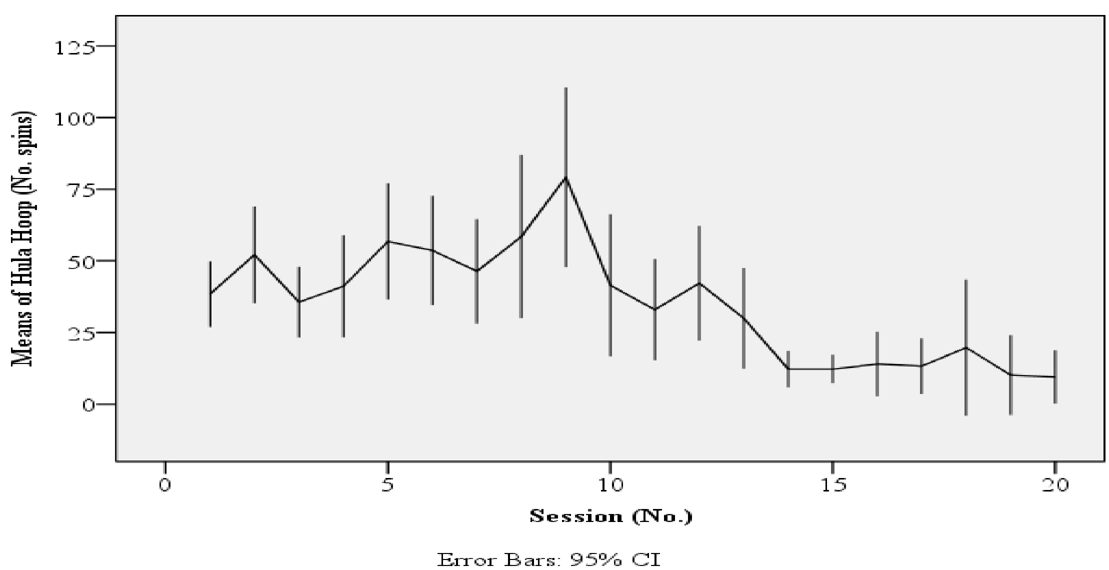


Figure 11. Participants' mean performance scores on hula hoop. Peak performance was shown on the ninth session. After the ninth session, there were four children remaining who had difficulty performing and advancing in this simulation, with three not advancing at all. Error bars represent scores within the 95th% confidence interval.

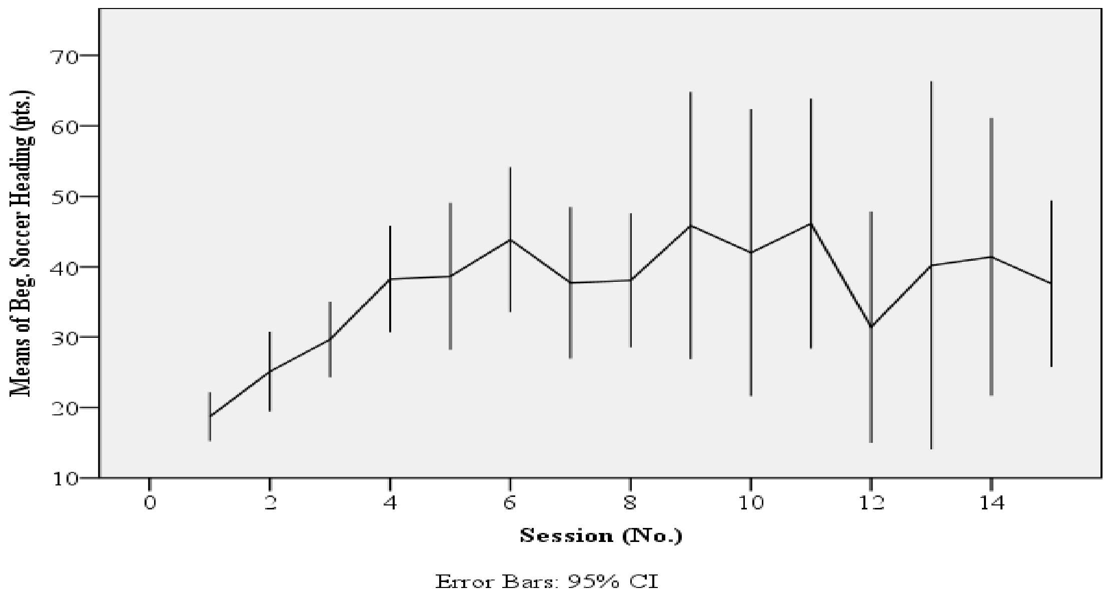


Figure 12. Participants' mean performance scores on beginner soccer heading. Error bars represent scores within the 95th% confidence interval.

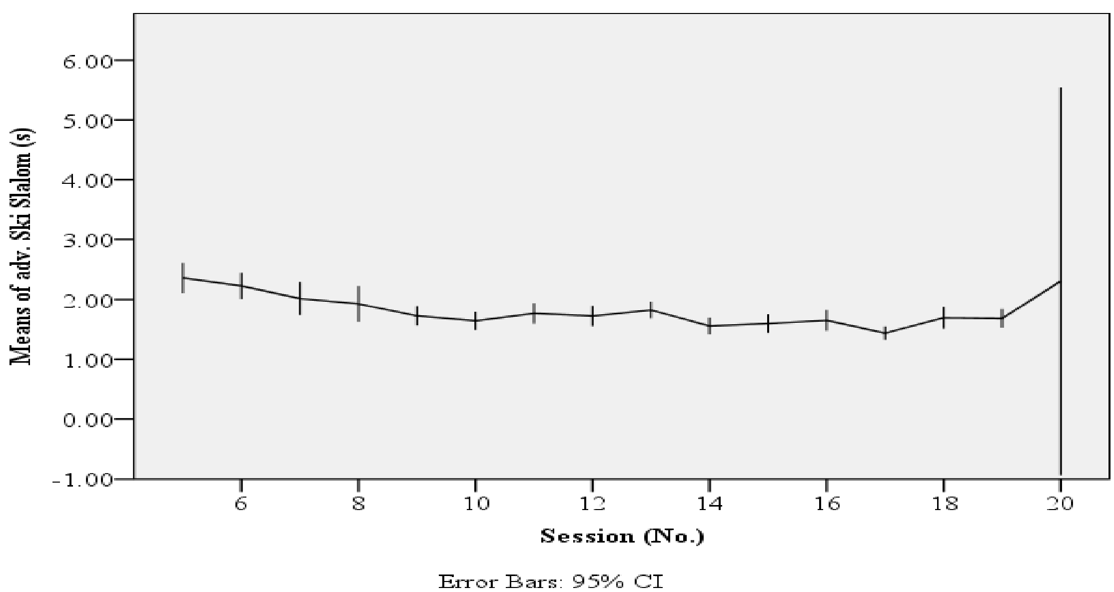


Figure 13. Participants' performance on advanced ski slalom. Error bars represent scores within the 95th% confidence interval. *Note*. scores are based on time. The lower the scores, the better the results.

Performance of TIS and TBS in the MABC

The children's performance on the MABC assessed their levels of motor competence and balance, measured with the TIS and TBS, respectively. Both of the one-factor repeated measures ANOVA procedures satisfied the assumption of sphericity (Mauchly's test of sphericity), which indicated that the variances of the differences between all combinations of related groups were equal (Mauchly, 1940). Bonferroni corrections were used in both analyses. The analysis for TISs at pre-, post-, and wash-out showed that there were no significant differences with a small effect size (F (2, 18) = 2.79, p = .088, ηp^2 = .24). Since the effect was close to medium (ηp^2 = .25), the decreases in mean TISs from the pre- (M = 21.90; SD = 4.27) to post-test (M = 18.60; SD = 5.73) (see Figure 14 and Appendix O), were evaluated. A dependent samples t-test for TISs from the pre- to post-test showed significance with large effects (t (9) = 4.60, p = .001, d = 1.46), with mean TISs showing decreases at post-test. There were no differences with small effects shown in TISs from the post-test to the wash-out assessment (t (9) = -.83, p = .43, d = .26).

The one-factor repeated measures analysis for TBSs showed significant differences with large effects (F (2, 18) = 9.57, p = .001, ηp^2 = .52). There were decreases in mean TBSs from the pre- to post-test (see Figure 15). A significant dependent-samples t-test supported that the differences in mean TBSs existed from the pre- to post-test with large effects (t (9) = 3.49, p = .007, d = 1.10). There were no differences shown in TBSs from the post-test to the wash-out assessment with small effects (t (9) = .66, p = .53, d = .20).

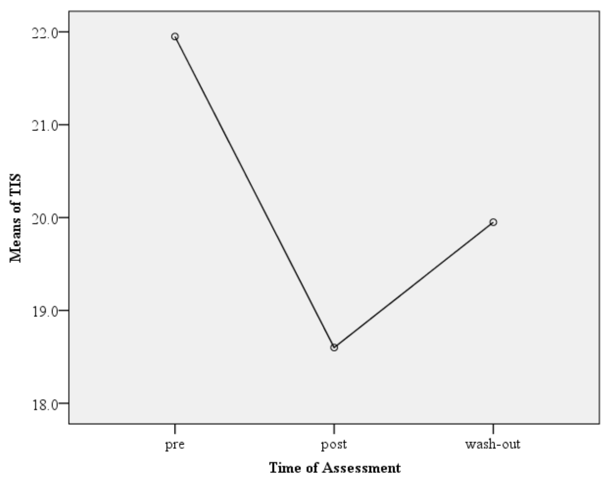


Figure 14. Means of TIS at pre-, post-, and wash-out.

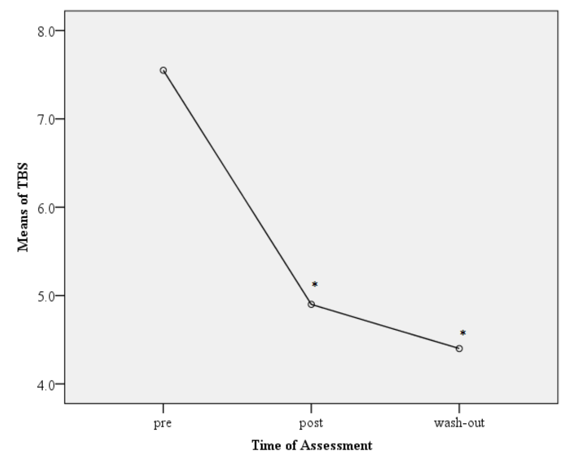


Figure 15. Means of TBS at pre-, post-, and wash-out. *Note*. * = p <.025 for pre- to post- and pre- to wash-out.

Postural Adaptation in the Balance Space Task

Internal consistency analyses. The internal consistency analyses using Cronbach's alpha (*a*) showed very high internal reliability of AP sway, ML sway, area of sway, and path length, at the pre-, post-, and wash-out assessments (see Table 4). As a result, the mean of the three trials in each of the COP measures of the balance space task, at each assessment time, were calculated and the one-factor repeated measures analyses then proceeded.

Table 4

Internal consistency of COP measures of balance space task

DV	Internal consistency (*a* =)		
	Pre-test	Post-test	Wash-out test
AP (cm)	.96	.97	.98
ML (cm)	.95	.95	.97
Ao (cm^2)	.96	.97	.95
L (cm)	.94	.97	.95

Note. AP = anterior-posterior sway; ML = medial-lateral sway; Ao = area of sway; L = path length.

Performance of COP measures in the balance space task. The children's performance on the balance space task assessed their postural adaptation level, measured by AP sway, ML sway, area of sway, and path length. As with repeated measures ANOVA procedures with MABC measures, all procedures here satisfied the assumption of sphericity (Mauchly's test of sphericity), and Bonferroni corrections were used in the analyses. None of the analyses displayed significant differences and all computed small effect sizes: AP sway (F (2, 18) = .92, p = .42, ηp^2= .09); path length (F (2, 14) = 1.93, p = .18, ηp^2 = .22); area of sway (F (2, 14) = .36, p = .71, ηp^2 = .05); ML sway (F (2, 18) = 1.05, p = .37, ηp^2 = .11).

Figures 16 to 19 show the comparison of mean scores of sway measures at the pre-, post-, and wash-out assessments. Although non-significant, AP sway showed increases from the pre- to post-test and from the post-test to the wash-out assessment. The remaining measures displayed decreases in sway from the pre- to post-test, and increases in sway from the post-test to the wash-out test. Since the effect for path length (ηp^2 =.22) was close to medium (ηp^2 =.25), these means were further investigated. A dependent samples *t*-test of path length measures from pre- to post-test which approached significance with a medium effect size (t (9) = 2.19, p = .057, d = .69) provides some evidence of change.

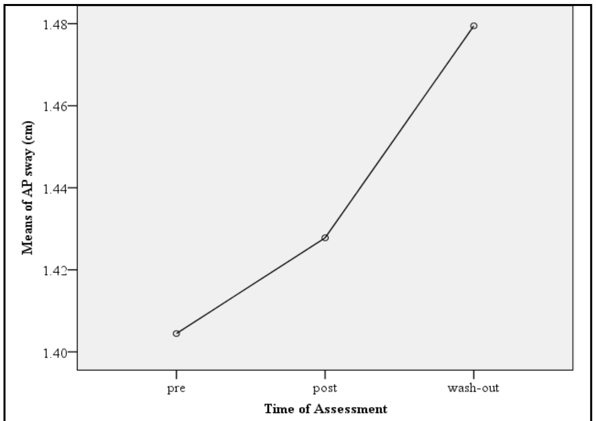


Figure 16. Means of AP sway at pre-, post-, and wash-out.

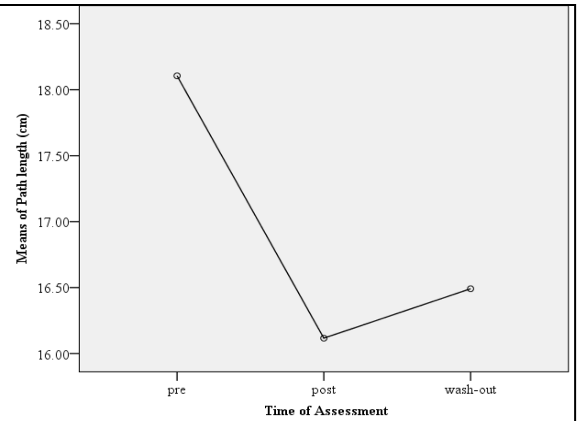


Figure 17. Means of path length at pre-, post-, and wash-out

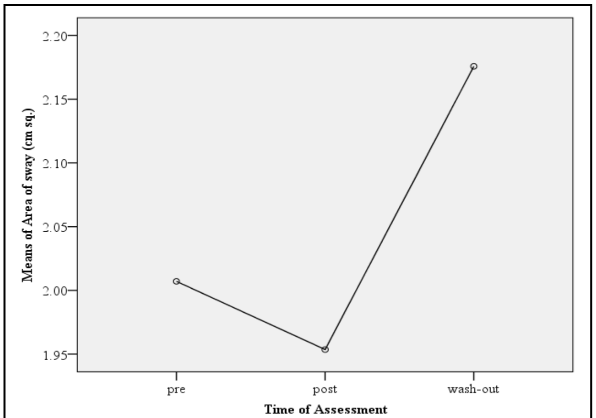


Figure 18. Means of area of sway at pre-, post-, and wash-out.

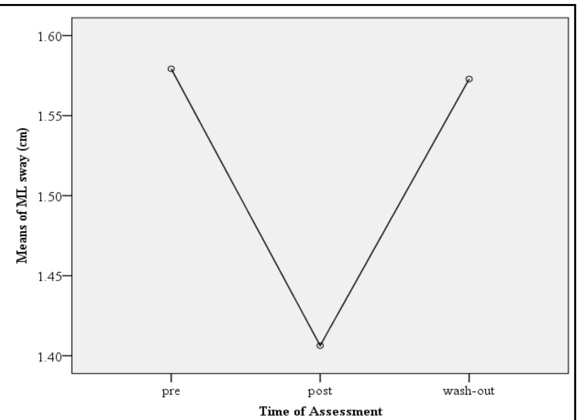


Figure 19. Means of ML sway at pre-, post-, and wash-out

Qualitative Inspection of Individual Data

Since the direction of change in three of the four COP measures was opposite to what was hypothesized, a further investigation of the participants' individual data proceeded. As can be seen in Table 5 by the individual data of mean COP measures of the balance space task, three of the older boys increased in AP sway, area of sway, and path length, while two of those boys increased in ML sway at post-test.

Table 5

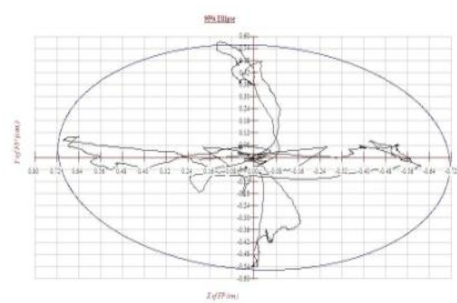
Individual mean COP measures taken at pre-, post-, and wash-out assessment

	AP (cm)			ML (cm)			Ao (cm^2)			L (cm)		
Test	1	2	3	1	2	3	1	2	3	1	2	3
Older boys												
2	1.18	1.55	1.45	1.46	1.37	1.98	1.56	2.15		15.55	16.20	
3	1.75	1.89	1.90	1.97	2.06	1.81	2.85	3.97	3.38	17.36	18.69	15.74
9	1.24	1.52	1.44	1.00	1.49	1.59	1.15	2.06	2.13	10.45	12.50	14.23
Remaining participants												
1	1.30	1.44	1.40	2.28	1.67	2.42	2.40	2.07		27.62	21.51	
4	1.73	1.66	1.71	1.91	1.89	2.10	3.48	2.33	3.81	24.18	22.39	22.47
5	0.61	0.66	0.56	1.29	0.81	0.72	0.63	0.41	0.33	14.39	14.61	10.50
6	1.78	1.53	1.60	1.27	1.33	1.38	1.73	1.91	1.94	22.05	16.37	20.57
7	1.75	1.65	1.70	2.35	1.51	1.22	3.59	2.79	2.09	24.70	21.25	18.61
8	1.34	1.05	1.49	1.27	0.86	1.40	1.48	0.92	2.06	17.13	11.48	15.77
10	1.37	1.31	1.54	0.99	1.06	1.12	1.15	1.26	1.68	14.58	11.64	14.05

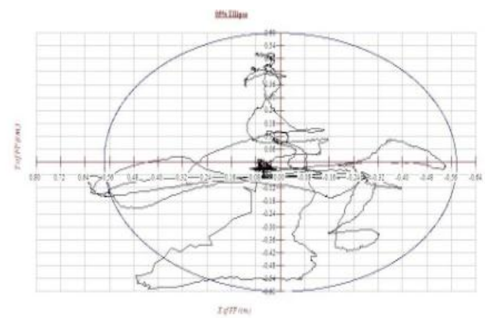
Note. AP = anterior-posterior sway; ML = medial-lateral sway; Ao = area of sway; L = path length; Test 1 = pre-; Test 2 = post-; Test 3 = wash-out. Due to a calibration error with the force plate, there is missing data in path length and area of sway measures for two participants.

The majority of the remaining participants demonstrated a decreasing trend in sway. Five children showed a decrease in AP sway; four in ML sway, five in area of sway; six in path length. At the wash-out assessment, two of the three older boys exhibited a decrease in AP sway; one in ML sway; one in area of sway. The majority of the remaining participants displayed an increase in sway. Five showed an increase in AP sway, ML sway, and area of sway, while three showed an increase in path length.

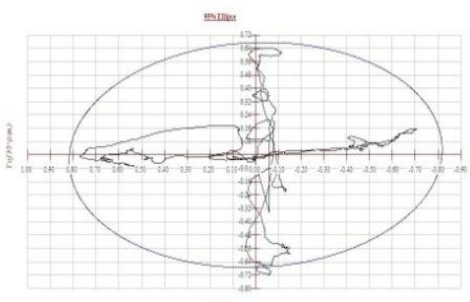
In addition to examining the participants' individual data, visual representations of their performance on the balance space task were reviewed qualitatively (see Appendix P). Figure 20 shows an older boy's performance of the balance space task, at each assessment time, compared to that of a younger girl's performance.



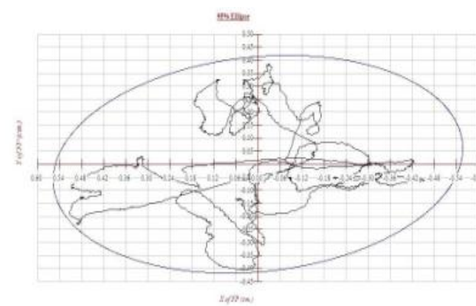
10 year old boy at pre-test



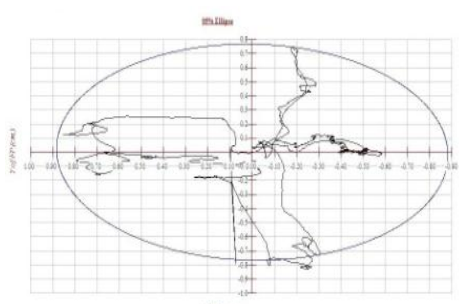
8 year old girl at pre-test



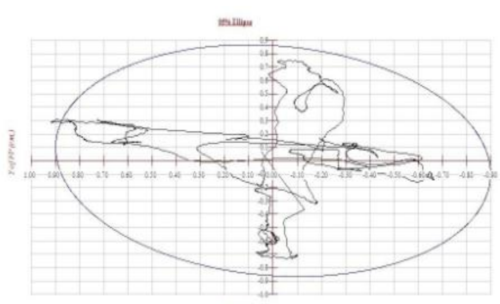
10 year old boy at post-test



8 year old girl at post-test



10 year old boy at wash-out test



8 year old girl at wash-out test

Figure 20. Comparison of performance on the balance space task at pre-, post-, and wash-out by a 10-year old boy and 8-year old girl.

Social Validation Survey

At the post-test, participants completed a social validation survey that allowed them to express their feelings about the Wii Fit balance intervention. Half of the participants said that their life had become a bit better since they had been in the Wii Fit program. Meanwhile, three children said their life had changed a great deal, and the remaining two said nothing had changed. Some participants conveyed that their balance and health had improved and they felt better about themselves. During the intervention, six participants changed their daily activity or exercise habits by exercising more, while the remaining four did not change their regular physical activity patterns. None of the participants changed their medication or had any treatment during the Wii Fit sessions. Eight children said they would participate in the Wii Fit program if it were offered again because they exercised more, it was fun, and it was active. The remaining two children said they would not join the program again because they were already too busy. When participants were asked if they would offer the program to friends, seven children said they would because their friends would improve their balance and have fun with many activities, while three responded undecided because they did not know if their friends would enjoy the program. A very positive response was that all ten children felt that the balance training was geared toward their ability level. Eight participants responded that the length of the program and exercise sessions were just right. Meanwhile, one child felt it was too long and became bored, and another child believed it was too short. Generally, everyone was satisfied with the Wii Fit balance intervention.

Discussion

The aim of this study was to examine the effects of a Wii Fit balance intervention on postural adaptation of children with movement and balance problems. It was anticipated that the Wii Fit program would have a positive impact on the participants' balance, and more particularly their postural adaptation. Results supported that the children made substantial improvement in the balance simulations throughout the entire Wii Fit intervention, by meeting the criteria and advancing through the simulations.

There were significant differences in TBSs with large effects, shown by the repeated measures ANOVA analysis. As well, significant differences with large effects in TBSs from the pre- to post-test were displayed in a dependent samples *t*-test, with mean TBSs exhibiting that the participants improved their balance performance at the post-test.

Conversely, there were no significant differences in both TISs and all COP measures, and all computed small effect sizes, illustrated by the repeated measures analyses. On the other hand, a significant dependent samples *t*-test of TISs from the pre- to post-test with large effects, suggested that the children improved their performance of the MABC tasks at the post-test.

Although non-significant, it was interesting that at the post-test, the children's mean scores displayed decreases in ML sway, area of sway, and path length of the balance space task, the opposite of what was hypothesized, whereas the trend in AP sway scores was as predicted. The dependent samples *t*-test of path length measures from pre- to post-test showed a medium effect, suggesting that these decreases in sway were a real effect of the intervention.

From the qualitative inspection of individual data, it is conjectured that a developmental pattern exists, with three of the older boys displaying both higher TBSs and an increase in COP measures at the post-test. Meanwhile, the majority of the remaining participants demonstrated a decrease in sway at the post-test. As these changes followed the research hypotheses it could be argued that a certain level of balance maturity is necessary for the Wii Fit intervention to have the desired effect on postural adaptation.

Overall responses made from the social validation survey were that the children felt better about their balance and health due to the intervention. It was anticipated that the intervention would have a positive impact on the children's balance and some results supported that it did.

Participant Demographics

The sample in this study represented the population of children with movement and balance difficulties for a number of reasons. It was confirmed that the participants had movement problems prior to taking part in the study by attending Lakehead University's Motor Development Clinic between the years 2007 and 2010. The stringent inclusion criteria for the research project required the children to meet the four criteria in the DSM-IV for DCD and have balance difficulties. All children had severe movement difficulties and the majority had balance problems. All participants passed the criteria which corroborated that the children had movement problems that affected their ADLs and/or academic achievement, and they did not have any general medical conditions or intellectual disabilities. The mean TBS (M = 7.50) indicated that overall the group had definite balance difficulties.

Participants' possible sway versus actual sway measures. The possible anterior and posterior sway calculations (Usui, Maekawa, & Hirasawa, 1995) represented the participants' stability limits in the AP directions and were compared to the actual distances in their performance of the balance space task. At any testing time, the children did not come close to their possible stability limits (see Figure 9).

Przysucha, Taylor, and Weber (2008) and Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010) also used the possible sway calculations, and computed comparable values to the results shown in this study. The mean PAS the children displayed in the current study was 12.72 cm, while the mean PPS was 8.39 cm. These scores compare favourably to both Przysucha et al, where PAS was reported as 12.18 or 13.79 cm, and PPS was 7.46 or 9.27 cm for younger and older participants, while Krasniuk et al reported a range in PAS between 10.80 and 11.25 cm, and a PPS between 7.20 and 8.00 cm.

In addition to the possible sway calculations computed in all three studies, the participants' actual sway values in Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010) were similar. In the current study, the participants showed an anterior sway between .75 to .81 cm, and a posterior sway between .61 and .68 cm. The three boys in Krasniuk et al showed an anterior sway between .60 and 1.80 cm, and a posterior sway between .35 and 1.25 cm. Although even healthy children do not lean to their potential stability limits during the balance space task (Riach & Starkes, 1993), Przysucha, Taylor, and Weber (2008) reported that boys with DCD did not lean as far as typically developing boys in the AP directions. The great amount of difficulty that children with DCD experience in postural adaptation during the balance space task was demonstrated by comparing the possible sway calculations, computed in the three studies, to the actual sway values of children with movement and balance problems, and to those of typically developing children.

Subtype in sample. The children in this sample not only displayed movement coordination difficulties with weaknesses in balance and manual dexterity but strengths in ball skills. These results were similar to Hoare (1994) and Macnab, Miller, and Polatajko (2001) who both reported a subtype of children with DCD with weaknesses in balance and manual dexterity. Another comparison was found between the children in this sample and the subtypes reported by Miyahara (1994) and Wright and Sugden (1996) who both reported on children with weaknesses in balance and strengths in ball skills.

Characteristics of DCD present in children. The interview between the researcher and parents with the developmental history form confirmed present characteristics of DCD in the participants. Children had difficulties with fine and gross motor tasks such as dressing, tying shoe laces, catching balls, riding bicycles, and climbing playground equipment. Remediation for these difficulties included occupational therapy and speech therapy. Although all participants had movement, and most had balance difficulties, and therefore characteristics of DCD, the majority of children were not formally diagnosed with DCD or concomitant disorders. Only two boys were diagnosed with DCD; one girl was diagnosed with a learning disability; another boy was diagnosed with ADHD. Other characteristics of DCD present in the participants involved the social aspects of their lives. The children had few to no friends and played mostly with their siblings or family members. Low self-esteem was evident in the children when they gave up easily or did not even attempt tasks they found difficult (Cantell & Kooistra, 2002, p. 29-31). When attempting difficult tasks, the participants became frustrated, started crying, or acted out in a negative manner.

Experience with the Wii Fit. The participants' responses from the Wii Fit and physical activity questionnaire inferred that the children had plenty of experience with the Wii console and the Wii Fit program. Comparing these responses to the participants' performance results on the Wii Fit simulations at the beginning of the intervention, however, did not confirm that the children had successful experiences. Instead, at the beginning of the intervention, the children scored fairly low and had difficulty understanding how to perform the tasks in the simulations.

Some participants did not comprehend that the movement they made corresponded with the movement their avatars made in the simulations, which was based on the amount of weight they placed on the Wii board. For example, if the participants were performing soccer heading and had to lean left to head a soccer ball, they would have had to place their weight on their left foot. Instead, the children flexed and laterally flexed at the waist or bobbed their heads to try to soccer head the oncoming balls. These initial actions were also present in the other simulations. In hula hoop, some children did not know how to isolate their upper and lower body parts. The majority of movement made in this simulation was from their upper body, so minimal weight was placed on the board, and as a result the hula hoops dropped to the ground. These observations showed how children with DCD have problems performing motor tasks.

To help correct the initial and incorrect movements performed by the participants, the researcher provided strategies that assisted the children in understanding how the console was designed. When children bobbed their heads, or flexed and laterally flexed their waists to perform tasks in the simulations, the researcher suggested to them to try and use their legs more than their upper bodies, and further hinted on which part of their feet they needed to place their weight.

When participants moved their feet on the Wii board, for example in table tilt, took a step back to move the balls backward, the children rarely placed their feet back on the correct positions of the board. Since the sensors were in the four corners of the Wii board, it was imperative that the feet remained inside the drawn out rectangles (see Figure 21). When the participants' feet were not in these correct positions, the researcher reminded them to correct their foot placement. Once these strategies were employed by the children, they caught on to how to perform the simulations.

Figure 21. Wii board. The board on the left illustrates that the four sensors are in the corners of the board. The board on the right shows the rectangles where the individual should stand while performing simulations. Adapted from "About the Wii console" by Nintendo, 2010. Copyright 2010 by author, Canada.

There were only a few participants that continued having difficulty in performing simulations. Isolating the upper and lower body parts in hula hoop was a problem for some of these children. With consent from the participants, the researcher held the children's shoulders while they performed hula hoop, and as soon as it appeared that the participants were performing the simulation properly, using their waist and legs and not their upper body, the researcher let go of their shoulders. This strategy was particularly successful on subsequent trials during the same session.

Conversely, bowling from Wii Sports, and ski slalom, hula hoop, ski jump, table tilt, and basic run from the Wii Fit were mentioned as simulations performed by some of the participants.

The initial low performance results obtained by the participants might have been due to the rigorous criteria taken and adapted from Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010). Every session, the criteria required the children to perform the five assigned simulations, five times in a row. Realistically, children with DCD would not perform simulations with these conditions, and instead, they would most likely only perform the simulations they succeeded in and enjoyed practicing.

Children with DCD might be inefficient in motor planning, which was shown in children with learning disabilities who took significantly longer to make judgment calls when stepping over an obstacle than typically developing children (Whitall, Sanghvi, & Getchell, 2007, p. 83-95). If this were the case in this study, the participants might have scored low at the beginning of the intervention because the serial tasks in the simulations were quick, while the children's reaction times were slower, resulting in more errors.

It is well established that children with DCD tend to avoid doing tasks with which they have difficulty. If the participants avoided doing simulations on the Wii Fit or similar tasks, they might have had little experience performing these tasks, and as a result had little knowledge about the simulations. In addition, feedback provided from the Wii Fit program might not have helped the children because they had difficulty interpreting it and reacted incorrectly or too slowly. Similar behaviour was first reported in a study by Marchiori, Wall, and Bedingfield (1987) where two physically awkward children did not improve or become more consistent when practicing 1200 hockey slap shots over a 6-week period.

Responses from the second part of the Wii Fit and physical activity questionnaire demonstrated that the participants had an abundance of experience with physical activity and sport. There was a great variation of interests in physical activity and sport between the participants that demonstrated individuality. A number of children outshined in soccer heading and this might have been because they were experienced in and enjoyed playing soccer. Participants one and two played soccer for two years, while participants three and six played for one year. Participant nine excelled in rhythm boxing which might have been due to his experience and interest in karate and Ukrainian dancing. Participant ten also did extremely well in rhythm boxing and expressed a great interest for this simulation which might have been due to his experience in Tai Kwon Do.

A Wii Fit Balance Intervention for Children with Movement and Balance Difficulties

It was anticipated that the participants would make first and second level advancements in the Wii Fit simulations throughout the entire intervention. As time progressed in the intervention, the participants' performance improved substantially; all children made first level advancements, and the majority made second level advancements. Progression in the simulations was specific to their strengths and weaknesses in the tasks. For instance, as shown in Figure 10, some children were exceptionally successful in hula hoop, while others struggled and became worse at the simulation as the intervention proceeded. Participant two had immense difficulty performing hula hoop, while participant ten excelled in the simulation. To achieve two stars in hula hoop, the performer must score at least 100 spins. As shown in Figure 10 on the left, participant two barely scored over 20 spins, and his scores were highly variable, with the highest score, 55 spins, occurring in the 12th session. On the other hand, participant ten achieved 100 spins in hula hoop by the second session and continued improving. This boy advanced from hula hoop by the third day.

Improvement in the Wii Fit balance simulations. As mentioned, the participants made substantial improvement in the Wii Fit balance simulations, showing advancement from 55.7% in basic step to 200% in ski jump, beginner, advanced, and expert tightrope walking, advanced soccer heading, table tilt, and beginner and advanced balance bubble (see Appendix Q for participants' improvement (%) in each simulation).

The three boys from the initial study (Krasniuk, MacLeod, Matthews, Twahir, & Taylor, 2010) showed comparable results to the children's performance in the Wii Fit simulations described in this study. The three boys displayed improvements between 44% in advanced soccer heading and 200% in beginner and advanced tightrope walking, and beginner balance bubble.

Qualitative analysis of participants' performance in the Wii Fit balance simulations. The visual representations of the participants' performance on the majority of Wii Fit simulations further demonstrated how the children improved and learned throughout the intervention by becoming more consistent, persistent, and adaptable in the simulations (Magill, 2004, p. 193-194). Figure 11 illustrates that the participants' peak results in the trend lines of hula hoop involved the ones who advanced onto more difficult simulations, and consequently the children who advanced were the ones who improved. Once those participants advanced onto other simulations and were not performing the predetermined ones anymore, the trend lines showed a decrease in values, as the children remaining in the original simulations were the ones still learning how to perform the movements.

A different trend was shown when scrutinizing the children's performance in beginner soccer heading (see Figure 12). All participants advanced from beginner soccer heading by the 15th session, with five advancing before the sixth, four before the 11th, and the last boy on the

15th. The trend line demonstrated that the mean score increased every session, but, the variability increased as well. An increase in mean scores and variability suggested that as the sessions progressed, the remaining children performing beginner soccer heading were still learning and improving in the simulation, but were not consistent in the scores on each trial. The children who already advanced displayed less variability because they performed beginner soccer heading more consistently and thus achieved the recommended scores quicker, which was demonstrated in the trend line between sessions 4 and 11. The scores in the trend line between days 4 and 11 represented more consistency, persistence, and adaptability in the children's movement patterns during the simulation. More adaptability was demonstrated in the participants' performances when their scores remained relatively consistent even though each trial of soccer heading was different. For example, the beginning trial of soccer heading might start with a ball coming from the left, while another trial with a ball coming from the right. Improved adaptability was also shown in the children's performance when they advanced onto more difficult simulations and performed well in them by meeting the criteria. The trend line revealed that there was a slight decrease in scores after the 11th session, which illustrated that the last boy's scores were lower than those of the other participants' who had already advanced on the simulation.

A last trend that appeared different from the others was shown in advanced ski slalom (see Figure 13). Eight of the nine participants performed advanced ski slalom from the sixth session until the 19th session and illustrated no change in scores and low variability throughout the intervention. In the 20th session there was high variability shown which was from the last participant who had never performed the simulation until then. This trend either showed that advanced ski slalom was too difficult for the participants to perform or that the participants already reached their peak performance and that was less than the requirements to advance onto snowboard slalom. The small variability in scores shown throughout the intervention, except for the 20th session, suggested that the children had already reached their peak performance in the simulation.

Where do the children fit in Fitts and Posner's stages of learning? As previously mentioned, the participants showed that they experienced difficulty at the beginning of the intervention on understanding how the Wii board worked and on performing the simulations, and therefore, were in the cognitive stage of Fitts and Posner's stages of learning. They spent most of their time problem-solving to determine how to perform the simulations and be successful, and this was shown by the highly variable and inconsistent mean scores they obtained every session. In the visual representations of the participants' performance in the simulations, the error bars displayed more variability at the beginning of the simulations. This pattern demonstrated that the participants had inconsistent results at the introduction of the simulations.

Once the children gained some experience from practicing the simulations and had some assistance from the researcher, they became more successful and transferred into the associative stage. By approximately the third session of performing the simulations, the participants advanced into more difficult simulations. The participants were quicker to respond to stimuli and did not have to think about what to do when they were presented to them, demonstrated by the lower variability in scores and improvement in mean scores. There were fewer detrimental errors made to their performance.

Most children did not reach the autonomous stage. The participants scored between one and two stars on average when there was a possibility of scoring up to four stars. Although, participants that did advance show lower variability in scores, the sample overall illustrated a considerable amount of variability in scores in the simulations throughout the intervention, shown qualitatively by the visual representations. Some children did not detect or correct their own errors and instead, became frustrated with the simulations or tried to distract themselves and the researchers from performing them.

Based on the task difficulty some of the participants experienced at the beginning of the intervention, in addition to the qualitative inspection of their results on the simulations, the Wii Fit program may have been too advanced for some of the younger children to understand and perform correctly. A limitation to the Wii Fit is that the task difficulty of the simulations cannot be lowered any more than its beginner levels. To help control this limitation, the researcher assisted the participants who had difficulty performing and understanding the simulations. Future research should be carefully planned to adapt task difficulty levels to meet participants' capabilities.

Effects of the Wii Fit on Motor Competence of Children with Movement and Balance Difficulties

The non-significant, one-factor repeated measures analysis of TISs, that computed small effects, did not support the hypothesis that the participants would show significant improvement on TISs at the post-test, and display more difficulty on the MABC tasks at the wash-out assessment. On the other hand, the significant differences in TISs, with large effects, from pre- to post-test, with mean TISs showing decreases at post-test, suggested that the participants did improve their performance after the intervention. The children's improvement in TISs at the post-test may have been from the static and dynamic balance (TBS) subsection of the MABC, which clearly changed.

The variability in the sample may have affected the participants' TIS results. Nine of the participants decreased their TISs at the post-test, showing that they improved their performance on the MABC tasks, while, one boy increased his TIS at the post-test, indicating that he had more difficulty performing the tasks. At the wash-out assessment, eight participants increased their TISs and two decreased their TISs. At each assessment, some of the participants' performances illustrated large changes in TISs (e.g., 19 to 13), while others performances showed minimal changes in TISs (e.g., 21.5 to 20.0).

Effects of the Wii Fit on Static and Dynamic Balance of Children with Movement and Balance Problems

It was anticipated that the children's static and dynamic balance, measured by the TBS, would show significant improvement at the post-test, and more difficulty at the wash-out assessment. Results of this study supported this hypothesis. The significant decreases in TBSs, and large effects, from the pre- to post-test demonstrated that the participants' performance on the static and dynamic balance tasks of the MABC improved after the intervention. The non-significant dependent samples *t*-test of TBSs from the post-test to the wash-out assessment showed that the children maintained their balance status, which may have been from the wash-out period not being long enough for the children to "wash-out" the effects of the intervention.

Similar results were demonstrated for one boy in the preliminary study by Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010). Krasniuk et al reported balance improvement in one boy; no changes in TBSs for another boy; more difficulties in balance tasks for the third boy. The boy who experienced no changes in TBS did not have balance problems and attained perfect scores. It was suggested that the third boy had more difficulty performing the balance tasks of the MABC because he moved up an age band and experienced great difficulty performing the different tests. Although the group in the current study showed significant improvement in balance performance after the intervention, measured by the TBS, the variability displayed in the preliminary study was comparable to that of the children in this sample, and both studies illustrated the heterogeneity of the population of DCD.

Effects of the Wii Fit on Postural Adaptation of Children with Movement and Balance Difficulties Measured by COP

It was hypothesized that at the post-test, the children would significantly increase their AP sway, ML sway, area of sway, and path length of the balance space task, suggesting an improvement in postural adaptation, and at the wash-out test, the participants would decrease those measures, showing that these effects were due to the intervention. Surprisingly, the opposite of what was anticipated occurred. None of the COP measures showed significant differences and all computed small effects, as analyzed by repeated measures procedures. Although non-significant, only the mean AP sway at post-test displayed an increasing trend, which was what was hypothesized. The remaining COP measures illustrated decreases in sway, and increases in sway at the wash-out assessment.

It was speculated from the effect size calculated from the path length repeated measures analysis that some change had occurred. The medium effect computed from the non-significant dependent samples *t*-test supported this conjecture. The decreases in sway may be from the children making fewer adjustments at post-test.

Qualitative Inspection of Individual Data

Interestingly, from inspecting the participants' individual data, a developmental pattern was shown. A transition in adult-like postural adaptation appears in children around the ages of 7 to 10 years, but may not reach adult levels until 11 years or as late as adolescence (Assaiante, Mallau, Viel, Jover, & Schmidtz, 2005; de Graaf-Peters, Blauw-Hospers, Dirks, Bakker, Bos, & Hadders-Algra, 2007; Schmid, Conforto, Lopez, Renzi, & D'Alessio, 2005; Streepey & Angulo-Kinzler, 2002). Since three of the older children showed an increase in sway measures, during the post-test balance space task, these participants displayed mature enough levels of postural adaptation for improvement to be possible as a result of the intervention. Meanwhile, the remaining seven participants could be characterized at a developmental level that did not yet permit increases in postural adaptation. Future research should use different age groups to compare the effects of a Wii Fit intervention on postural adaptation of older and younger children.

In addition to this speculation, from the qualitative representation of the participants' performance on the balance space task at each assessment, the three older participants showed more smooth and controlled movement, with less need for adjustment. Meanwhile, the remaining seven children experienced more difficulty, shown by their jerky movement, with more adjustment needed, and less control. Figure 20 supports this argument by comparing an older boy's performance of the balance space task to a younger girl's performance. The older boy displayed smooth and controlled movement with less adjustment made. He increased in all sway measures at the post-test and decreased in only AP sway at the wash-out test. Meanwhile, the younger girl showed more difficulty in her performance, with less control and more adjustments made. In contrast to the older boy, she decreased in all sway measures at the post-test and increased in all sway measures at the wash-out test.

To further support the developmental pattern supposition, the three older participants' individual data coincides with the increase in AP sway and area of sway of the post-test balance space task, shown in the three 9-to-11 year old boys in the preliminary study. Since the three boys in the preliminary study were between the ages of 9 and 11 years, their level of postural adaptation was mature enough for improvement to be attainable during the intervention.

Thus far, the current study and preliminary research have only examined the effects on postural adaptation of children with movement and balance problems. Most literature on the effects of Wii Fit interventions has investigated different aspects of balance of persons with difficulties, due to stroke and cerebral palsy for example, which makes it difficult for generalization. Also, other than this study, Deutsch, Robbins, Morrison, and Bowlby (2009) were the only researchers to implement a wash-out period and test to examine if intervention was needed in the participants' lifestyle to maintain any gains. To support inferences made in this study that can be generalized to children with movement and balance difficulties, future research should make use of a control group and clear age and subtype membership. As well, a universal assessment tool for balance and postural adaptation should be implemented to add consistency to researchers' methods

Effects of the Wii Fit Balance Program on Subjective Well-being

Responses from the social validation survey revealed that the participants gained positive physical and psychological benefits from partaking in the Wii Fit balance intervention. As mentioned a couple of times already, children with DCD tend not to participate in physical activities that they do not do well in because they are unsuccessful, and in turn lack competence and motivation (Cantell & Kooistra, 2002, p. 29-31). For an intervention to be effective for children with DCD, that is, the children are successful, competent, and motivated, an approach that provides "optimally challenging, success-oriented and joyful experiences" must be implemented (Rose, Larkin, & Berger, 1998, p. 325). The majority of the participants said that their life had changed since they had been in the Wii Fit program, with improved balance and health, and they felt better about themselves. Children also said they would participate in the intervention again and offer the program to their friends because it was fun and it improved balance. Based on these responses the intervention positively affected the participants' competence, motivation, and success in balance.

Limitations and Recommendations

As with all research, there were some limitations to this study. The researcher's original proposal for this intervention was to employ a cross-over design, with two groups involving children with movement and balance difficulties. One group would perform the intervention, while the other group would act as a control, on a waiting list. Once the intervention was complete, the children on the waiting list would then perform the intervention, and the other participants would act as the control. Due to the limited population of DCD, and even more limited subtype of children with DCD who have balance problems, there were not enough children to have two groups. In addition, the children who were interested in the study wanted to be part of the Wii Fit intervention. As a result, there was no control group to examine if the changes in measures were from training with the Wii Fit. To help control this limitation, there was a wash-out period and assessment, which meant that the participants acted as their own controls (Jones & Kenward, 2003). Wash-outs add their own complications because of the necessity for an additional assessment and the danger of increased activity between post-test and wash-out. For future studies, a Wii Fit intervention could incorporate a control or comparison group.

Although the intervention was highly structured and progressed according to individual success, participants experienced different levels of task. Some of the children exhibited great difficulty in performing the tasks in both testing and training conditions. To help control this limitation, the researcher assisted these children by demonstration and verbal instruction, and then the children practiced. Future research should carefully plan how tasks can be adapted to meet all participants' capabilities.

The responses from the social validation survey showed that six participants exercised more during the study, which may have affected their performance in both testing and training. To help control this limitation, at the beginning of the study, both participants and parents signed a consent form which asked the children to not participate in any form of Wii Fit or balance training, but otherwise to not alter their daily activities. Also, the researcher asked the participants and parents to report any form of balance training or Wii Fit practice the children may have done during the study. Based on these factors, the children who reported that they exercised more during the study most likely did not participate in any form of training that would affect their results.

Although the implementation of the Wii Fit training was intuitively pleasing because children are generally motivated to continue practicing for an extended period of time, the requirements of the balance space task were quite different from the Wii Fit simulations. Instead, the goals and objectives in the simulations required the children to control their movement by directing and placing their body weight on the Wii board. For example, to soccer head a ball from the left, while standing on the board, participants would place their weight on their left foot. Compared to the balance space task, this movement turned out to be minimal, and as a result might have affected how the children performed at the post-test. During the intervention the participants learned that to be able to control their movement and succeed in the simulations, they did not have to make large movements, such as leaning as far as they could in any direction. This level of adaptation was only in the repertoire of the three older participants. For future studies, researchers should employ assessments and sample sizes that can clearly demonstrate these developmental characteristics.

Although the pilot study (Krasniuk & Taylor, 2010) suggested very high internally reliable and concurrently valid measures of COP of the balance space task of healthy adults, when the Wii board was placed on the force plate, the Wii board may have desensitized the sway measures. As the performer stood on the Wii board placed on the force plate, the board increased his or her base of support, as the force plate measured and analyzed the performance of the balance space task. Also, the base of the Wii board was raised off the floor, as the four corners were the only parts of the board touching the force plate surface. From these two factors, the sway measures analyzed may have been centralized during the performance of the balance space task. Descriptive statistics (means and standard deviations) (see Appendix R) from the pilot study results suggested that when the participants stood on the Wii board placed on the force plate, smaller means and standard deviations of COP measures were computed. These results implied that there was some desensitization in sway measures that may have constricted them to the centre of the board, but, pilot study results justified that very high internally reliable and concurrently valid measures of COP were still produced for healthy adults. In this study, placing the Wii board on the force plate added control in measurement and maximized similarity between testing and training protocols, however, future research should test this protocol on typically developing children, and furthermore, children with DCD to support this justification.

Conclusion

This study examined the effects of a 20-session Wii Fit intervention on postural adaptation of 10 children with movement and balance difficulties and showed improvement was made in some areas of balance. The participants enjoyed and made considerable progress in the Wii Fit simulations throughout the entire intervention, similar to preliminary research by Krasniuk, MacLeod, Matthews, Twahir, and Taylor (2010). As predicted, the children's functional balance levels (TBSs) significantly improved with large effects after the intervention. Conversely, motor competence levels (TISs) were shown to be non-significant with small effects ($\eta p^2 = .24$); however, with the significant dependent samples *t*-test analysis that showed large effects, it was suggested that the intervention had some effects on the participants' performance which would imply improvement.

As well, changes in postural adaptation levels (AP sway, ML sway, area of sway, and path length) of the balance space task were shown to be non-significant with small effects. Interesting findings from these results were that AP sway was the only measure to show an increasing trend at post-test, which was what was hypothesized. The remaining three measures showed a decreasing trend at post-test. The speculation that the intervention had some effects on the children's performance of the balance space task measured by path length, coupled with the qualitative analysis of plots suggests that the children made fewer adjustments at post-test. This result may coincide with the children's improvement on the balance tasks of the MABC.

A developmental pattern was conjectured in this study. Three of the older boys displayed more developed levels of postural adaptation, shown by increased sway at post-test, as predicted, and more smooth and controlled movement, with less need for adjustment, illustrated by the visual analysis of their performance in the balance space task. The remaining seven children did not improve in postural adaptation, shown by decreased sway at post-test. As well, their visual representations showed less control, with more jerky movement and adjustments made in the balance space task.

During the intervention, the children learned that they could make minimal movement on the Wii Fit simulations and be successful, as the avatar on the screen was controlled by the amount of weight the participants placed on the Wii board. In contrast, the participants were unable to adapt to the requirement of moving to their stability limits in the balance space task. This same developmental difference was mirrored in the way that the children interacted both with the Wii tasks and the balance space measures. Different levels of task difficulty were evident in both the testing and the training period. In the testing, some of the younger participants, had more difficulty than others performing and understanding the balance space task and had more demonstration, instruction, and practice on the task. As well, during the training period some of the younger participants experienced more difficulty performing and comprehending the simulations and had to receive instruction from the researcher on how to perform the movement. These difficulties were in line with their scores on the TIS and as such not unexpected.

The social validation survey revealed that the participants felt better about themselves, feeling healthier and having better balance. Weaknesses in balance and manual dexterity, and strengths in ball skills were revealed in the sample, and although generalizations cannot be made from this study, the results may be applied to this subtype of DCD. This balance intervention study added to the very small, but new and expanding literature on training with the Wii Fit, involving children with movement and balance difficulties. This study was the first to use a more controlled research design, and have a larger, well-defined and homogeneous sample. Future research should incorporate control and/or comparison groups using different age groups; further investigate task difficulty as a variable affecting change; and incorporate virtual reality in the testing protocols to add control between testing and training.

References

Allen, D., & Taylor, M. J. (2001). *The effects of tai chi on balance and mobility in older women who are at various risk levels for falls*. Poster presented at the International Symposium on Adapted Physical Activity, Vienna, Austria.

American Psychiatric Assocation. (2000). *Diagnostic and statistical manual of mental disorders.* (4^{th} ed, pp. 57-59). Washington, DC: Author.

Assaiante, C., Mallau, S., Viel, S., Jover, M., & Schmitz, C. (2005). Development of postural control in healthy children: A functional approach. *Neural Plasticity, 12*, 109-118.

Ayyash, H. F., & Preece, P. M. (2003). Evidence-based treatment of motor co-ordination disorder. *Current Paediatrics, 13*, 360-364.

Blaszczyk, J. W., Hansen, P. D., & Lowe, D. L. (1993). Postural sway and perception of the upright stance stability borders. *Perception, 22*, 1333-1341.

Burdea, G. C. (2003). Virtual rehabilitation – benefits and challenges. *Methods of Information in Medicine, 42*, 519-523. Retrieved from, http://sciencedirect.com

Burke, J. W., McNeill, M. D. J., Charles, D. K., Morrow, P. J., Crosbie, J. H., & McDonough, S. M. (2009). Optimising engagement for stroke rehabilitation using serious games. *The Visual Computer: International Journal of Computer Graphics, 25*, 1085-1099. doi: 10.1007/s00371-009-0387-4

Cantell, M. H., & Kooistra, L. (2002). Chapter 2: Long-term outcomes of developmental coordination disorder. In S. A. Cermak & D. Larkin (Eds.), *Developmental coordination disorder* (pp. 23-38). Canada: Delmar Thomson Learning.

Cantell, M. H., Smyth, M. M., & Ahonen, T. P. (1994). Clumsiness in adolescence: Educational, motor, and social outcomes of motor delay detected at 5 years. *Adapted Physical Activity Quarterly, 11*, 115-129.

Cermak, S. A., Gubbay, S. S., & Larkin, D. (2002). Chapter 1: What is developmental coordination disorder? In S. A. Cermak & D. Larkin (Eds.), *Developmental coordination disorder* (pp. 7-13). Canada: Delmar Thomson Learning.

Cohen, J. (1992). Statistics a power primer. *Psychology Bulletin, 112*, 155-159.

Davis, W. E., & Burton, A. W. (1991). Ecological task analysis: Translating movement behavior theory into practice. *Adapted Physical Activity Quarterly, 8*, 154-177.

Deconinck, F. J., De Clercq, D., Van Coster, R., Oostra, A., Dewitte, G., Savelsbergh, G. J., … Lenoir, M. (2008). Sensory contributions to balance in boys with and without developmental coordination disorder. *Adapted Physical Activity Quarterly, 25*, 17-35.

de Graaf-Peters, V. B., Blauw-Hospers, C. H., Dirks, T., Bakker, H., Bos, A. F., & Hadders-Algra, M. (2007). Development of postural control in typically developing children and children with cerebral palsy: Possibilities for intervention? *Neuroscience and Biobehavioral Reviews, 31*, 1191-1200.

Deutsch, J. E., Borbely, M., Filler, J., Huhn, K., & Guarrera-Bowlby, P. (2008). Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. *Physical Therapy, 88*, 1196-1207.

Deutsch, J. E., Robbins, D., Morrison, J., & Bowlby, P. G. (2009). Wii-based compared to standard of care balance and mobility rehabilitation for two individuals post-stroke. Retrieved from, http://IEEE Xplore database

Dewey, D., & Kaplan, B. J. (1994). Subtyping of developmental motor deficits. *Developmental Neuropsychology, 10*, 265-284.

Fitts, P. M., & Posner, M. I. (1967). *Human performance*. Belmont, CA: Brooks/Cole.

Geuze, R. H. (2003). Static balance and developmental coordination disorder. *Human Movement Science, 22*, 527-548.

Geuze, R. H. (2005). Postural control in children with developmental coordination disorder. *Neural Plasticity, 12*, 183-196.

Geuze, R. H., & Börger, H. (1993). Children who are clumsy: Five years later. *Adapted Physical Activity, 10*, 10-21.

Geuze, R. H., de Jong, F. J., & Taylor, M. J. (1999). *Balance control of children with DCD*. Poster presented at the Biennial Conference on Children with a Developmental Coordination Disorder, Groningen, Netherlands.

Henderson, S. E., & Sugden, D. (1992). *Movement assessment battery for children manual*. London, England: The Psychological Corporation.

Hillier, S. (2007). Intervention for children with developmental coordination disorder: A systematic review. *The Internet Journal of Allied Health Sciences and Practice, 5*, 1-11. Retrieved from, http://ijahsp.nova.edu/articles/vol5num3/hillier.pdf

Hoare, D. (1994). Subtypes of developmental coordination disorder. *Adapted Physical Activity Quarterly, 11*, 158-169.

Holden, M. K. (2005). Virtual environments for motor rehabilitation: Review. *Cyber Psychology & Behaviour, 8*, 187-211. Retrieved from, http://sciencedirect.com

Inder, J. M., & Sullivan, S. J. (2005). Motor and postural response profiles of four children with developmental coordination disorder. *Pediatric Physical Therapy, 17*, 18-29.

Jones, B., & Kenward, M. G. (2003). *Design and analysis of cross-over trials*. (2nd ed.). Washington, DC: Chapman and Hall.

Kaplan, B. J., Wilson, B. N., Dewey, D., & Crawford, S. G. (1998). DCD may not be a discrete disorder. *Human Movement Science, 17*, 471-490.

Kirby, A., Sugden, D., Beveridge, S., & Edwards, L. (2008). Developmental co-ordination disorder (DCD) in adolescents and adults in further and higher education. *Journal of Research in Special Educational Needs, 8*, 120-131.

Krasniuk, S. M., MacLeod, J., Matthews, S., Twahir, J., & Taylor, M. J. (2010). *The effects of the Wii Fit balance games on static and dynamic balance of 9-11 year old boys with developmental coordination disorder.* Paper presented at the North American Federation of Adapted Physical Activity Symposium, Riverside Valley, California.

Krasniuk, S. M., & Taylor, M. J. (2010). *Comparison of centre of pressure (COP) measures obtained on the Wii Fit balance board and the AMTI force plate: A pilot study.* Poster presented at the North American Federation of Adapted Physical Activity Symposium, Riverside Valley, California.

Macnab, J. J., Miller, L. T., & Polatajko, H. J. (2001). The search for subtypes of DCD: Is cluster analysis the answer? *Human Movement Science, 20*, 49-72.

Magill, R. A. (2004). *Motor learning and control*. New York, NY: McGraw-Hill.

Mandich, A. D., Polatajko, H. J., Macnab, J. J., & Miller, L. T. (2001). Treatment of children with developmental coordination disorder: What is the evidence? *Physical & Occupational Therapy in Pediatrics, 20*, 51-68.

Marchiori, G. E., Wall, A. E., & Bedingfield, W. (1987). Kinematic analysis of skill acquisition in physically awkward boys. *Adapted Physical Activity Quarterly, 4*, 305-315.

Mauchly, J. W. (1940). Significance test for sphericity of a normal n-variate distribution. *The Annals of Mathematical Statistics, 11*, 204-209.

Missiuna, C., & Mandich, A. (2002). Chapter 15: Integrating motor learning theories into practice. In S. A. Cermak & D. Larkin (Eds.), *Developmental coordination disorder* (pp. 221-233). Canada: Delmar Thomson Learning.

Missiuna, C., Moll, S., King, G., Stewart, D., & Macdonald, K. (2008). Life experiences of young adults who have coordination difficulties. *Canadian Journal of Occupational Therapy, 75*, 157-166.

Missiuna, C., Rivard, L., & Pollock, N. (2004). They're bright but can't write: Developmental coordination disorder in school aged children. *TEACHING Exceptional Children Plus:* 1, Article 3. Retrieved from, http://scholarship.bc.edu/education/tecplus/vol1/iss1/3

Miyahara, M. (1994). Subtypes of students with learning difficulties based upon gross motor functions. *Adapted Physical Activity Quarterly, 11*, 368-382.

Newell, K. M. (1986). Constraints on the development of coordination. In M. G. Wade & H. T. A. Whiting (Eds.), *Motor development in children: Aspects of coordination and control* (pp. 341-360). Boston, MA: Martinus Nijhoff.

Newell, K. M., & Jordan, K. (2007). Chapter 1: Task constraints and movement organization: A common language. In W. E. Davis, & G. D. Broadhead (Eds.), *Ecological task analysis and movement* (pp.12-13). Windsor, Canada: Human Kinetics.

Nintendo, (2008). *Wii Fit* [video game]. Canada: author.

Nintendo, (2010). *About the Wii console*. Retrieved November 17, 2010, from, http://www.nintendo.com/wii/console.

Nitz, J. C., Kuys, S., Isles, R., & Fu, S. (2010). Is the Wii Fit a new-generation tool for improving balance, health, and well-being? A pilot study. *Climacteric, 5*, 487-491.

Pasch, M., Berthouze, B., van Dijk, E. M. A. G., & Nijholt, A. (2008). *Motivations, strategies, and movement patterns of video gamers playing Nintendo Wii boxing*. In Facial and bodily expressions for control and adaptation of games (ECAG), Amsterdam, the Netherlands. Retrieved from, http://eprints.eemcs.utwente.nl/13240/

Polatajko, H. J., & Cantin, N. (2010). Exploring the effectiveness of occupational interventions, other than the sensory integration approach, with children and adolescents experiencing difficulty processing and integrating sensory information. *American Journal of Occupational Therapy, 64*, 415-429.

Przysucha, E. P., & Taylor, M. J. (2004). Control of stance and developmental coordination disorder: The role of visual information. *Adapted Physical Activity Quarterly, 21*, 19-33.

Przysucha, E. P., Taylor, M. J., & Weber, D. (2008). The nature and control of postural adaptations of boys with and without developmental coordination disorder. *Adapted Physical Activity Quarterly, 25*, 1-16.

Riach, C. L., & Starkes, J. L. (1993). Stability limits of quiet standing postural control in children and adults. *Gait & Posture, 1*, 105-111.

Rose, B., Larkin, D., & Berger, B. G. (1998). The importance of motor coordination for children's motivational orientations in sport. *Adapted Physical Activity Quarterly, 15*, 316-327.

Schmid, M., Conforto, S., Lopez, L., Renzi, P., & D'Alession, T. (2005). The development of postural strategies in children: A factorial design study. *Journal of NeuroEngineering and Rehabilitation, 30*, 2-29.

Schmidt, R. A., & Wrisberg, C. A. (2004). *Motor learning and performance* (3rd ed.). Windsor, Canada: Human Kinetics.

Shumway-Cook, A., Horak, F., & Black, F. O. (1987). A critical examination of vestibular function in motor-impaired learning disabled children. *International Journal of Pediatric Otorhinolaryngology, 14*, 21-30.

Shumway-Cook, A., & Woollacott, M. (2012). *Motor control translating research into clinical practice*. (4th ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Streepey, J. W., & Angulo-Kinzler, R. M. (2002). The role of task difficulty in control of dynamic balance in children and adults. *Human Movement Science, 21*, 423-438.

Sugarman, H., Burstin, A., Weisel-Eichler, A., & Brown, R. (2009). Use of the Wii Fit system for the treatment of balance problems in the elderly: A feasibility study. *Virtual Rehabilitation International Conference,* 111-116. doi: 10.1109/ICVR.2009.5174215

Sugden, D. A., & Chambers, M. E. (1998). Intervention approaches and children with developmental coordination disorder. *Pediatric Rehabilitation, 2*, 139-147.

Usui, N., Maekawa, K., & Hirasawa, Y. (1995). Development of the upright postural sway of children. *Developmental Medicine and Child Neurology, 37*, 985-996.

Van Waelvelde, H., De Weerdt, W., De Cock, P., & Smits-Engelsman, B. C. M. (2004). Aspects of the validity of the movement assessment battery for children. *Human Movement Science, 23*, 49-60.

Van Waelvelde, H., Peersman, W., Lenoir, M., & Smits Engelsman, B. C. M. (2007). The reliability of the movement assessment battery for children for preschool children with mild to moderate motor impairment. *Clinical Rehabilitation, 21*, 465-470.

Visser, J. (2003). Developmental coordination disorder: a review of research on subtypes and comorbidities. *Human Movement Science, 22*, 479-193.

Wescott, S. L., & Burtner, P. (2004). Postural control in children: Implications for pediatric practice. *Physical & Occupational Therapy in Pediatrics, 24*, 5-55.

Whitall, J., Sanghvi, S., & Getchell, N. (2007). Chapter 4: Perception-action judgments in children with learning disabilities. In W. E. Davis & G. D. Broadhead (Eds.), *Ecological task analysis and movement* (pp. 83-95). Champaign, IL: Human Kinetics.

Wilson, P. H. (2005). Practitioner review: Approaches to assessment and treatment of children with DCD: An evaluative review. *Journal of Child Psychology and Psychiatry, 46*, 806-823.

Winter, D. A. (1995). Human balance and posture control during standing and walking. *Gait & Posture, 3*, 193-214.

Winter, D. A., Patla, A. E., & Frank, J. S. (1990). Assessment of balance control in humans. *Medical Progress through Technology, 16*, 31-51.

Wolf, S. L., Barnhart, H. X., Ellison, G. L., & Coogler, C. E. (1997). The effect of tai chi quan and computerized balance training on postural stability in older subjects. *Physical Therapy, 77*, 371-381.

Woollacott, M. H., & Shumway-Cook, A. (1990). Changes in posture control across the life span – a systems approach. *Physical Therapy, 70*, 799-807.

Wright, H. C., & Sugden, D. A. (1996). The nature of developmental coordination disorder: Inter and intra group differences. *Adapted Physical Activity Quarterly, 13*, 358-374.

Yang, Y. & Taylor, M. J. (2010). *The benefits of a Taiji exercise intervention on balance, mobility and quality of life for people with cancer*. Paper presented at the European Federation of Adapted Physical Activity Conference, Jyväskylä, Finland.

Zwicker, J. G., Missiuna, C., & Boyd, L. A. (2009). Neural correlates of developmental coordination disorder: A review of hypotheses. *Journal of Child Neurology, 24*, 1273-1281.

Zwicker, J. G., Missiuna, C., Harris, S. R., & Boyd, L. A. (2010). Brain activation of children with developmental coordination disorder is different than peers. *Pediatrics, 126*, 678-686. doi: 10.1542/peds.2010-0059

Appendix A

Movement Assessment Battery for Children

RECORD FORM

MOVEMENT ABC

Movement Assessment Battery for Children

Compiled by Sheila E. Henderson and David A. Sugden

AGE BAND 2 **7–8 years**

Name .... Gender ....

Home address .... Date of test ....

.... Date of birth ....

.... Age ....

School .... Grade/class ....

....

Assessed by ....

Preferred hand (defined as the hand used to write with) ....

Other information ....

....

Published by The Psychological Corporation Limited, 24-28 Oval Road, London NW1 7DX.

Printed in the United Kingdom
ISBN 0 7491 0133 4

SUMMARY OF QUANTITATIVE DATA

MOVEMENT ABC CHECKLIST SCORE	_____ + _____ + _____ + _____ = _____	Motor score
MOVEMENT ABC TEST SCORE		
Manual Dexterity	_____ + _____ + _____ = _____	
Ball Skills	_____ + _____ = _____	
Static and Dynamic Balance	_____ + _____ + _____ = _____	
TOTAL IMPAIRMENT SCORE		☐

SUMMARY OF QUALITATIVE OBSERVATIONS

MANUAL DEXTERITY (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

BALL SKILLS (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

STATIC AND DYNAMIC BALANCE (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

PLACING PEGS — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Preferred hand	Nonpreferred hand
Trial 1	Trial 1 ....
Trial 2	Trial 2 ....

age 7	age 8	score	age 7	age 8
0–24	0–21	0 / 0	0–29	0–25
25–27	22–23	1 / 1	30–31	26–28
28–29	24	2 / 2	32–33	29–30
30–33	25–27	3 / 3	34–37	31–32
34–39	28–29	4 / 4	38–47	33–34
40+	30+	5 / 5	48+	35+

Item score

* Item score = (Preferred hand + Nonpreferred hand) ÷ 2

Qualitative observations

Body control/posture

- Does not look at board while inserting pegs ☐
- Holds face too close to task ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to pick up pegs ☐
- Exaggerates finger movements in releasing pegs ☐
- Does not use the supporting hand to hold board steady ☐
- Does *extremely* poorly with one hand (asymmetry striking) ☐
- Changes hands or uses both hands during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Misaligns pegs with respect to holes ☐
- Uses excessive force when inserting pegs ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐

Other

....

....

THREADING LACE — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....

score	age 7	age 8
0	0–20	0–20
1	21–22	21–22
2	23–24	23–24
3	25–28	25–28
4	29–43	29–39
5	44+	40+

Item score

Qualitative observations

Body control/posture

- Does not look at holes while inserting tip of lace ☐
- Holds materials too close to face ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to hold lace ☐
- Holds lace too far from tip ☐
- Holds lace too near tip ☐
- Finds it difficult to push tip with one hand and pull it through with the other ☐
- Changes threading hand during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Sometimes misses hole with tip of lace ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Gets muddled in the threading sequence ☐
- Goes too fast for accuracy ☐

Other

....

....

FLOWER TRAIL — MANUAL DEXTERITY

Quantitative data

Record **number of deviations**; **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....

Trial 2 ....

Hand used ....

score	age 7	age 8
0	0–2	0
1	3	1
2	4	2
3	5–6	3–6
4	7–10	7–9
5	11+	10+

Item score

Qualitative observations

Body control/posture

- Does not look at trail ☐
- Holds face too near paper ☐
- Holds head at an odd angle ☐

- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is *exceptionally* slow ☐
- Goes too fast for accuracy ☐

Other

....

....

ONE-HAND BOUNCE AND CATCH — BALL SKILLS

Quantitative data

Record **number of catches**; **R** for refusal; **I** for inappropriate

Preferred hand ....

Nonpreferred hand ....

Preferred hand age 7	Preferred hand age 8	score	Nonpreferred hand age 7	Nonpreferred hand age 8
9–10	10	0 / 0	8–10	9–10
8	9	1 / 1	7	8
7	8	2 / 2	6	7
6	7	3 / 3	5	6
4–5	5–6	4 / 4	4	5
0–3	0–4	5 / 5	0–3	0–4

*Item score

* Item score = (Preferred hand + Nonpreferred hand) ÷ 2

Qualitative observations

Body control/posture

- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐

- Holds hand out flat with fingers stiff as the ball rebounds ☐
- Tries to catch ball with hand facing downwards ☐
- Arm and hand do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐
- Does *extremely* poorly with one hand (asymmetry striking) ☐

- Body appears tense/rigid throughout ☐

Adjustments to task requirements

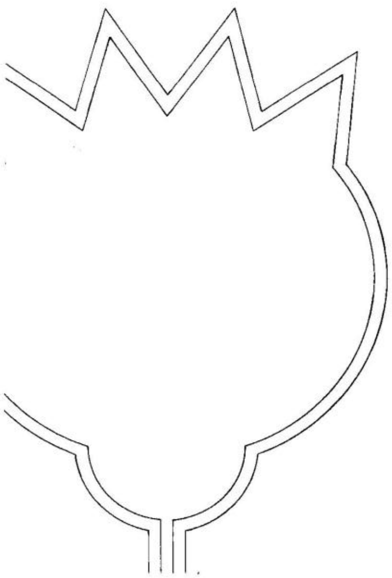
- Bounces ball too close to feet or too far away ☐
- Does not adjust body position for catching ☐
- Judges force of bounce poorly (too much or too little) ☐
- Does not adjust position of feet as necessary ☐
- Movements lack fluency ☐

Other

....

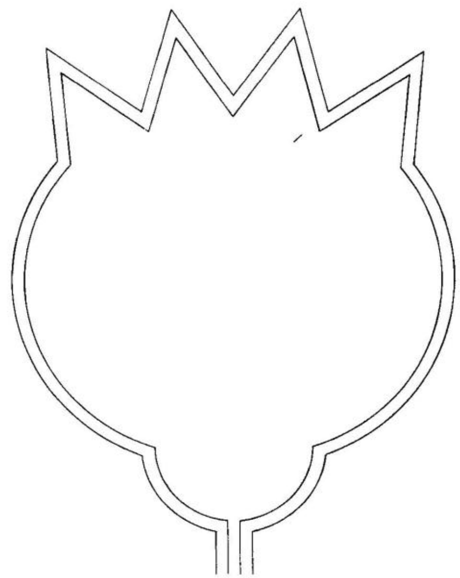
....

FLOWER TRAIL



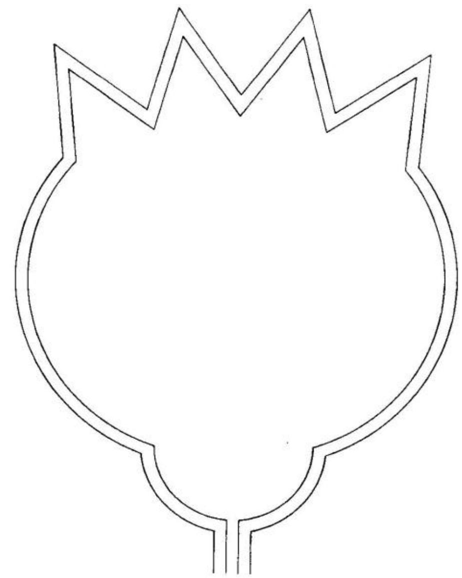
START HERE

FLOWER TRAIL



START HERE

FLOWER TRAIL



START HERE

.... | Name .... | Name ....

THROWING BEAN BAG INTO BOX — BALL SKILLS

Quantitative data

Record **number of goals**; **R** for refusal; **I** for inappropriate

....

Hand used ....

score	age 7	age 8
0	6–10	6–10
1	5	5
2	4	4
3	3	3
4	2	2
5	0–1	0–1

Item score

Qualitative observations

Body control/posture

- Does not keep eyes on target ☐
- Does not use a pendular swing of the arm ☐
- Does not follow through with throwing arm ☐
- Releases bean bag too early or too late ☐
- Changes hands from trial to trial ☐
- Trunk and hips do not rotate as throwing arm comes forward ☐
- Over-rotates and loses balance ☐

Adjustments to task requirements

- Errors are consistently to one side of the box (asymmetry striking) ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- Movements lack fluency ☐

Other

....

....

STORK BALANCE — STATIC BALANCE

Quantitative data

Record **time balanced** (secs); **R** for refusal; **I** for inappropriate

Preferred leg

Trial 1 ....

Trial 2 ....

Nonpreferred leg

Trial 1 ....

Trial 2 ....

Preferred leg age 7	Preferred leg age 8	score	Nonpreferred leg age 7	Nonpreferred leg age 8
12–20	20	0 / 0	11–20	19–20
9–11	13–19	1 / 1	8–10	11–18
7–8	9–12	2 / 2	5–7	9–10
6	6–8	3 / 3	4	6–8
4–5	4–5	4 / 4	3	4–5
0–3	0–3	5 / 5	0–2	0–3

* Item score

* Item score = (Preferred leg + Nonpreferred leg) ÷ 2

Qualitative observations

Body control/posture

- Does not hold head and eyes steady ☐
- Looks down at feet ☐
- Makes no or few compensatory arm movements to help maintain balance ☐
- Exaggerated movements of arms and trunk disrupt balance ☐
- Body is held rigid ☐
- Sways wildly to try to maintain balance ☐
- Does *extremely* poorly on one leg (asymmetry striking) ☐

Other

....

JUMPING IN SQUARES — DYNAMIC BALANCE

Quantitative data

Record **number of correct jumps**; **F** for failure; **R** for refusal; **I** for inappropriate.

Trial 1 ....
Trial 2 ....
Trial 3 ....

score	age 7	age 8
0	5	5
1	–	–
2	4	4
3	3	3
4	2	2
5	0–1	0–1

Item score

Qualitative observations

Body control/posture

Does not use arms to assist jump ☐
Arms swing out of phase with legs ☐
Arm movements are exaggerated ☐

Body appears rigid/tense ☐
Body appears limp/floppy ☐

Makes no preparatory crouch ☐
Lacks springiness/no push-off from feet ☐
Uneven take-off and loss of symmetry in flight and landing ☐
Jumps with stiff legs/on flat feet ☐
Stumbles on landing ☐

Adjustments to task requirements

Does not combine upward and forward movements effectively ☐
Uses too much effort ☐
Movements are jerky ☐

Other

....

....

HEEL-TO-TOE WALKING — DYNAMIC BALANCE

Quantitative data

Record **number of correct steps**; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....
Trial 3 ....

score	age 7	age 8
0	13–15	15
1	8–12	14
2	7	13
3	5–6	10–12
4	3–4	7–9
5	0–2	0–6

Item score

Qualitative observations

Body control/posture

Does not look ahead ☐
Does not keep head and eyes steady ☐

Does not compensate with arms to maintain balance ☐
Exaggerated arm movements disrupt balance ☐

Body appears rigid/tense ☐
Body appears limp/floppy ☐

Is very wobbly when placing feet on line ☐
Sways wildly to try to maintain balance ☐

Adjustments to task requirements

Goes too fast for accuracy ☐
Individual movements lack smoothness and fluency ☐
Sequencing of steps is not smooth/pauses frequently ☐

Other

....

....

MOVEMENT ABC

Movement Assessment Battery for Children

Compiled by Sheila E. Henderson and David A. Sugden

AGE BAND 3 9–10 years

Name..	Gender ....
Home address	Date of test ....
....	Date of birth ....
....	Age ....
School	Grade/class ....
....	
Assessed by	
Preferred hand (defined as the hand used to write with)	
Other information	
....	

Published by The Psychological Corporation Limited, 24-28 Oval Road, London NW1 7DX.

Printed in the United Kingdom
ISBN 0 7491 0134 2

SUMMARY OF QUANTITATIVE DATA

MOVEMENT ABC CHECKLIST SCORE									Motor score
		+		+		+		=	
MOVEMENT ABC TEST SCORE									
Manual Dexterity				+		+		=	
Ball Skills						+		=	
Static and Dynamic Balance				+		+		=	
TOTAL IMPAIRMENT SCORE									

SUMMARY OF QUALITATIVE OBSERVATIONS

MANUAL DEXTERITY (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

BALL SKILLS (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

STATIC AND DYNAMIC BALANCE (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

SHIFTING PEGS BY ROWS — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Preferred hand
Trial 1 ....
Trial 2 ....

Nonpreferred hand
Trial 1 ....
Trial 2 ....

age 9	age 10	score	age 9	age 10
0–12	0–12	0 / 0	0–14	0–13
13	13	1 / 1	15	14
14	–	2 / 2	16	15
15	14	3 / 3	17	16
16–17	15–16	4 / 4	18–19	17
18+	17+	5 / 5	20+	18+

Item score*

* Item score = (Preferred hand + Nonpreferred hand) ÷ 2

Qualitative observations

Body control/posture

- Does not look at board while inserting pegs ☐
- Holds face too close to task ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to pick up pegs ☐
- Exaggerates finger movements in releasing pegs ☐
- Does not use the supporting hand to hold board steady ☐
- Does *extremely* poorly with one hand (asymmetry striking) ☐
- Changes hands or uses both hands during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Misaligns pegs with respect to holes ☐
- Uses excessive force when inserting pegs ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐

Other

....

....

THREADING NUTS ON BOLT — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....

score	age 9	age 10
0	0–20	0–17
1	21–23	18–19
2	24	20–21
3	25–28	22
4	29–33	23–24
5	34+	25+

Item score

Qualitative observations

Body control/posture

- Does not look at nuts and bolt while threading ☐
- Holds materials too close to face ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to pick up nuts ☐
- Does not hold the bolt steady to receive nuts ☐
- Finds it difficult to coordinate hand movements ☐
- Changes threading hand during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/ fidgets ☐

Adjustments to task requirements

- Does not align the nuts correctly on bolt ☐
- Tries to force nut when misaligned ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐

Other

....

....

FLOWER TRAIL — MANUAL DEXTERITY

Quantitative data

Record **number of deviations**; **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....
Hand used ....

score	age 9	age 10
0	0	0
1	1	1
2	-	-
3	2	2
4	3	-
5	4+	3+

Item score

Qualitative observations

Body control/posture

- Does not look at trail ☐
- Holds face too near paper ☐
- Holds head at an odd angle ☐

- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is *exceptionally* slow ☐
- Goes too fast for accuracy ☐

Other

....

....

TWO-HAND CATCH — BALL SKILLS

Quantitative data

Record **number of correct catches**; **R** for refusal;
I for inappropriate

....

score	age 9	age 10
0	6–10	8–10
1	5	7
2	4	6
3	3	4–5
4	1–2	1–3
5	0	0

Item score

Qualitative observations

Body control/posture

- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐

- Arms are not raised symmetrically for catching ☐
- Holds hands out flat with fingers stiff as the ball approaches ☐
- Arms and hands do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐

- Body appears rigid/tense throughout ☐

Adjustments to task requirements

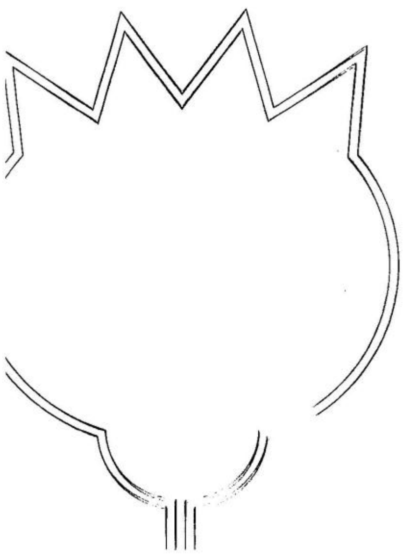
- Does not adjust body position for catching ☐
- Does not adjust position of feet as necessary ☐
- Judges force of throw poorly (too much or too little) ☐
- Movements lack fluency ☐

Other

....

....

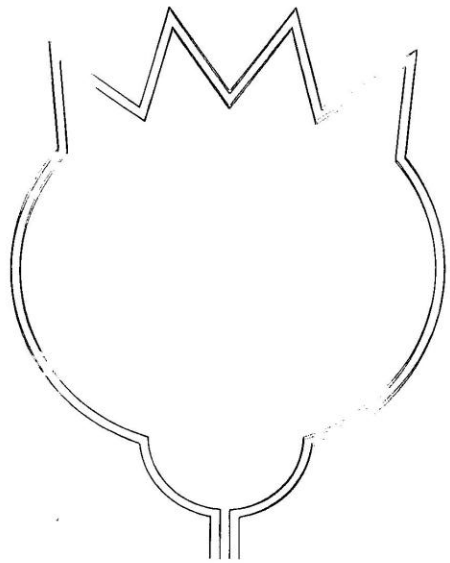
FLOWER TRAIL



START HERE

....

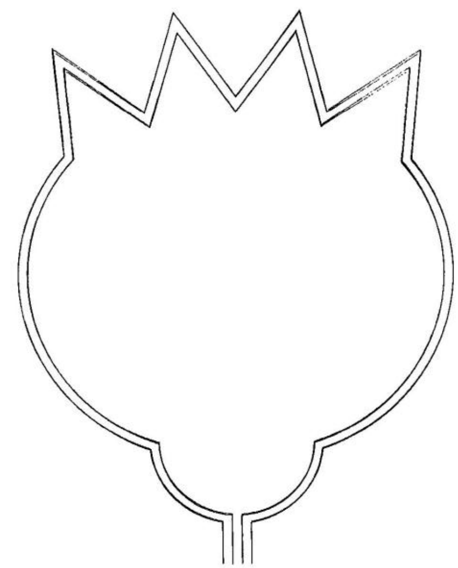
FLOWER TRAIL



START HERE

Name ....

FLOWER TRAIL



START HERE

Name ....

THROWING BEAN BAG INTO BOX — BALL SKILLS

Quantitative data

Record **number of goals**; **R** for refusal; **I** for inappropriate

....

Hand used ....

score
0
1
2
3
4
5

age 9	age 10
5–10	6–10
4	5
3	–
2	4
–	3
0–1	0–2

Item score

Qualitative observations

Body control/posture

- Does not keep eyes on target ☐
- Does not use a pendular swing of the arm ☐
- Does not follow through with throwing arm ☐
- Releases bean bag too early or too late ☐
- Changes hands from trial to trial ☐
- Trunk and hips do not rotate as throwing arm comes forward ☐
- Over-rotates and loses balance ☐

Adjustments to task requirements

- Errors are consistently to one side of the box (asymmetry striking) ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- Movements lack fluency ☐

Other

....

....

ONE-BOARD BALANCE — STATIC BALANCE

Quantitative data

Record **time balanced** (secs); **R** for refusal; **I** for inappropriate

Preferred leg	Nonpreferred leg
Trial 1	Trial 1 ________
Trial 2	Trial 2 ________

Preferred leg age 9	Preferred leg age 10	score	Nonpreferred leg age 9	Nonpreferred leg age 10
6–20	9–20	0/0	6–20	8–20
5	6–8	1/1	5	6–7
4	5	2/2	4	5
3	4	3/3	3	4
2	3	4/4	2	3
0–1	0–2	5/5	0–1	0–2

* Item score

* Item score = (Preferred leg + Nonpreferred leg) ÷ 2

Qualitative observations

Body control/posture

- Does not hold head and eyes steady ☐
- Looks down at feet ☐
- Makes no or few compensatory arm movements to help maintain balance ☐
- Exaggerated movements of arms and trunk disrupt balance ☐
- Body is held rigid ☐
- Sways wildly to try to maintain balance ☐
- Does *extremely* poorly on one leg (asymmetry striking) ☐

Other

....

....

HOPPING IN SQUARES — DYNAMIC BALANCE

Quantitative data

Record **number of correct hops**; **F** for failure; **R** for refusal; **I** for inappropriate.

Preferred leg
Trial 1 ....
Trial 2 ....
Trial 3 ....

Nonpreferred leg
Trial 1 ....
Trial 2 ....
Trial 3 ....

age 9	age 10	score	age 9	age 10
5	5	0	5	5
–	–	1	–	–
–	–	2	4	4
4	4	3	3	3
1–3	3	4	1–2	2
0	0–2	5	0	0–1

* Item score

* Item score = (Preferred leg – Nonpreferred leg) ÷ 2

Qualitative observations

Body control/posture

- Does not use arms to assist hop ☐
- Arms swing out of phase with legs ☐
- Arm movements are exaggerated ☐

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐

- Nonsupporting leg held up in front of body ☐
- Lacks springiness/no push-off from feet ☐
- Noticeably poorer on one foot than the other ☐
- Hops with stiff legs/on flat feet ☐
- Stumbles on landing ☐

Adjustments to task requirements

- Does not combine upward and forward movements effectively ☐
- Uses too much effort ☐
- Movements are jerky ☐

Other

....

....

BALL BALANCE — DYNAMIC BALANCE

Quantitative data

Record **number of drops; F for failure; R for refusal; I for inappropriate**

Trial 1 ....
Trial 2 ....
Trial 3 ....

Hand used ....

score	age 9	age 10
0	0	0
1	–	–
2	1	1
3	2	2
4	3–4	3–4
5	5+	5+

Item score

Qualitative observations

Body control/posture

- Does not look ahead ☐
- Does not keep head steady ☐

- Does not compensate with free arm to maintain balance ☐
- Exaggerated arm movements disrupt balance ☐

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Shuffles forward, does not lift feet off floor ☐

Adjustments to task requirements

- Goes too fast to control ball ☐
- Individual movements lack smoothness and fluency ☐
- Sequencing of steps is not smooth/pauses frequently ☐

Other

....

....

Appendix B

Developmental History Form

1. In order to be able to understand and work with your child to better advantage we would like to ask a few questions about his/her developmental history and behaviour.

   Child's Full Name: ______________________________

   Address: ______________________ Telephone: __________

   Grade: __________ School: ______________________

   Father's Name: ______________________________

   Mother's Name: ______________________________

   Siblings: ______________________________

2. Before or after his/her birth was he/she ever identified as an "at risk" or "high risk" child? If yes, what were the implications? Could you explain the details?

   At risk: Comments

   Birth Complications __________

   Premature __________

   Overdue __________

   Small for Dates __________

   Birth Weight __________

   Anoxia __________

3. Compared to other siblings and children of his/her age did you find his/her development different in any way?

   Developmental History: Comments

   Early Infant Behaviour (content, irritable, etc.) ________

   Sat Alone ________

   Crawled ________

   Walked

3. Continued

		Comments
Talked:		
- single words	________	
- sentences	________	
Rode a Bicycle	________	
Dressed Him/Herself	________	
Tied Shoe Laces	________	
Caught a Ball	________	
Climbed Stairs	________	
Marking Time	________	
In Opposition	________	
Climbed Playground Equipment	________	

4. Does he/she have any serious health problems?

Medical History:		Comments
Illnesses	________	
Operations	________	
Accidents	________	
Allergies	________	
Neurological Problems	________	
Sensory Problems (medical diagnosis of eye, ear or tactile problems)	________	
Physical Disability (mini CP, dislocated hips, spine or foot problems, etc.)	________	
Hyperactivity	________	
Medication	________	
History of Family Health Problems	________	

5. Has your child ever been assessed and diagnosed for developmental difficulties? If so, what type of remediation followed?

Early Remediation and School History:		Comments
Assessments (results)	________	
Physical Therapy	________	
Speech Therapy	________	
Early Intervention Programs	________	
Early School Difficulties	________	
Alternative Schools	________	
Resource Room/LAP	________	
Reading Remediation	________	

6. How would you describe your child's social life?

Social Life:		Comments
Many playmates? (school and home)	________	
Does he/she get along with peers?	________	
Does he/she get along with siblings?	________	
Does he/she take part in neighbourhood games?	________	
Does he/she give up easily on things he/she finds difficult?	________	
How does he/she react to a difficult academic task?	________	
physical task?	________	

Appendix C

Force Plate Protocol

Participants will perform the force plate protocol which involves performing three balance tasks while standing on the Wii Fit balance board placed on the force plate. The tasks require the participants to be barefoot and stand as still as possible, or lean as far as possible, and complete the tasks to the best of their abilities for 20 seconds. All measures will be taken at a sampling frequency of 100 Hz with the gain set at 4000x, 5x, and the electronic filter set at 10.5 Hz.

The protocol consists of performing quiet standing with eyes open and closed which will produce COP measures that reflect the participants' balance control, and the balance space task which will produce COP measures that reflect their postural adaptation. All participants will be given a practice trial and three formal trials.

Materials needed during the test:

- Height measure instrument (cm)
- Weight scale (kg)
- Paper and pencil
- AMTI strain gauge force plate
- Wii Fit balance board
- Computer and AMTI AccuSway Plus system

Procedure:

1. Participants come in one at a time and the researcher confirms their name and age. Participants will be asked to take off their shoes and socks, followed by height, weight, and foot measurements taken and recorded. Participants will stand barefoot on two plain sheets of paper, while each foot is traced with a pencil.

2. To ensure that all participants stand in the same location on the Wii board, participants will be asked to stand inside the feet tracings marked with tape, on the Wii board placed on the force plate. The force plate will be zeroed and acquired for each participant. Weight will be automatically calculated on the computer when the participants stand on the force plate.

3. The number of trial and session, as well as participants' identification, age, weight and height, will be recorded.

4. Explain the performance and demonstrate:

    a. Eyes open – participants are asked to stand on the Wii balance board, placed on the force plate, with hands crossed over the chest and to remain as still as possible with both feet inside the outlined tape on the board, while looking straight, focusing on an eye-leveled yellow *X* target taped on a blue mat, 4.2 meters from the force plate. The task will be 20 seconds long. There will be one practice trial and three formal trials.
    b. Eyes closed task – participants are asked to stand on the Wii balance board, placed on the force plate, with hands crossed over the chest and to remain as still as possible with both feet inside the outlined tape on the board, with eyes closed. The task will be 20 seconds long. There will be one practice trial and three formal trials.
    c. Balance space task – participants are asked to stand on the Wii balance board, placed on the force plate, with hands crossed over the chest. Participants will be asked to lean as far as they possibly can forward, backward, to the right, and to the left, while keeping the trunk upright, knees and hips extended, and without lifting the toes or heels off the ground. This task will be 20 seconds long, and there will be one practice trial and three formal trials.

5. Start collecting data: Following demonstration by the researchers, participants will perform the tasks with data and recordings being collected. With one participant at a time, the force plate will first be zeroed, and then the participant will be asked to stand on it. Weight will be automatically recorded. The participant will be asked to step away from the plate, and when he or she is ready, will be asked to step back onto the force plate. The recorder sitting by the computer will click acquire with the mouse. The performance will be recorded on the computer. Each trial will be saved before starting a new trial. The platform will be zeroed before each trial.

Appendix D

Invitational Letter

Dear (Participant's Name) and (Parent or Guardian's Name), Date

In (year child attended the Motor Development Clinic) (child's name) attended the Lakehead University Motor Development Clinic. As a former participant in this clinic I am inviting (child's name) to take part in a study being conducted by my master's student Sarah Krasniuk. Sarah is investigating the *Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems*. As you know, trying to keep your balance while you are moving is a common problem of children who attend the Motor Development Clinic. Two years ago Sarah studied the effects of Wii Fit balance training with three boys who had been in the clinic program. They enjoyed the program and Sarah was able to present this research at conferences in both Finland and California. She also just completed a pilot study with young adults to learn more about how the Wii really works. Now, I would like to invite you to be part of a bigger study to see if the Wii training program can help you to improve your balance.

As a child who has balance problems, attended Lakehead University's Motor Development Clinic between the years 2007 to 2010 and is between the ages of 7 and 10 years, you are eligible to take part in this study. As long as you have good or corrected vision (glasses) do not have any ankle, knee, or hip problems or take any medications that may affect your vision or balance I would like you to consider this opportunity. The study will involve some initial balance and motor performance testing, 20 sessions of Wii Fit balance training followed by the same balance and motor performance tests.

If you think you might be interested in this study or want more information please contact Sarah Krasniuk at 343-8182 or me at the number below.

Dr. Jane Taylor
(807)343-8752
jtaylor@lakeheadu.ca

Appendix E

Letters of Information

Dear (Child's name), Date

Hello, my name is Sarah Krasniuk. I am a Lakehead University student in Kinesiology working with Professor Jane Taylor on a project using the Wii Fit to help improve balance skills. This project is called *Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems*. You have already worked with Jane and I on movement and balance skills when you were a part of Lakehead University's Motor Development Clinic. Now, I would like to invite you to be part of a bigger project to determine whether the Wii Fit can also help you improve your balance.

You can be part of this project if you are 7 to 10 years old, have balance problems and have attended the Clinic between 2007 and 2010. You must also have good vision or wear glasses. You cannot have any ankle, knee, or hip problems or take any medications that may change your vision or balance. Before you begin the project I will ask you to sign a consent form indicating that you understand what you will be asked to do.

For this project you will first tell us what games you have played on the Wii Fit and what physical activities you are doing now. Then at the beginning and the end of the study we will ask you to do a balance and an MABC test. Before the balance test we will take your weight, height, and foot measurements. Then, we will ask you to do three things while standing on the Wii balance board. They are: (a) stand as still as possible with eyes open, (b) stand as still as possible with eyes closed, and (c) lean as far forward, backward, to the right, and to the left, without moving your feet. The balance test will take about 15 minutes, with each trial lasting 20 seconds. There will be nine trials in all. The entire MABC test will take about 1 hour. You did this test before when you came into the Motor Development Clinic. Lacing, catching and jumping are some tasks in the MABC test. When I have scored the tests, I will call or email you and your parents to give you a group number, one or two. If you are in group one, you will begin Wii Fit training immediately. If you are in group two, you will start Wii Fit training as soon as group one is done their training.

In the Wii Fit training, you will be doing balance games twice a week for 20 sessions. Each session will be 1.5 hours. The sessions will be set at a time that is good for you and your parents. Every session, you will do different activities on the Wii Fit, including soccer, skiing and hula hoop. All of the activities will take place at the clinic at Lakehead University's Sanders Field House (room 1028).

Learning the Wii Fit games and having fun are two benefits of this project. You may improve your balance and may also have less chance of falling. During the project you will be asked not to do any extra training on the Wii Fit or do any other balance training. There are no harms or risks related to this project. You will play games that are like the activities you do in physical education class or at recess.

You are a volunteer. That means if at any time you do not want to continue you can refuse to do any part of the project or stop volunteering for the project altogether. All of the information we collect from you is private; only Jane and I will see your scores. Results from the project will be written about but we will not use your name. All of the information will be stored securely for 5 years at Lakehead University's School of Kinesiology. You can ask us for your own results if you want to see them.

If you agree to take part, please sign the consent form so that we can set up a time to begin the project. If you have any questions at any time please ask us. This project has been approved by the Lakehead University Research Ethics Board. If you or your parents have any questions with the ethics of the project you can contact the Board at (807) 343-8283 or by email research@lakeheadu.ca.

Thank you for your cooperation,

Sincerely,

SKrasniuk
Sarah Krasniuk
(807) 986-3574
smkrasni@lakeheadu.ca

M Jane Taylor
Dr. Jane Taylor
(807)343-8752
jtaylor@lakeheadu.ca

Dear (Parent or Guardian's name), Date

My name is Sarah Krasniuk, a Lakehead University master's student in Kinesiology and teaching assistant for the Motor Development Clinic. Under the supervision Dr. Jane Taylor, I am investigating the *Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems*. As you know, postural adaptation or the ability to maintain balance while moving is a common problem of children who attend Lakehead University's Motor Development Clinic. In 2008, I was one of the undergraduate researchers who studied the effects of Wii Fit balance training for three children with movement and balance problems who had also attended the Motor Development Clinic. The children enjoyed the Wii Fit program and made improvements in all of the balance games and in postural adaptation, so I became motivated to continue research in this area. Recently, I completed a pilot study with young adults examining the validity of the Wii board on measures of centre of pressure (how we evaluate balance). Now, I would like to invite your child to be part of my master's project to investigate whether the Wii Fit training program can help improve postural adaptation.

Eligibility for this study requires that your child is between 7 and 10 years old, has movement and balance problems, and attended Lakehead University's Motor Development Clinic between 2007 and 2010. Your child must also have good or corrected vision, no ankle, knee, or hip problems and not be taking any medications that affect vision or balance. Before the study commences, I will also ask your child to read his or her own information letter and when it is clear that you both understand what is required, to indicate consent by signing consent forms.

Before performing any testing your child will complete the Wii Fit and physical activity questionnaire. In addition, both the balance test and Movement Assessment Battery for Children (MABC) will be performed at the beginning and end of the study. In the balance test, anthropometric measurements (e.g., height, weight, foot measures) will be recorded. Then, while your child is standing on the Wii board placed on the force plate, he/she will perform three balance tasks which include: (a) standing as still as possible with eyes open, (b) then with eyes closed, and (c) leaning as far forward, backward, right, and left without taking a step. The balance test will take approximately 15 minutes, with each trial lasting 20 seconds and there will be nine trials in all. The MABC, which involves tasks like lacing, catching and jumping will take approximately 1 hour. Once the scores are analyzed, I will contact you and your child (via telephone or email) to assign him/her a group number, either one or two. Group one will begin the training immediately and group two will start training once group one has finished.

The Wii Fit training will comprise two sessions per week for 20 sessions, each of 90 minutes in duration. These will be scheduled at a time that is convenient for you and your child. Every session will include soccer, skiing and hula hoop games. All activities will be in the clinic at the Sanders Field House (room 1028).

Your child will learn new games, have fun, may improve his/her balance status and reduce the risk for falling. During the study your child will be asked not to do any extra training on the Wii Fit or do any other balance training. There are no potential physical or psychological harms or risks associated with this study. The physical requirements are no greater than the requirements of a typical physical education class or recess.

Participation in this study is completely voluntary. If at any point you or your child feel uncomfortable and/or do not wish to continue with a particular question or activity in the study, you both have the option to refuse or to withdraw from the study entirely without penalty. All data will be kept confidential; only Jane and I will have access to the data and personal information. Results from the study may be presented and/or published but no names or personal information will be released. All data will be stored securely for 5 years at Lakehead University. The findings may be made available to you upon request.

If you agree to the participation of your child in this study, please sign the consent form so that we can set up a meeting time to begin the study. If you have any questions or concerns, please do not hesitate to contact either of us. The project has been approved by the Lakehead University Research Ethics Board. If you have any questions with the ethics of the project you can contact the Board at (807) 343-8283 or by email research@lakeheadu.ca.

Thank you for your cooperation,

Sincerely,

Sarah Krasniuk
(807) 986-3574
smkrasni@lakeheadu.ca

Dr. Jane Taylor
(807)343-8752
jtaylor@lakeheadu.ca

Appendix F

Participant Consent Form

I _________________________________agree to be in the study about balance and the Wii fit called

Print name of child

Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems

I have read the information letter and understand that:

Please check (✓) the following:

1. _____Sarah Krasniuk is a student at Lakehead University working on a project with Professor Jane Taylor.
2. _____I have good vision or glasses and do not have any ankle, knee, or hip problems, or take any medications that affect my balance or vision.
3. _____I will do a balance test to the best of my ability at the beginning and end of the study that will take 15 minutes.
4. _____I will do the MABC at the beginning and end of the study to the best of my ability and this testing will take approximately 1 hour.
5. _____I will participate in Wii Fit training for 20 sessions, doing balance games.
6. _____I will learn some Wii Fit games and have fun, and no harm will come to me because I am taking part.
7. _____I should not use the Wii Fit or do any other balance training during the project.
8. _____ I am a volunteer and can stop participating at any time.
9. _____ I may choose not to answer any questions or do any tasks that I would prefer to leave out.
10. _____The information that I provide will be kept private and will be stored for a minimum of 5 years at Lakehead University's School of Kinesiology. All data collected during the study will be private and my name will not be used at any time.
11. _____ I can ask for my results.
12. _____The results of the research may be published.

Signature of:

Participant____Date___________________

Parent Consent Form

I agree to the participation of my child ________________________________ in the study

Print name of child

Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems

I have read the letter of information letter and understand that:

Please check (✓) the following:

1. _____Sarah Krasniuk is a master's student in Kinesiology at Lakehead University conducting research under Professor Jane Taylor.
2. _____My child has good/corrected vision, does not have any ankle, hip, or knee injuries that affect his/her balance, and does not take any medications that affect vision or balance.
3. _____My child will perform a 15-minute balance test at the beginning and end of the study: 3 balance tasks, 3 trials, 9 trials in all.
4. _____My child will perform the MABC, which will take approximately 1 hour, at the beginning and end of the study.
5. _____My child will complete 20 sessions of Wii Fit training, with 2 sessions per week, each being 90 minutes in duration.
6. _____The benefits my child may gain include experience with the Wii Fit and having fun, and that there will be no harm done to my child as he/she is partaking in training.
7. _____My child should not use the Wii Fit or do any other balance training during this study.
8. _____ My child and I are volunteers and can withdraw from the study at any time.
9. _____ I may choose not to answer any questions or do any task that I would prefer to leave out.
10. _____The information that I provide will be confidential and will be stored for a minimum of 5 years at Lakehead University's School of Kinesiology. All data collected during the study will be coded and no names will be released in the report at any time.
11. _____ I will receive a summary of the project upon request.
12. _____The results of the research may be published.

Signature of:

Parent/guardian____Date____________________

Appendix G

Wii Fit and Physical Activity Questionnaire

Name: ______________________

Age: ______________

Please answer the following questions:

Wii Fit:

Please circle the most correct answer:

1. Do you enjoy playing video games? Yes or No
2. Do you own a Wii or a Wii Fit? Yes or No
3. How often do you play video games that are relative to the Wii or Wii Fit?

<1 time/ week   2-5 times/week   6+ times/week   >1 time/daily

4. When did you start playing video games on the Wii or Wii Fit?

<1 month ago   2-6 months ago   6-12 months ago   12+ months ago

5. Please list the games off of the Wii Fit that you enjoy playing?

____

____

Physical Activity

Please circle the most correct answer:

6. Do you enjoy participating in physical activity or sports? Yes or No

7. Please list the type of physical activities or sports you have taken part in and for how long you have participated in them.

Physical Activity/Sport	Experience (years)
1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	

8. Please list any injuries you have received from participating in any of these physical activities or sports.

Physical Activity/Sport	Injury
1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	

Appendix H

Wii Fit Balance Intervention

Wii Fit Program: Week 1

Instructor: Sarah Krasniuk **Date: __________________**

Participant #: ___________

Body Test ►<u>Warm-up</u>

Includes Centre of Balance test, BMI, and Body Control Tests.

Centre of Balance test: standing straight on the Wii board, with your feet spread equally apart and toes slightly pointed out. The test measures your balance using the four sensors on the board. Your current centre of balance is illustrated as a red dot on the television onscreen board. The goal is to shift your weight accordingly so that you move the red dot into the blue centre and hold for 3 seconds.

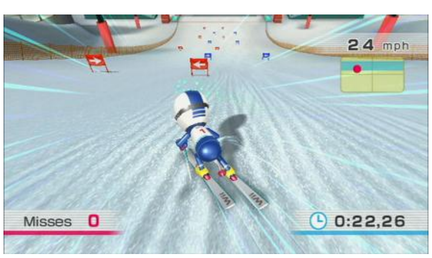
BMI: The Wii Fit asks you your height and measures your weight to calculate your BMI. Results will appear on the onscreen of the game, stating whether you meet the normative data or fit into a different category (e.g., underweight, overweight, obese).

Basic Balance Test: This test requires you to shift your weight between the left and right sides of your body. The vertical bars represent the left and right sides, and as you shift your weight to a side, the bars become filled in with red. There is a blue rectangular area inside the vertical bars, and the goal is to shift the red into the blue rectangular area and hold for 3 seconds. There are 5 rounds to complete in 30 seconds.

Wii Fit hula hoop ► The objective of hula hoop is to quickly rotate your hips in a circular motion to keep the hula hoops on its waist while getting as many spins as possible in a 70-second period. The faster you spin, the more points you get. Mii characters throw hula hoops to the left/right of you and you must lean in the corresponding direction to gain hula hoops to get more spins and points.

Wii Fit soccer heading ► The objective of this game is shift your weight (left/right) to soccer head balls that come your way and avoid hitting other miscellaneous objects like panda heads and shoes. The beginner level includes 80 soccer balls and the advanced level includes 120 balls. A perfect score for the beginner level is 555 points, and for the advanced level is 655 points.

Wii Fit ski slalom ► The objective of ski slalom is to shift your weight (left/right) so that you ski between the red and blue flags on the course as quickly as possible without missing any. Optimal speed is shown in the upper-right corner when the colour red (which represents your body weight) is maintained in the blue balance bar. A score of 18 seconds on the beginner setting is a perfect score, while a score of 30 seconds with no missed gates is a perfect score.



Wii Fit ski jump ► The objective of ski jump is to achieve the farthest cumulative distance (meters) in 2 jumps. You start ski jump in a squatted position with your upper body leaning slightly forward. When the red jump zone that says 'extend' appears, you extend both legs at the same time. To achieve the optimal position for the entire task, in the upper right corner on-screen, the red balance dot should be inside the blue dot. The highest score achieved so far is 404 m.

Wii Fit table tilt ► The objective of table tilt is to lean (forward/backward/left/right) to put the balls into the holes and prevent the balls from falling off the table. Completing a level scores you 10 points and adds an additional 20 seconds to the clock, with starting at 30 seconds for each level. There are a total of 8 levels to complete; 1 point is awarded for each second you have left at the end. A score of 0 to 29 gives you 1 star; 30 to 79 2 stars; 80 to 99 3 stars; and 100+ 4 stars.

Appendix I

Random Assignment of Simulations

Session 1: hula hoop, soccer heading, ski slalom, ski jump, and table tilt

Session 2: hula hoop, soccer heading, ski slalom, ski jump, and table tilt

Session 3: ski slalom, table tilt, ski jump, soccer heading, and hula hoop

Session 4: ski jump, soccer heading, table tilt, ski slalom, and hula hoop

Session 5: soccer heading, hula hoop, ski jump, table tilt, and ski slalom

Session 6: soccer heading, ski slalom, ski jump, hula hoop, and table tilt

Session 7: soccer heading, hula hoop, ski jump, table tilt, and ski slalom

Session 8: ski jump, table tilt, hula hoop, soccer heading, and ski slalom

Session 9: table tilt, hula hoop, ski slalom, soccer heading, and ski jump

Session 10: hula hoop, ski jump, soccer heading, table tilt, and ski slalom

Session 11: soccer heading, ski jump, hula hoop, table tilt, and ski slalom

Session 12: ski jump, ski slalom, soccer heading, hula hoop, and table tilt

Session 13: hula hoop, ski jump, soccer heading, table tilt, and ski slalom

Session 14: ski jump, table tilt, hula hoop, soccer heading, and ski slalom

Session 15: soccer heading, hula hoop, ski jump, ski slalom, and table tilt

Session 16: table tilt, ski slalom, ski jump, soccer heading, and table tilt

Session 17: soccer heading, table tilt, ski slalom, ski jump, and hula hoop

Session 18: ski slalom, soccer heading, table tilt, hula hoop, and ski jump

Session 19: hula hoop, ski slalom, soccer heading, table tilt, and ski jump

Session 20: ski jump, soccer heading, ski slalom, table tilt, and hula hoop

Appendix J

Wash-out Information Letter

June 14, 2011

Request to Complete One Additional Testing Session For the Study

"Effects of a virtual reality intervention on postural adaptation of children with movement and balance problems"

Dear Parents and Participants

Thank you very much for participating in our study. You have made a great commitment of time and effort and we really appreciate it. Sarah has given you some idea of your progress. We are very proud of you and how well you have done.

When we were first recruiting you for the study we asked people to either be part of the intervention or part of the control group. Since most of you wanted to be training on the Wii we were only able to have one group in our study. In order for you to act as your own controls we would like to ask you to return one more time so that we can do the balance test and the Movement ABC test (just like you did at the beginning and end of the study). This testing would be done at the end of a 7-week rest or retention period, in which we would ask you not to practice the games you have been doing during your training.

This information is very important to us in order for us to determine how effective the training has been. We hope you will be able to do this. We appreciate that it is another commitment from you and we will make every effort to accommodate your schedules.

Sincerely,

M. Jane Taylor, Ph.D.

Sarah Krasniuk, HBK

Wash-out Consent Form

Participants and Parents Consent Form

I have read the request to return one more time to provide balance and MABC test data. I understand that this information is necessary to complete the study but my participation is completely voluntary. I am asked not to practice Wii Fit for the next 7 weeks and I will arrange a time to come in that suits my schedule.

If you agree, please (√) the following and sign and print your names:

1. ______ I understand that a retention period is needed to determine the lasting effects of the Wii Fit intervention on postural adaptation

2. ______ I will do a 15-minute balance test to the best of my ability once more in 7 weeks.
3. ______ I will do the MABC to the best of my ability that will take approximately 1 hour once more in 7 weeks.

Participant's name: (print) ____________________________________

Signature of:

Participant______________________________________ Date__________________________

Signature of Parent

Appendix K

Social Validation Survey

Social Validation Survey

Please read the following questions and provide the response which best explains your opinion about the exercise program. Your honest opinions, positive or negative are greatly appreciated.

1. *How do you feel that your life has changed since you have been in the Wii fit program?*

1	2	3	4	5
Much worse	A bit worse	Nothing changed	A bit better	A great deal

Please explain why you feel that way

2. *Did you change any other daily activity or exercise habits during the Wii fit session?*

Yes No

Please explain what type of your daily exercise or activity has been changed.

3. *Did you have any treatment or medication changes during the Wii session?*

Yes No

Please explain what treatment or medication was changed.

4. *If this Wii fit program were offered again, would you choose to participate?*

Yes No

Please explain what type of your daily exercise or activity has been changed.

5. Would you recommend this program to a friend?

   Yes No Undecided

   Please explain why you feel that way

6. *Do you feel that your training was geared toward your ability level?*

   Yes No Undecided

   Please explain why you feel this way

7. *How did you feel about the length of the program and the exercise session?*

1	2	3
Too long	Just Right	Too short

   Please explain why you feel that way

8. In general were you satisfied with this program?

   Yes No Undecided

   Please explain why you feel this way

9. *Do you have any other comments about your participation in the Wii fit program?*

Appendix L

Individual Participant Demographics at the Pre-test

Table L1

Individual participant demographics at the pre-test

No.	Age (yrs)	Wt (kg)	Ht (cm)	FtL (cm)	FtW (cm)	A (cm)	P (cm)	TIS (%)	TBS (%)	Tball (%)	TMDS (%)
1	7	33.0	136	20.4	7.7	.7	.6	16.5 (2)	8.0 (<5)	1.5 (>15)	7.0 (<5)
2	10	41.1	150	22.9	8.9	.7	.5	20.5 (<1)	4.5 (>15)	1.0 (>15)	15.0 (<5)
3	10	38.5	151	22.6	8.9	1.1	.7	19.0 (<1)	9.0 (<5)	1.0 (>15)	9.0 (<5)
4	9	33.5	142	22.2	8.2	.9	.8	31.5 (<1)	12.0 (<5)	5.0 (5)	14.5 (<5)
5	7	27.5	114	19.0	8.1	.3	.3	24.5 (<1)	9.5 (<5)	4.5 (5-15)	10.5 (<5)
6	9	27.5	129	20.0	8.4	1.0	.8	25.0 (<1)	4.0 (>15)	9.0 (<5)	12.0 (<5)
7	8	28.7	141	20.3	7.5	1.0	.8	18.0 (1)	8.5 (<5)	3 (5-15)	6.5 (5)
8	7	30.5	138	20.5	7.5	.7	.6	21.5 (<1)	9.0 (<5)	4.0 (5-15)	8.5 (<5)
9	10	47.1	145	21.2	9.4	.7	.6	21.5 (<1)	3.5 (>15)	5.0 (5)	13.0 (<5)
10	8	41.5	143	22.0	8.6	.8	.6	21.0 (<1)	7.0 (5-15)	4.0 (5-15)	10.0 (<5)

Note. No. = participant number; Wt = weight; Ht = height; FtL = foot length; FtW = foot width; A = anterior sway; P = posterior sway; TIS = Total Impairment Score; TBS = Total Balance Score; Tball = Total Ball Skills Score; TMDS = Total Manual Dexterity Score.

Appendix M

Responses of Second Part of Wii Fit and Physical Activity Questionnaire

Table M1

Physical activity or sport and length of time participants have performed in them

Participant	Physical activity or sport	Length of time (years)
1	Swimming	5
	Soccer	2
2	Swimming	5
	Soccer	2
3	Basketball	2 to 3 months
	Wrestling	1 month
	T-ball	3
	Soccer	1
	Running club	3
4	Swimming	2
	Bowling	7
	Skating	2 days
5	Swimming	1.5
	Gymnastics	1
	Bowling	Not on a regular basis
	Mini putting	Not on a regular basis
6	Hockey	2
	Soccer	1
7	Soccer	4
	Skiing	4
	Gymnastics	1
	Biking	3
	Frisbee	3
	Swimming	6
	Dancing	4
8	Gymnastics	2.5
	Soccer	Not on regular basis
	Swimming	4
9	Soccer	8 weeks
	Skating	10 weeks
	Swimming	10 weeks
	Karate	10 weeks
	Ukrainian dancing	1
10	Tai Kwon doe	2
	Soccer	3
	Gymnastics	2

Appendix N

Descriptive Statistics of Participants' Performance in Simulations

Table N1

Number of participants performing, and means, standard deviations, ranges of scores, and mean star values of the participants' performance in the Wii Fit simulations

Simulation	*No.*	*M*	*SD*	*Ranges*	*M* stars
Hula hoop (spins)	10	42.60	52.40	2.00-266.00	1.15
Super hula hoop (spins)	7	313.00	160.00	22.00-760.00	1.30
Rhythm boxing (pts)	4	219.00	43.70	120.00-301.00	1.77
Basic step (pts)	3	169.00	22.30	118.00-209.00	1.72
Adv. step (pts)	3	340.00	62.80	200.00-427.00	1.58
Ski jump (m)	10	112.00	49.10	.00-252.00	1.16
Tightrope walk (s)	5	10.80	7.58	.00-.47	1.27
Adv. tightrope walk (s)	3	9.96	8.43	.00-.39	1.62
Exp. tightrope walk (s)	2	10.00	5.96	.00-.56	1.11
Ski slalom (s)	10	1.29	.45	.40-3.16	1.07
Adv. ski slalom (s)	8	1.70	.42	1.01-3.00	1.02
Snowboard slalom (s)	4	1.27	.39	.53-2.34	1.00
Soccer heading (pts)	10	33.70	23.90	1.00-154.00	1.32
Adv. soccer heading (pts)	10	32.00	26.30	.00-157.00	1.30
Penguin slide (pts)	8	52.40	10.50	31.00-81.00	1.92
Table tilt (pts)	10	25.40	14.50	.00-70.00	1.26
Balance bubble (s)	8	684.00	301.00	.00-.36	1.01
Adv. balance bubble (s)	2	727.00	299.00	.00-.42	1.07

Note. No. = number of participants; Adv. = advanced; Exp. = expert; pts = points.

Visual Representation of Participants' Performance in Simulations

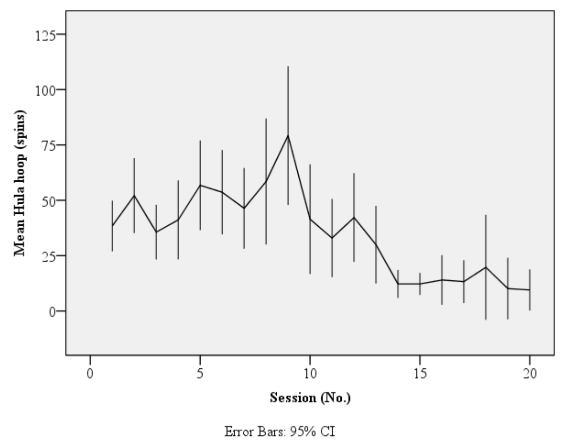


Figure N1. Participants' mean hula hoop scores of sessions performed in the intervention.

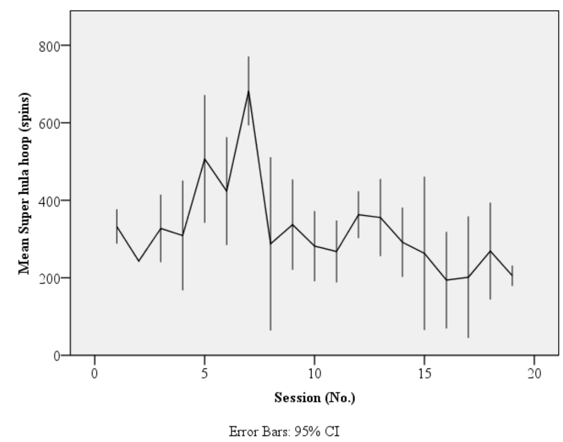


Figure N2. Participants' mean super hula hoop scores of sessions performed in the intervention.

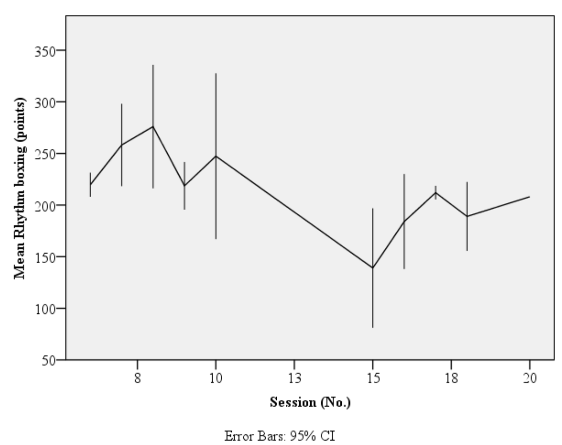


Figure N3. Participants' mean rhythm boxing scores of sessions performed in the intervention.

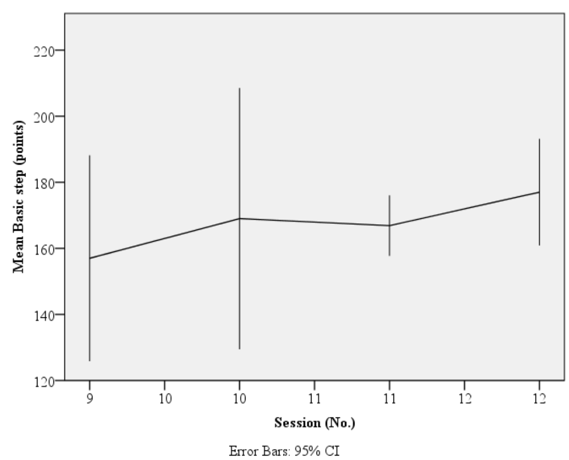


Figure N4. Participants' mean basic step scores of sessions performed in the intervention.

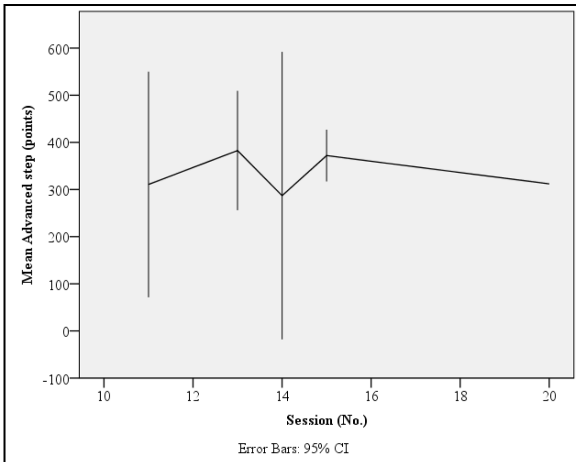


Figure N5. Participants' mean advanced step scores of sessions performed in the intervention.

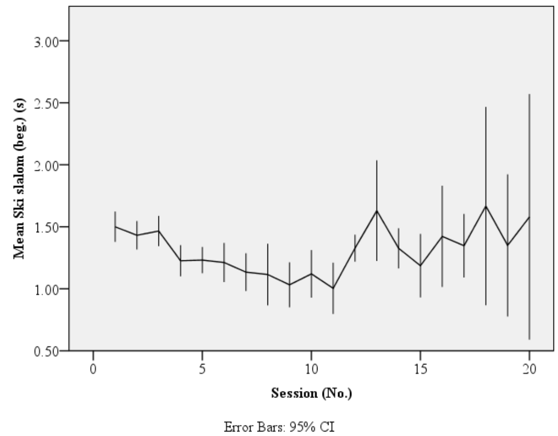


Figure N6. Participants' mean ski slalom scores of sessions performed in the intervention. *Note*. Scores are based on time. The lower the scores, the better the results.

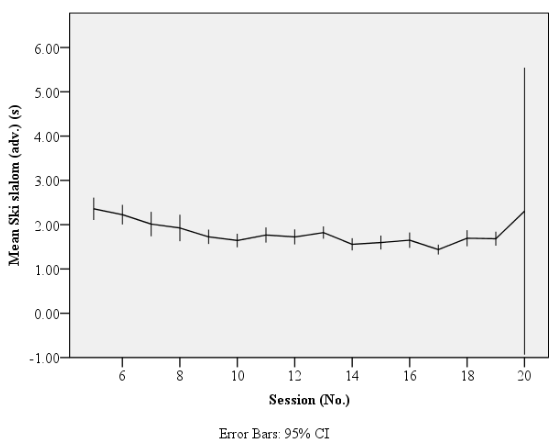


Figure N7. Participants' mean advanced ski slalom scores of sessions performed in the intervention. *Note*. Scores are based on time. The lower the scores, the better the results.

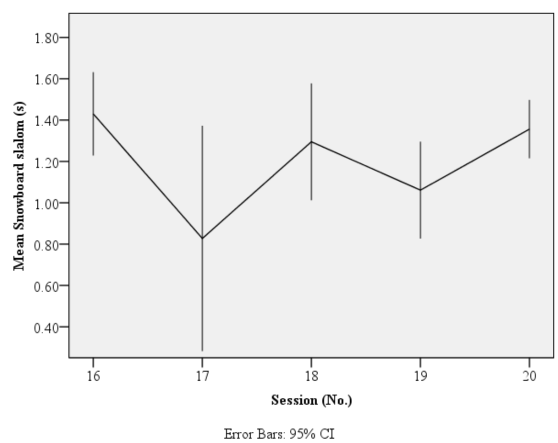


Figure N8. Participants' mean snowboard slalom scores of sessions performed in the intervention. *Note*. Scores are based on time. The lower the scores, the better the results.

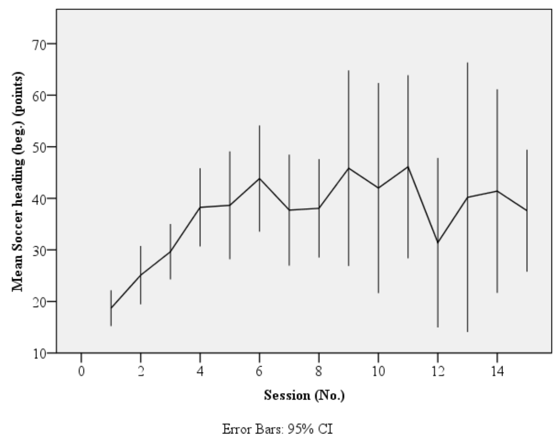


Figure N9. Participant's mean soccer heading scores of sessions performed in the intervention.

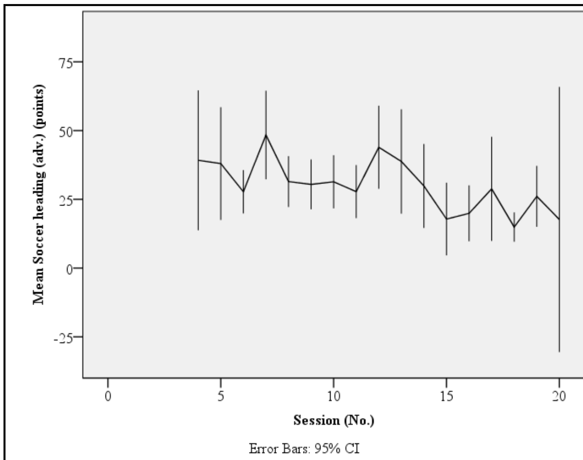


Figure N10. Participants' mean advanced soccer heading scores of sessions performed in the intervention.

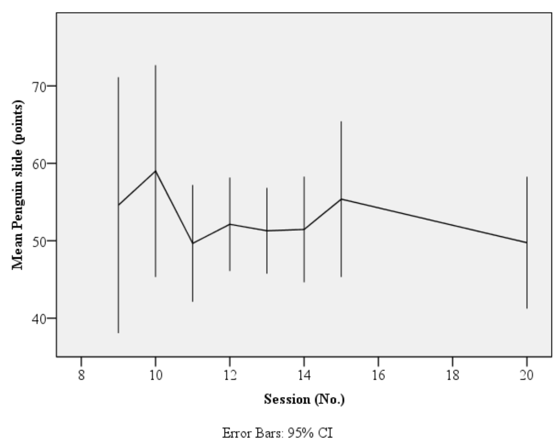


Figure N11. Participants' mean penguin slide scores of sessions performed in the intervention.

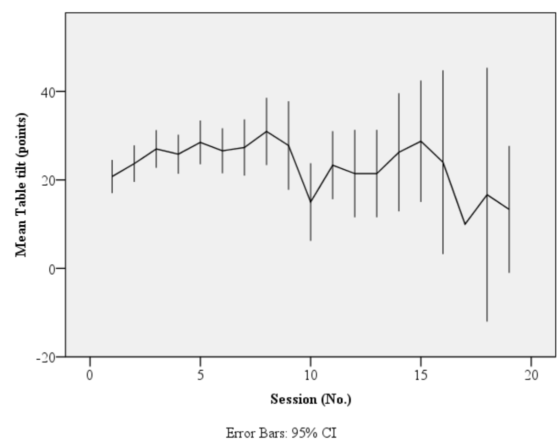


Figure N12. Participants' mean table tilt scores of sessions performed in the intervention.

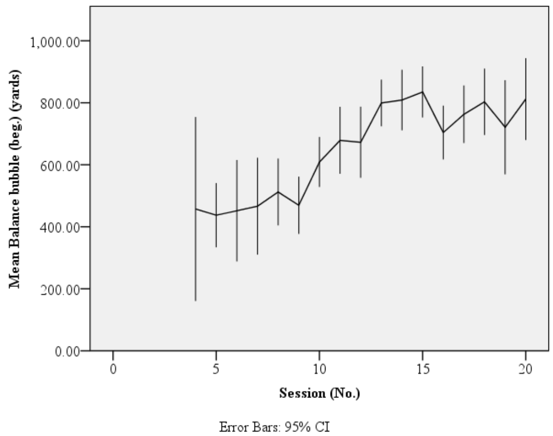


Figure N13. Participants' mean balance bubble scores of sessions performed in the intervention.

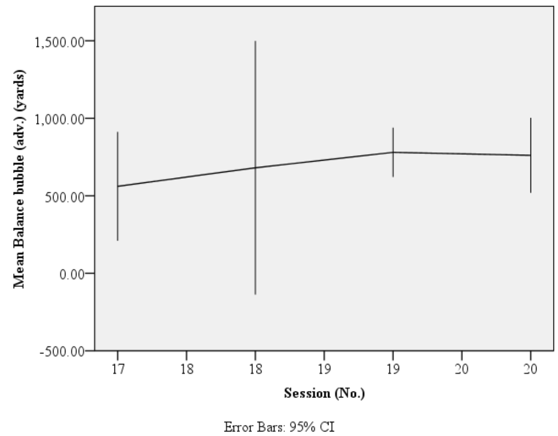


Figure N14. Participants' mean advanced balance bubble scores of sessions performed in the intervention.

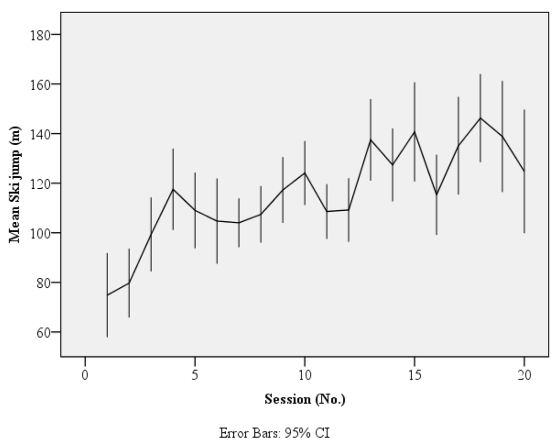


Figure N15. Participants' mean ski jump scores of sessions performed in the intervention.

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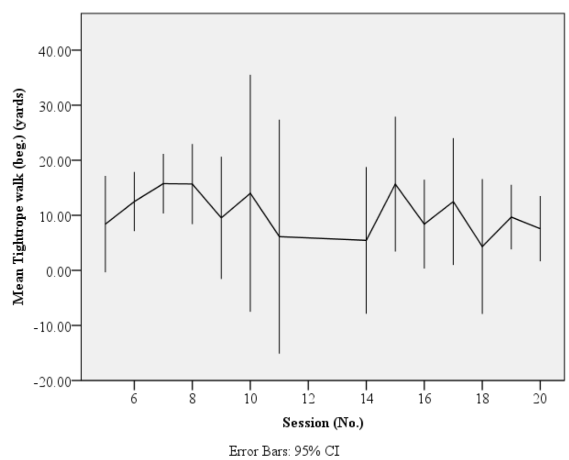

Figure N16. Participants' mean tightrope walk scores of sessions performed in the intervention.

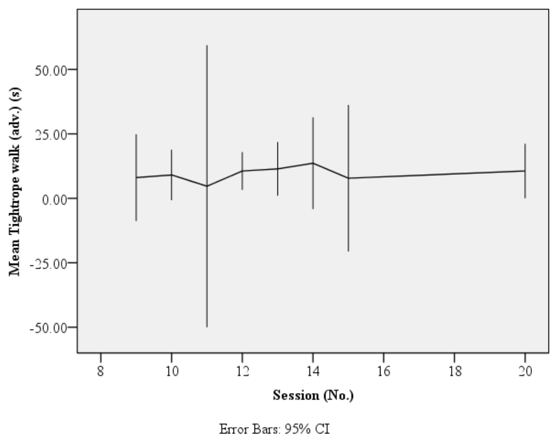

Figure N17. Participants' mean advanced tightrope walk scores of sessions performed in the intervention. *Note*. Scores are based on time. The lower the scores, the better the results.

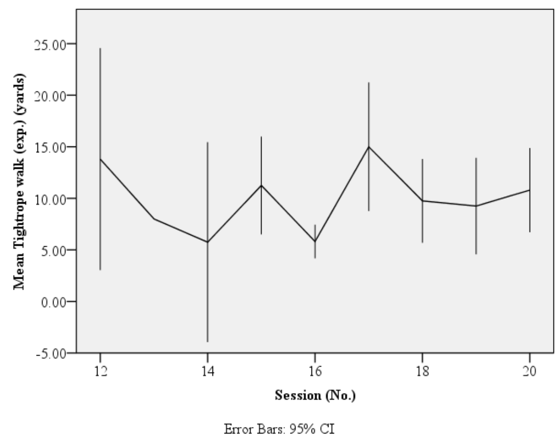

Figure N18. Participants' mean expert tightrope walk scores of sessions performed in the intervention.

Appendix O

Descriptive Statistics of TISs at Pre-, Post-, and Wash-out

Table O1

Means and standard deviations for TISs at pre-, post-, and wash-out assessments

DV	Pre-		Post-		Wash-out	
	M	*SD*	*M*	*SD*	*M*	*SD*
TIS (%)	21.90 (<1st)	4.27	18.60 (<1st)	5.73	20.00 (<1st)	7.40

Appendix P

Visual Representation of Participants' Performance on the Balance Space Task

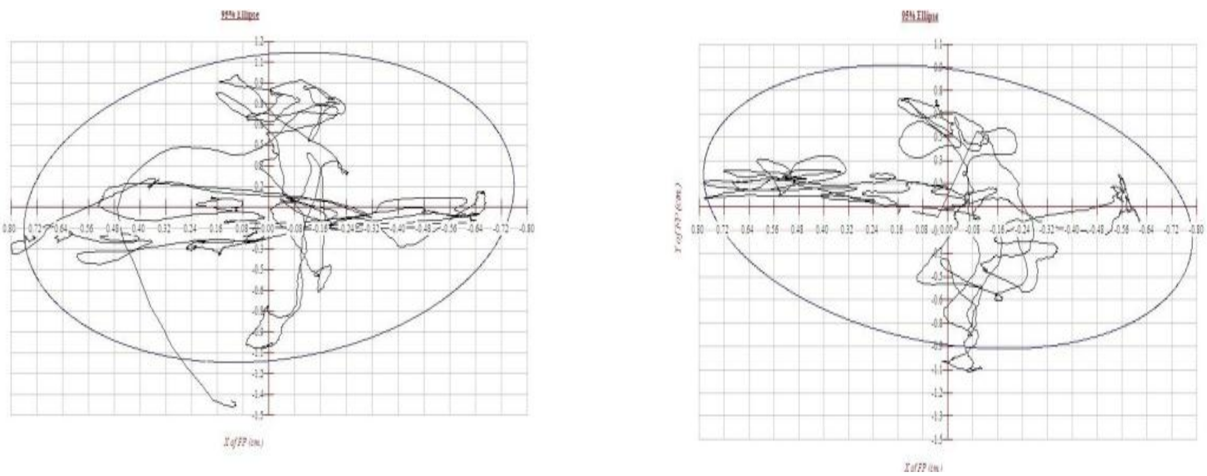

Figure P1. Participant 1 performing the balance space task at pre- (left) and post- (right).

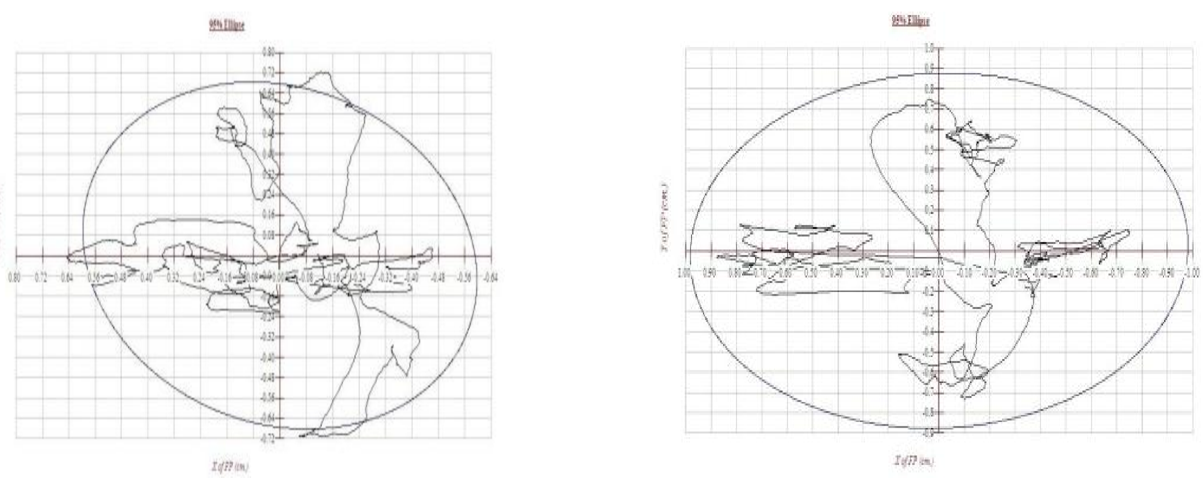

Figure P2. Participant 2 performing the balance space task at pre- (left) and post- (right).

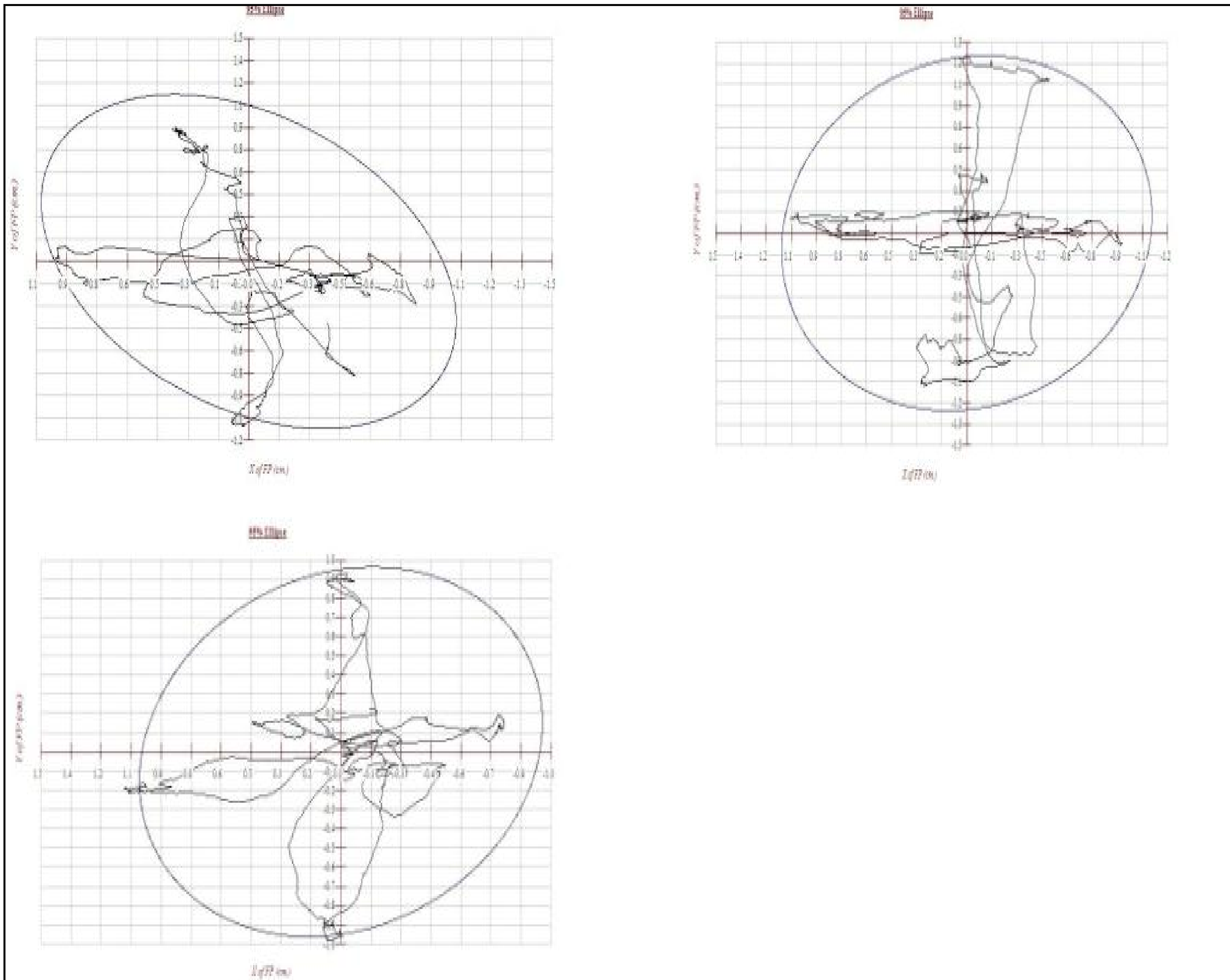

Figure P3. Participant 3 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

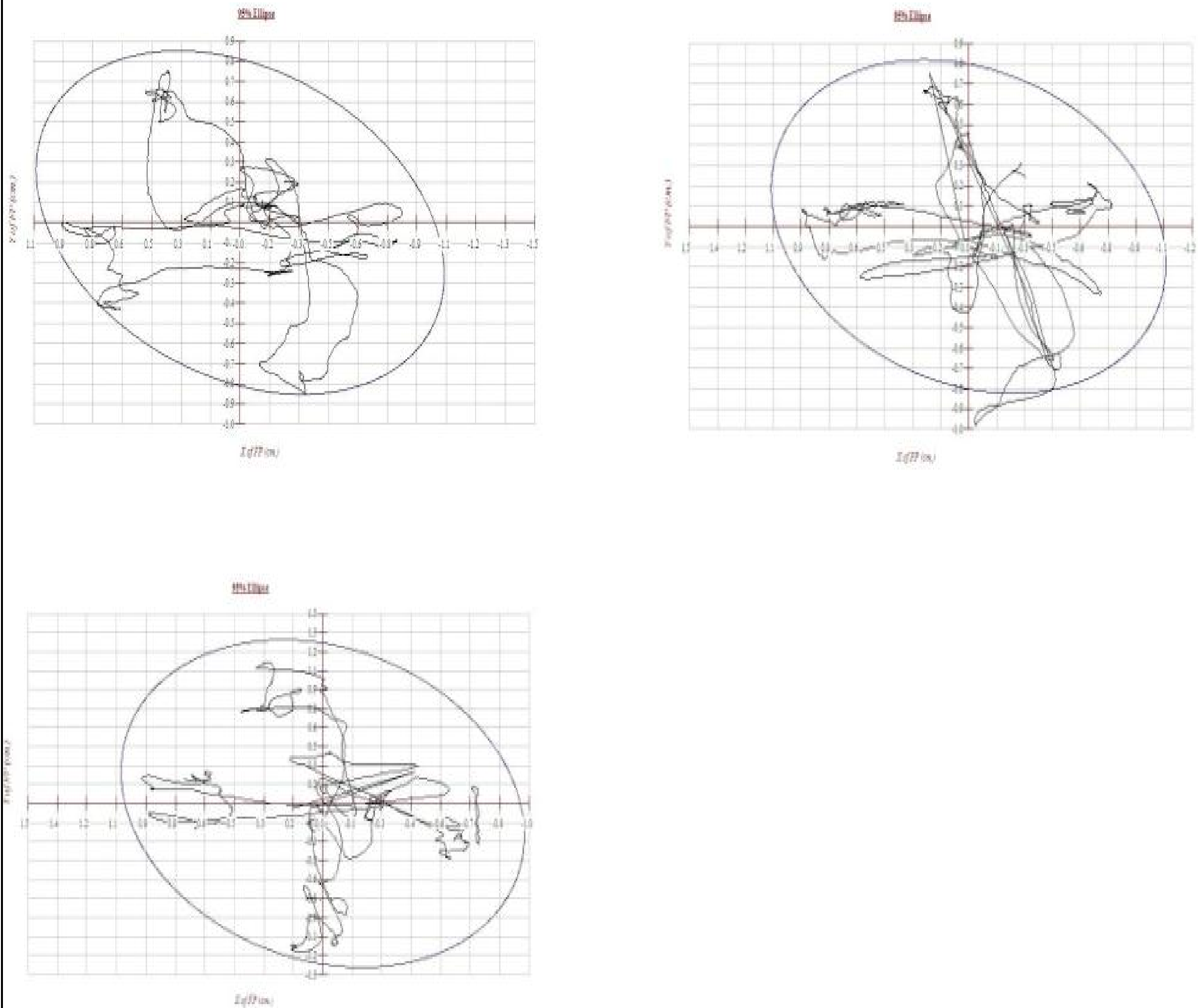

Figure P4. Participant 4 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

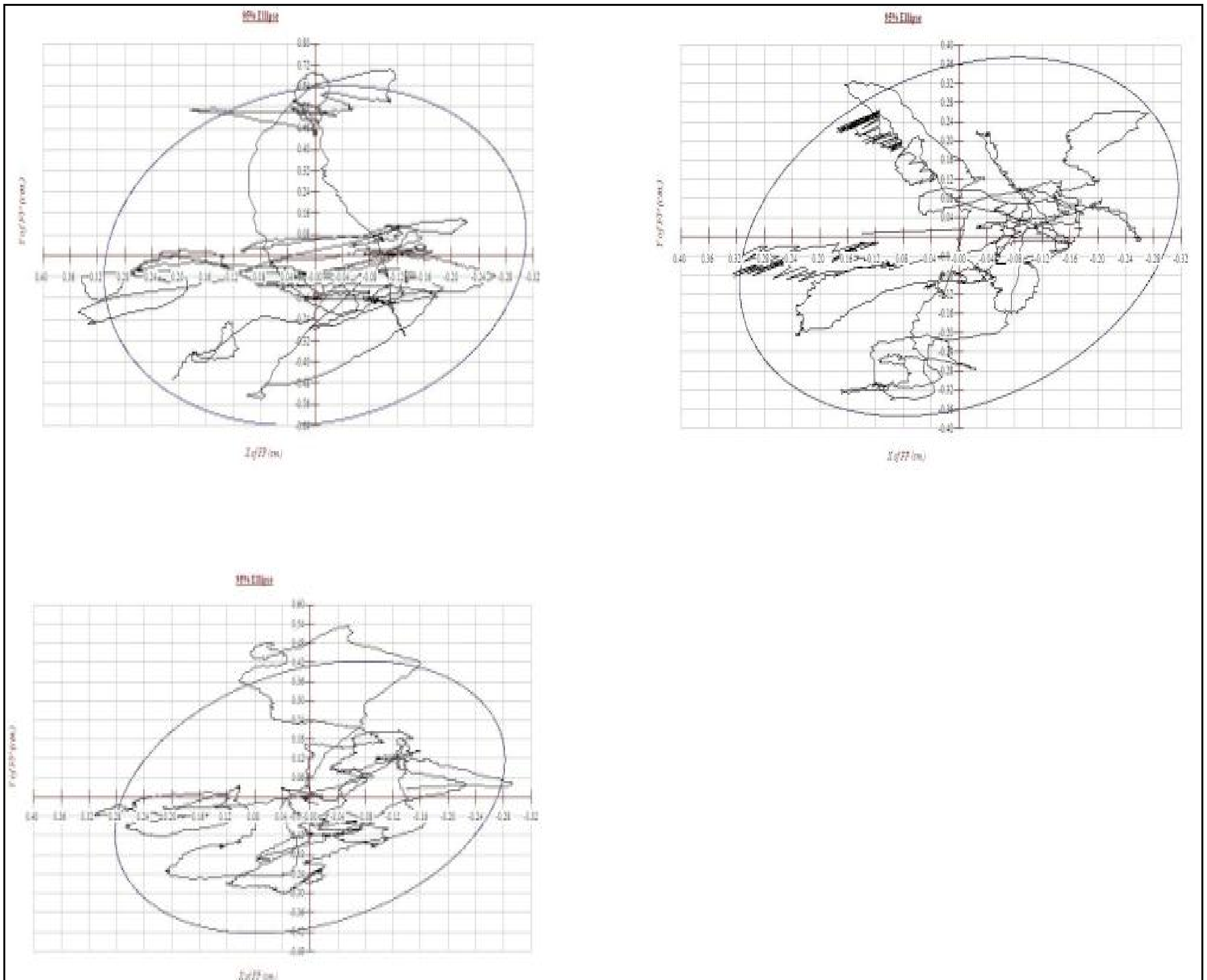

Figure P5. Participant 5 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

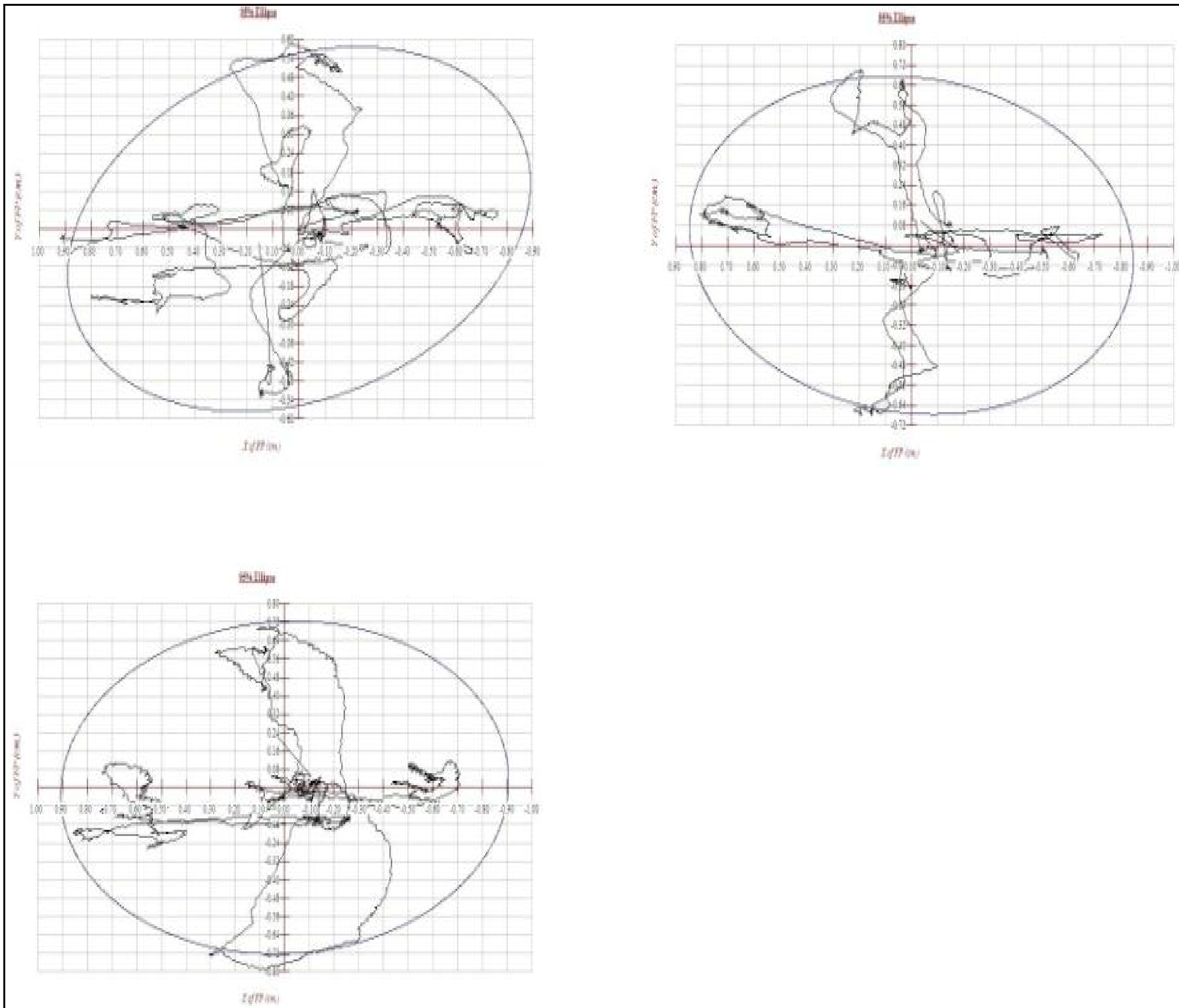

Figure P6. Participant 6 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

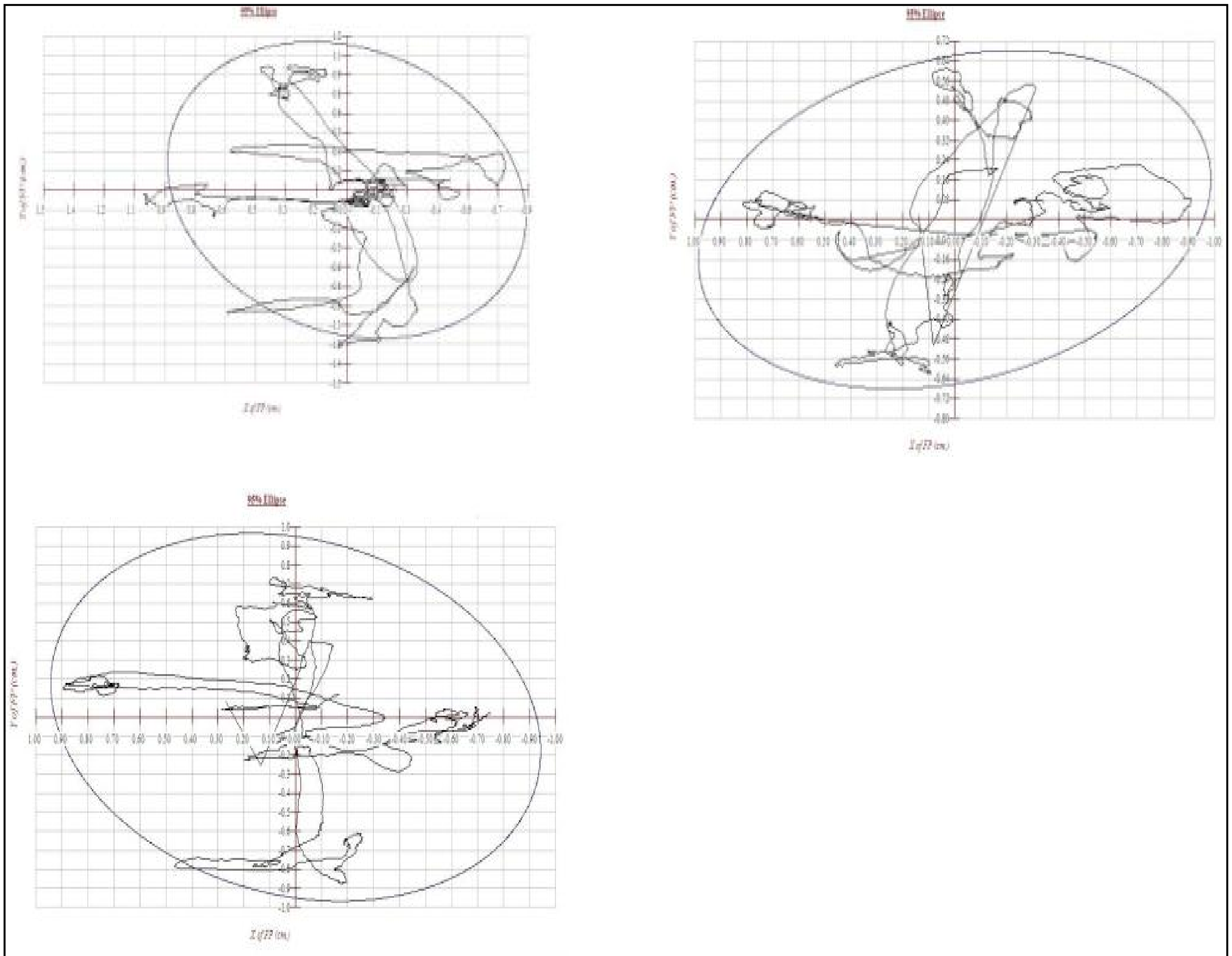

Figure P7. Participant 7 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

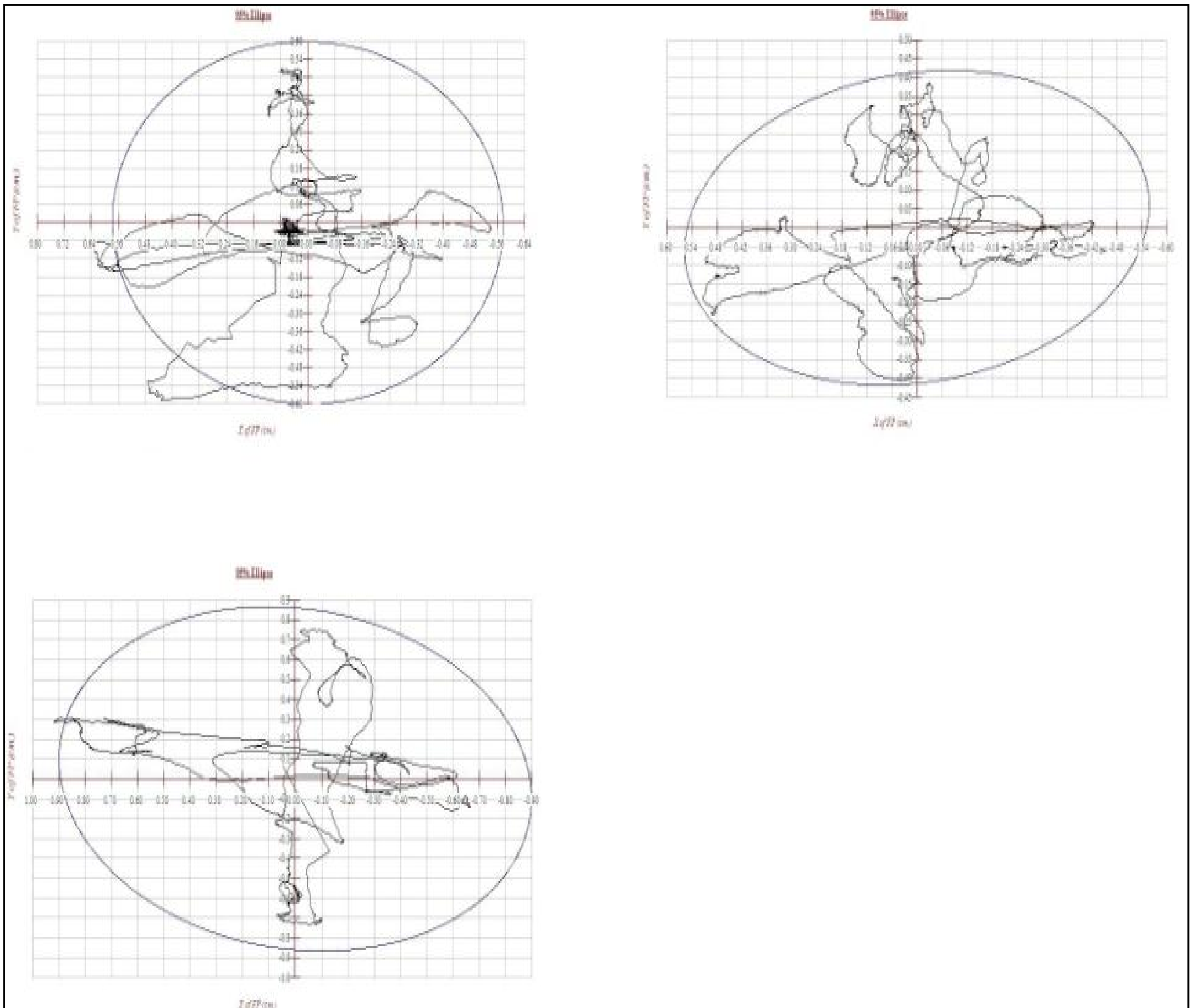

Figure P8. Participant 8 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

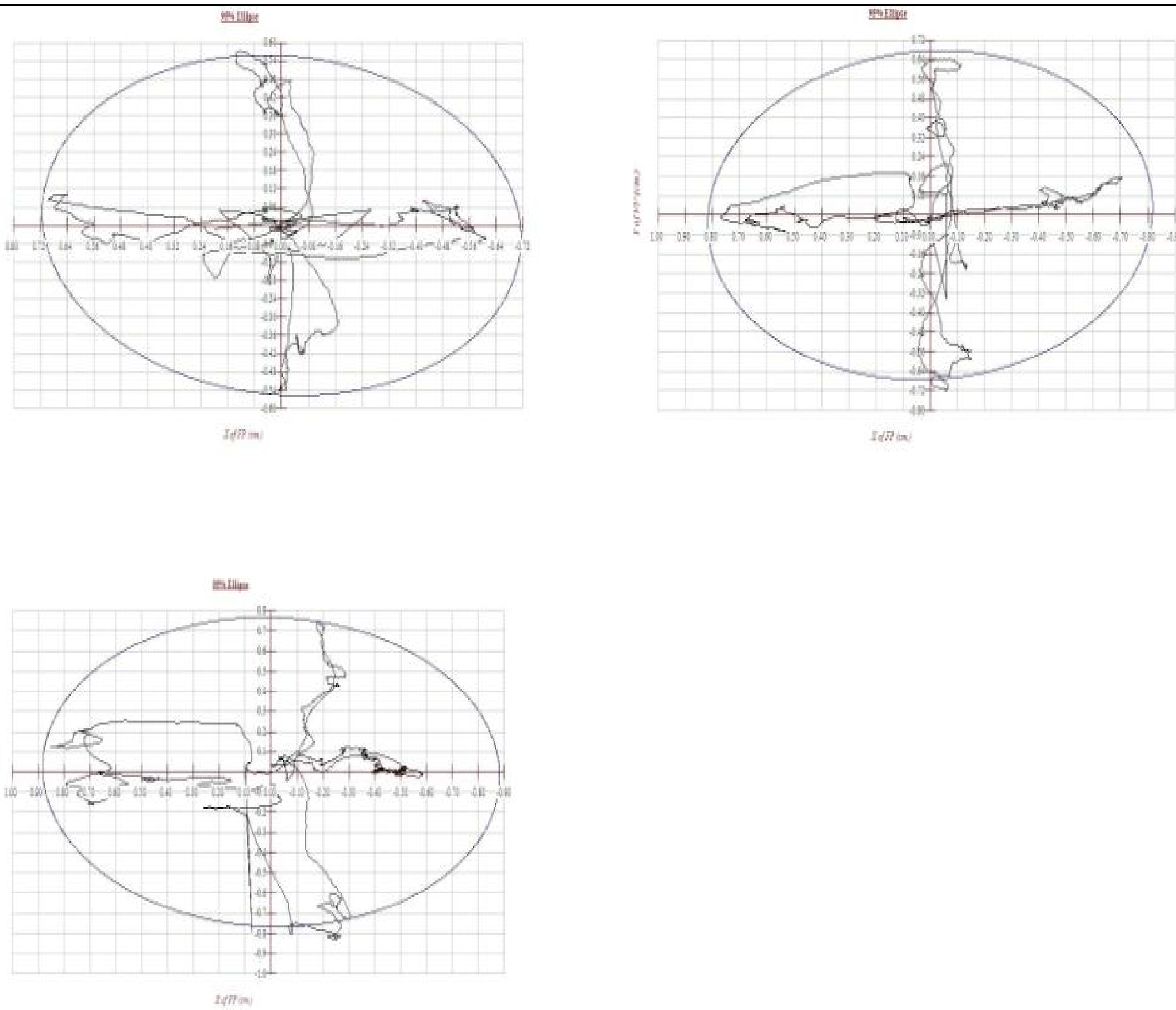

Figure P9. Participant 9 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

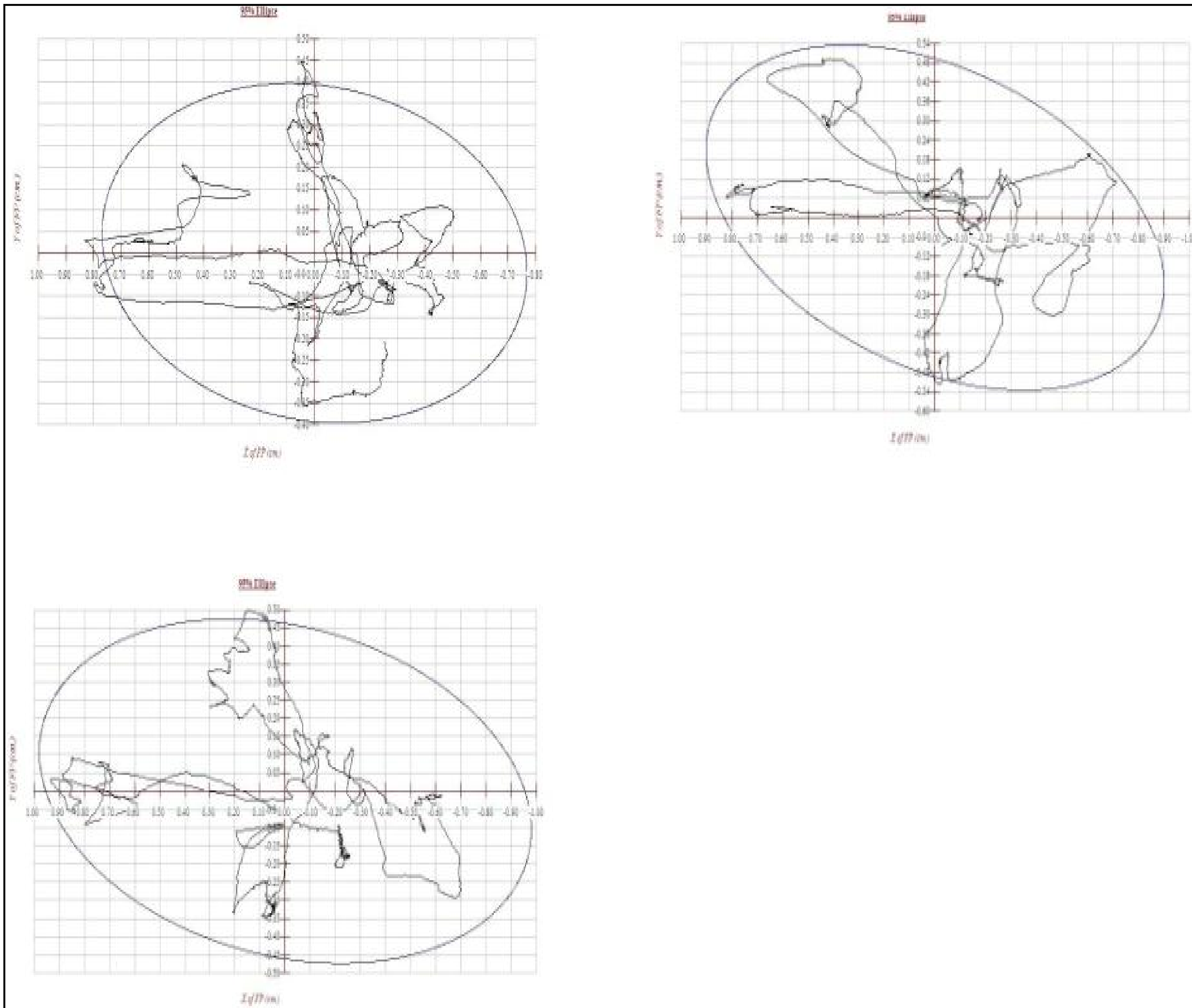

Figure P10. Participant 10 performing the balance space task at pre- (top left), post- (right), and wash-out (bottom left).

Appendix Q

Participants' Improvement in the Wii Fit Simulations

Table Q1

Participants' improvement in Wii Fit simulations

Wii Fit simulation	Percent difference (%)
Hula hoop (spins)	197.00
Super hula hoop (spins)	188.00
Rhythm boxing (pts)	86.00
Basic step (pts)	55.70
Adv. step (pts)	72.40
Ski jump (m)	200.00
Tightrope walk (s)	200.00
Adv. tightrope walk (s)	200.00
Exp. tightrope walk (s)	200.00
Ski slalom (s)	155.00
Adv. ski slalom (s)	99.30
Snowboard slalom (s)	126.00
Soccer heading (pts)	197.00
Adv. soccer heading (pts)	200.00
Penguin slide (pts)	89.30
Table tilt (pts)	200.00
Balance bubble (s)	200.00
Adv. balance bubble (s)	200.00

Note. Adv. = advanced; Exp. = expert; pts = points

Appendix R

Descriptive Statistics of COP Measures of Balance Space Task in Force Plate Protocol: Pilot Study

Table R1

Means and standard deviations of COP measures of the balance space task while standing on the force plate, and while standing on the Wii board placed on the plate

DV	*M*	*SD*
AP force plate (cm)	1.62	.43
AP Wii Fit (cm)	1.55	.41
ML force plate (cm)	1.62	.36
ML Wii Fit (cm)	1.48	.36
Ao force plate (cm^2)	2.58	1.42
Ao Wii Fit (cm^2)	2.26	1.22
L force plate (cm)	13.35	3.64
L Wii Fit (cm)	12.11	3.16
V (cm/s)	.61	.16
V (cm/s)	.67	.18

Note. AP = anterior-posterior sway; ML = medial-lateral sway; Ao = area of sway; L = path length; V = velocity.