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AN INVESTIGATION INTO THE ATTENTION PROFILE OF BOYS WITH AND WITHOUT DEVELOPMENTAL COORDINATION DISORDER

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Abstract

Attention problems have been identified as an associated problem in children with Developmental Coordination Disorder (DCD), using the Child Behaviour Checklist, and the Covert Orienting of Visuospatial Attention Task. Their patterns indicate a deficit in the voluntary disengagement of attention, while reflexive orienting seems to be unaffected. Recently, attention has been investigated using the Attention Network Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002) which measures the efficiency of orienting, alerting and executive control networks. As no research presently exists, the goal was to examine attention networks in boys with and without DCD using the Attention Network Test for Children (ANT-C; Rueda et al., 2004).

Twenty-five boys between 7 and 10 years were recruited to participate in the study. Each participant was screened using the MABC, and then tested on the ANT-C. Fourteen boys with a mean age of 9 years comprised the DCD group (MABC percentile mean = 5.5), while eleven boys with a mean age of 8.6 years comprised the comparison group (MABC percentile mean = 51.1).

A series of independent sample t-tests revealed the boys with DCD were not significantly different from the comparison group on the alerting ($t_{(23)}$=-0.44, p=0.67, d=-0.18); orienting ($t_{(23)}$= -1.39, p = 0.18, d= -0.55); or executive control ($t_{(23)}$=-0.68, p=0.51, d=0.28) networks. In addition, the two groups were similar on error rates ($t_{(23)}$=0.94, p=0.36) and overall reaction time ($t_{(23)}$=0.61, p=0.55). In contrast, using bivariate correlations, relationships were found between the alerting network and both the orienting (r = 0.70, p = 0.02) and executive control (r = 0.64, p = 0.04) networks in the group without DCD. In the group with DCD, these relationships were not observed. The presence or lack of relationship between networks suggests the two groups use differing strategies to achieve similar efficiency scores.

Based on the previous literature, which described attention difficulties in children with DCD, the results of the study were unexpected. High variability within and between each group, demonstrated by individual profiles and standard deviation, may have had a strong effect on the outcome of the inferential statistics. In addition, the validity of the ANT-C in regard to previous studies has also been questioned. It appears the ANT-C is not measuring the same aspects of attention that have been determined problematic in previous studies. Therefore, the attention profiles of boys with and without DCD remain similar on network efficiency, error rate and median reaction time, but may differ on the strategies used to achieve them.

Acknowledgements

I can still remember my first day of Graduate Orientation like it was yesterday. I was sitting in Jane's office balling my eyes out, so overwhelmed with the choice I had made to return to Thunder Bay to complete this Master's. All I saw ahead of me was a mountain ten times the elevation of the Sleeping Giant and I had no idea where to start climbing. Well here I am two and a half years later, standing on the top! I have persevered around marshes, over boulders and across rivers, taking two steps forward and one step back along this journey for knowledge and unexpected self growth.

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Introduction

In 1994, the term Developmental Coordination Disorder (DCD) was adopted at the International Consensus Meeting on Children and Clumsiness to describe children with motor difficulties (Polatajko, Fox & Missiuna, 1995). DCD is a motor-based performance problem that limits a child's ability to fully participate in the everyday activities of childhood. It is estimated that 6% of children between the ages of 5 and 11 years have DCD. The major characteristics of DCD are difficulties mastering either gross or fine motor tasks or both, generalizing learned movements to other tasks, and organizing and coordinating movements to accomplish a specific task, in comparison to children of the same age (Polatajko & Cantin, 2005; American Psychiatric Association, 1994, p.54).

The current diagnostic criteria for DCD requires a child's performance in daily motor coordination activities to be substantially below that expected given the child's chronological age and measured intelligence. The disturbance must significantly interfere with academic achievement or activities of daily living, and is not due to another medical condition. If mental retardation is present, the motor difficulties must be in excess of those usually associated with it (American Psychiatric Association, 1994, pp.53-54).

There are a variety of factors that have been identified in an attempt to determine the cause of DCD, however it is still largely unknown (Cermak & Larkin, 2002, p.16). One contributing factor that has been identified is a deficit in visual-spatial processing (Wilson & McKenzie, 1998). The results of this meta-analysis have led to an investigation into the orienting attention network of children with DCD with attention cueing tasks. The orienting network is responsible for directing attention from an unattended location to a target location or object (Posner & Badgaiyan, 1998, pg. 62). Orienting may be overt, with eye movements, or covert, without any eye movement (Posner & Rothbart, 2007). It can also be reflexive or voluntary

(Posner, 1980). Children with DCD have been identified with a deficit in the voluntary disengagement of attention, while reflexive orienting is not implicated in the disorder (Wilson & Maruff, 1999).

In addition to the orienting network, there are two other attention networks, the alerting and the executive control. The alerting network is responsible for achieving and maintaining a vigilant state to incoming stimuli (Fan, McCandliss, Sommer, Raz & Posner, 2002). The executive control network is responsible for the more complex mental operations engaged during monitoring and resolving conflict among stimuli (Fan et al.). Together these three networks form the organ system of attention with its own anatomy and circuitry (Fan & Posner, 2004).

Attention problems have been identified as an associated problem in children with DCD, and these children have been identified as a group at risk for attention problems (Sugden & Chambers, 2005, pg. 14; Dewey, Kaplan, Crawford & Wilson, 2002). Other than the research completed on the orienting network, to date, there is no research that specifically explores all three attention networks. Therefore, it is of interest that the efficiency of the alerting, orienting and executive control networks be examined in children with DCD.

Statement of the Problem

The purpose of the present study was to use the Attention Network Test for Children to investigate the attention profile of boys with and without DCD and determine if there was a difference between groups. The aspects explored within the profile included, the efficiency of the alerting, orienting and executive control networks, error rates, overall median reaction time, and the relationships between the networks (Rueda et al., 2004).

Definitions

Attention Network Test for Children (ANT-C) is a measurement tool developed to examine individual differences in the efficiency of the attention networks of alerting, orienting and executive control using reaction times to various conditions of the test (Fan et al., 2002; Posner & Rothbart, 2006). There are 12 conditions based on four warning cues, and three target types. The four warning cues are no cue, double cue, center cue and spatial cue, while the three target types include congruent, incongruent and neutral (Rueda et al., 2004).

Attention can be described as the mental ability to select stimuli, responses, memories and thoughts that are behaviourally relevant among a host of others in our environment (Raz, 2004; Sugden & Chambers, 2005).

Alerting is the function characterized by the process of achieving and maintaining a state of high sensitivity to incoming stimuli (Raz, 2004). In general, a larger alerting score indicates difficulty in maintaining attentiveness without a warning cue (Fan & Posner, 2004).

Developmental Coordination Disorder (DCD) is a neurodevelopmental (motor skill) disorder characterized by a marked impairment in the development of motor coordination abilities that significantly interferes with performance of daily activities and/or academic achievement. The difficulties observed are not consistent with the child's intellectual abilities and are not caused by a pervasive developmental disorder or general medical conditions that could explain the coordination deficits (Polatajko & Cantin, 2005).

Executive Control is the function which involves more complex mental operations engaged during monitoring and resolving conflict among stimuli. A greater executive control score generally indicates difficulty in resolving conflict (Fan et al., 2002; Fan & Posner, 2004).

Movement Assessment Battery for Children (M-ABC) is a clinical and educational tool designed to identify and describe the strengths and weaknesses of motor function impairments in children aged 4 to 12. The test provides objective quantitative data on three performance areas (manual dexterity, ball skills and balance) for a diagnosis. Children with Total Impairment Scores below the 5^{th} percentile are considered to have DCD, while children between the 5th and 15th percentile are considered at risk (Henderson & Sugden, 1992, p.108).

Orienting is the function characterized by the process of aligning attention and selection of information from a source of sensory stimuli (Posner & Rothbart, 2007; Raz, 2004). The network directs attention from an attended location to a target location or object (Posner & Badgaiyan, 1998, p.62). Usually, a larger orienting score indicates difficulty disengaging from the center cue, where the target does not appear (Fan & Posner, 2004).

Review of Literature

Developmental Coordination Disorder

The concept of Developmental Coordination Disorder is not new (Cermak & Larkin, 2002, p. 2). Over the past 100 years, DCD has been described as clumsiness, a motor/learning disability, a perceptuomotor dysfunction, and developmental dyspraxia (Polatajko & Cantin, 2005). In October 1994 at the International Consensus Meeting on Children and Clumsiness, the term ‘clumsy’ was rejected as a label for children with motor difficulties, and the term DCD, endorsed by the American Psychiatric Association, was adopted (Polatajko et al.,1995).

DCD is a motor-based performance problem that limits a child’s ability to fully participate in the everyday activities of childhood, in comparison to children of the same age. A child with DCD may have difficulties mastering either gross or fine motor coordination tasks or both which may be apparent in locomotion, agility, manual dexterity, complex skills and/or balance (Sugden, 2006). In addition, children with DCD may have difficulty learning new movements, generalizing learned movements to other tasks, and organizing and coordinating their movements to accomplish a specific task. The motor performance of children with DCD is consistently slower, less accurate, less precise and more variable than that of their peers (Polatajko & Cantin, 2005). The American Psychiatric Association and the World Health Organization recognize DCD as a disorder, and provide varying, but similar diagnostic criteria. The main consensus for a diagnosis of DCD is that a performance in daily activities that requires motor coordination is substantially below what is expected given the child’s age and intelligence that significantly interferes with academic achievement or activities of daily living, but is not due to a general medical condition. However, if mental retardation is present the motor difficulties must be in excess of those usually associated with it (American Psychiatric Association, 1994, pg. 55).

Children with DCD form a heterogeneous group and there are no typical cases (Cermak & Larkin, 2002, p.42). Numerous research studies have been completed using cluster or factor analysis to confirm the heterogeneity between cases (Visser, 2003; Sugden & Chambers, 2005). Henderson and Sugden (1992) suggest there are clear subgroups of children with DCD that exist with different patterns of performance (p.121). The first group of children demonstrates poor gross motor skills in comparison to their fine motor skills, while the second group is often competent in tasks requiring large body movements but has difficulty with fine motor tasks. The final group of children shows an equal impairment in both gross and fine motor skills.

In 1994, Hoare investigated the possibility that the movement difficulties associated with DCD might be divisible into subtypes. She tested her participants on six variables, which consisted of kinesthetic acuity, motor free visual perception, visual-motor integration, static balance, running and the Purdue Pegboard. The results of the cluster analysis demonstrated clear heterogeneity into five clusters. The first cluster was below average on dynamic balance and kinesthetic acuity. Clusters two and three were identified by visual perception competencies with poor kinesthetic acuity, and visual motor deficits, respectively. The fourth cluster had poor static balance and visual-motor functions, while cluster five had poor static and dynamic balance and manual dexterity. McNabb, Miller, and Polatajko (2001) later repeated Hoare's study, and successfully replicated the five clusters.

Dewey and Kaplan (1994), Wright and Sugden (1996), and Wilson, Kaplan, Crawford, Campbell and Dewey (2000) also investigated whether subtypes of developmental motor deficits could be identified. All three research groups chose different variables from Hoare and consequently found different subtypes. The variables used by Dewey and Kaplan were balance, bilateral coordination, upper limb coordination, transitive gestures, and motor sequencing. Again after a cluster analysis, they found four subtypes. Subtype number one demonstrated deficits in motor sequencing, while subtype two had deficits in balance, coordination and gestural performance. The third subtype had severe deficits in all motor skills areas, and the fourth subtype showed no motor deficits when compared to the other groups. In contrast, Wright and Sugden, and Wilson et al. used a single test to divide their participants. The test of choice for Wright and Sugden was the Movement Abilities Test for Children (MABC). The cluster analysis produced four subtypes from the participant's scores. Cluster one showed generalized low scores, but not severe in any. The second cluster had poor performance in dynamic environments, while the third cluster demonstrated generalized poor scores across motor tasks, particularly in dynamic environments. Finally, cluster four was identified by poor fine motor control, speed and dynamic balance.

Wilson et al. (2000), on the other hand, chose to use a factor analysis of the scores on the Developmental Coordination Disorder Questionnaire (DCD-Q) to group their participants. Similar to Wright and Sugden (1996), Wilson et al. found four groups, which were separated by a deficit in fine motor skills, a deficit in gross motor skills, a deficit in ball skills and control during movement, or complex general motor problems.

Although each study produced differing clusters, a sensorimotor subtype appeared in all of the studies regardless of the specific sensorimotor variables used in the study, whereas the presence of other subtypes depended on the inclusion and combination of the particular measures (Visser, 2003). The lack of consistency in the results may be attributed to the excess variation resulting from different source populations, differences in the choice of variables, and differences in statistical methods (MacNabb et al., 2001). Therefore, since subgroups exist, it is not surprising that a child with DCD would score differently on different tests or exhibit a different profile on subtests within a test (Wilson et al., 2000). Even with differing profiles, it is important to remember each child with DCD has the ability to learn motor skills, however he or she usually requires more practice than children without DCD, and the quality of movement may be compromised (Cermak & Larkin, 2002, p.7).

As previously mentioned by Henderson and Sugden (1992), children with DCD may or may not have difficulty with gross or fine motor skills. Gross motor skills are tasks that involve the larger muscle groups of the body, such as crawling, walking, jumping, catching, and kicking, while fine motor skills are tasks that involve the use of smaller muscle groups that produce more intricate movements such as, writing, cutting, tying shoe laces, buttoning clothing, and moving pieces in a board game (American Psychiatric Association, 1994).

The gross motor skills of walking and catching have been of interest to researchers studying children with DCD. Woodruff, Bothwell-Myers, Tingley and Albert (2002) developed an index of walking performance to investigate the differences in gait patterns between children with DCD and controls. They were unable to find significant differences between the means of the toe off, single stance, toe off and stride length all expressed as a percentage of the gait cycle. However, they found children with DCD had a much larger variance around the means than the controls. These characteristics suggest an abnormality in the gait pattern of children with DCD. More specifically, an abnormality in the time and distance patterns of children with DCD.

The catching skills of children with DCD are also significantly different from their peers. VanWaelvelde, DeWeerdt, DeCock and Smits-Engelsman (2004) examined children with DCD and matched younger typically developing children who were able to catch a similar number of balls, on a two handed catching task. The qualitative ball catching performance was significantly poorer in the children with DCD than their match. In the preparation phase of catching, the children with DCD showed less elbow flexion and held their hands in front of the body. In preparation for contact with the ball, there was less arm extension, and less flexion of the elbows to absorb force upon contact. They also had a greater number of grasping errors. On a one-handed catching task completed by Deconick et al. (2006), boys with DCD were not found to have differences in timing of the grasp, but failed to achieve maximal hand opening and peak closing velocity as high as their age matched peers.

Research examining the fine motor skills of children with DCD is focused on their drawing and handwriting skills. The drawing skills of children with DCD, as determined by Barnett and Henderson (2002) using the "Draw a Man" test, are characterized by irregular, poorly controlled lines. Shapes drawn were often incomplete, lines did not meet at junctions clearly, and shading was often inaccurate and variable. These characteristics suggest poor control of pencil pressure or force in children with DCD. The group was also poor at representing proportions, depicting features, and providing details in those features. In addition, they had a tendency to draw smaller objects on the page than their well coordinated age matched peers.

Smits-Engelsman, Niemeijer and van Galen (2001) used the Flower Trail component of the MABC to compare children with DCD to published norms and matched controls. Similar to Barnett and Henderson's research (1992), they found higher drawing errors. In contrast, there was no significant difference between groups with respect to pen pressure. Other characteristics of the poor writers identified were, less time to complete the task and a higher velocity with fewer velocity peaks. There was also no significance between the variables of average trajectory length, and number of times the pen was lifted from the page. In addition, there was a tendency for good writers to spend more time pausing above the paper prior to writing. Figures of the handwriting skills of children with DCD, by Sugden and Chambers (2005) illustrate the difficulties with letter formation, spacing and alignment (pp. 170-171). In addition, children with DCD write slower than their peers (Sugden & Chambers, pp.170-171).

Approximately, 6% of children between the ages of 5 and 11 years are estimated to have DCD (American Psychiatric Association, 1994, p.54). The onset of DCD is typically in the early years of life when the child first attempts running, holding a knife and fork, buttoning clothes, or playing ball games (American Psychiatric Association, p.54), but is rarely diagnosed before the age of 5 years when the child first attends school. This may be because the child's lack of coordination only becomes a problem when it results in failure to satisfy his or her particular environmental demands, and it is in school where the child's inability to meet requirements becomes problematic (Sugden, 2006; Cermak & Larkin, 2002, p.15). The disorder has varying, but significant impact throughout the life span. A small portion of children do appear to improve, but more often than not a child's motor difficulties continue into adolescence and adulthood (Sugden).

The long-term outcomes of DCD were examined by Geuze and Borger (1993). They retested children between the ages of 11 and 17 who were diagnosed as clumsy, 5 years prior. At least 50% of the participants showed persistent motor difficulties into adolescence. Similarly, Losse et al. (1991) performed a ten year follow up with children who were determined to have motor coordination difficulties when they were 6 years old. At 16 yeas of age, the majority of the young adults continued to have difficulties with motor coordination.

In 2003, Cousins and Smyth gathered adults diagnosed or self-identified with a history of motor impairments and tested them on manual dexterity, handwriting, construction, obstacle avoidance, dynamic balance, static balance, dual task performance, ball skills, reaction time, movement time and sequencing. The gross motor skills provided the participants with greater difficulty than the fine motor skills, but on a whole the adults were found to retain their motor difficulties.

Fitzpatrick and Watkinson (2003) explored the retrospective views of adults experiencing life with physical awkwardness by conducting an interview. All participants had similar experiences growing up, which began with a breakdown in the execution of a sport skill followed by self-evaluation and humiliation from reactions of others, expression of the consequences of the failure, and attempts to evade any further exposure to awkwardness in the future. On a positive note, these participants were able to come to terms with their physical awkwardness and each participant currently participates in physical activity to some extent.

Assessment of Developmental Coordination Disorder. In the process of identifying children with DCD, there are two distinct phases, including screening and evaluation (Taylor, 2006). There are a number of tests designed to identify and others to assess motor impairment or dysfunction in children (Dewey & Wilson, 2001). The Motor Behaviour Checklist (MBC) is a quick checklist devised to aid parents, teachers, and other professionals in screening children with motor performance difficulties (Taylor). Initially, the teacher answers, yes or no to the statement, "I am concerned about the motor development of this child". If concern is indicated, then the teacher completes 10 additional questions. The questions describe general motor abilities, performance of simple everyday activities, and behavioural patterns of each student. The questions are answered using a 4-point likert scale of descriptions ranging from well-coordinated behaviour to those associated with a performance below the expected level of proficiency (Przysucha & Taylor, 2004). The MBC has been used reliably to screen children for DCD in a catching study by Lefebvre and Reid (1998), and a balance study by Przysucha and Taylor. Other screening tools exist, such as the Movement Assessment Battery for Children Checklist and the Developmental Coordination Disorder Questionnaire (Taylor), however they are longer in length, and therefore require more time to complete (Henderson & Sugden, 1992, p.2; Wilson et al., 2000).

The tests developed to assess motor impairment or dysfunction in children, include the Movement Assessment Battery for Children Performance Test (MABC), the Bruininks-Oseretsky

Test for Motor Proficiency (BOTMP), and the Developmental Coordination Disorder Questionnaire (Dewey & Wilson, 2001). None of these tests is considered the gold standard when it comes to the identification of DCD, however the MABC does appear to be emerging as the most frequently used motor assessment tool used by researchers and clinicians internationally (Polatajko & Cantin, 2005).

The MABC was created to yield an estimate of movement competence in children aged 4 to 12 years (Henderson & Sugden, 1992, pp.2-3). It is not designed for identification of children who have above average motor profiles, as it is not sufficiently discriminating at that end of the normal distribution (Sugden & Chambers, 2005, p.143). There are four age bands (4-6, 7-8, 9-10 and 11-12) of eight tasks divided into three performance areas, manual dexterity, ball skills, and balance (Henderson & Sugden, p.2). The test is scored in four steps. First, the raw score for each task is recorded. The raw score for each task is then converted into a scale score, ranging from zero to five, with lower scores indicating a better performance. The individual task scores are then summed to produce the Total Impairment Score (TIS), which is next converted into percentile form (Burton & Miller, 1998, p.173). A TIS that is at or below the 5th percentile is indicative of a definite motor problem, while a TIS between the 5th and 15th percentile suggests the child is considered at risk of DCD or has a borderline motor dysfunction (Henderson & Sugden, p.107).

The MABC is widely used in research all around the world to classify children into groups designated as clumsy, motor impaired, DCD or typically developing (Sugden & Chambers, 2005, p.143; Smits-Engelsman, Henderson & Michels, 1998). Researchers in China, Japan, Scotland, Australia, Sweden, the Netherlands, and Singapore have found the MABC to be a useful tool to identify children with DCD (Chow, Henderson & Barnett, 2001; Miyahara et al., 1998; Mon-Williams, Pascal & Wann, 1994; Piek & Edwards, 1997; Rosblad & Gard, 1998;

Smits-Engelsman et al. 1998; Wright, Sugden, Ng & Tan, 1994). Smits-Engelsman et al., Rosblad et al. and Wright et al. determined the MABC to be a suitable tool in the Netherlands, Sweden, and Singapore in differentiating children with DCD from their peers. The norms provided in the MABC manual are satisfactory, but may require some alteration. Chow et al. and Miyahara et al. found the test content was suitable for children in China and Japan, however cross-cultural differences were found in the scores. Therefore, norms for these countries may need adjustment. Many of the studies were however, limited to one age band and may yield different conclusions if expanded to other age categories.

Although the MABC is widely used and has unique features that enhance its usefulness for screening, intervention planning, and clinical exploration, Burton and Miller (1998) suggest there is insufficient evidence to adequately establish the reliability and validity of the test (pp.176-177). In contrast, Croce, Horvat, and McCarthy (2001) determined the test-retest reliability to be high. They believe the high test-retest reliability supports the use of the MABC and allows teachers, clinicians, and researchers to be confident of the initial assessment of a child and identification of motor deficiencies. Most recently, Van Waelvelde, Peersman, Lenoir and Smits-Engelsman (2007) identified the reliability of most individual scores and the sub-scores for ball skills were poor, while the manual dexterity and balance scores showed good to moderate reliability. On a whole, they believe the total impairment score of the MABC is a reliable measure for identification of mild to moderate motor impairment in young children.

The validity of the MABC has been determined by comparing scores with the BOTMP. There are a number of studies that examined whether children identified with DCD on one test were consistently identified on the other. Dewey and Wilson (2001) discovered it was not uncommon for children to score within the average range on one test, but to be impaired on the other. Crawford, Wilson and Dewey (2001) also found low levels of agreement between the two tests. Over one third of the children identified with DCD by the BOTMP were not identified by the MABC, whereas one quarter of those not identified with DCD by the BOTMP were identified with DCD on the MABC. Croce et al. (2001) highlighted a statement by Henderson and Sugden (1992) that acknowledged the two tests are similar in some respects, but different in others. Each test was designed with a different goal in mind. The MABC focuses on the identification of impairment, while the BOTMP measures motor ability across both gross and fine motor function (Henderson & Sugden, p.206). With that in mind, Croce et al. believe the concurrent validity between the MABC and the BOTMP is good.

Other aspects that make the MABC an appealing assessment tool are the ease of administering the items of the MABC to participants, reported by Croce et al. (2001). Their participants also commented that the testing was not tedious, difficult, or discouraging, which was not the case for the BOTMP. In addition, Chow and Henderson (2005) found a relatively inexperienced tester can be trained to use the MABC quite reliably by studying the manual and testing children of widely differing ability.

Attention

Attention has most recently been viewed through a neurological approach (Fan et al., 2002). This involves perceiving attention as an organ system with its own anatomy and circuitry. An organ system is defined as differentiated structures made up of various cells and tissues that are adapted for the performance of some specific function and grouped with other structures into a system, in this case attention. The specific functions of attention are broken down into three networks, alerting, orienting, and executive control (Fan & Posner, 2004).

The alerting network is responsible for achieving and maintaining a vigilant state to incoming stimuli (Fan et al., 2002). The main function of the network is to reduce background noise and maintain an adequate amplification for the task at hand (Posner & Badgaiyan, 1998, p.69). It is critical for optimal performance in tasks involving higher cognitive functions, such as tasks involving reaction time and the appearance of infrequent stimuli (Raz, 2004; Posner & Badgaiyan, p.68). The structures of the brain associated with the alerting network are the frontal and parietal regions of the right hemisphere, and the locus ceruleus (Fan et al.; Raz). The locus ceruleus is the originating location of norepinephrine, which is the neurotransmitter linked to the network (Posner & Badgaiyan, p.68).

The orienting network is responsible for selecting information and aligning attention with a source of sensory signals (Raz, 2004; Posner & Rothbart, 2007). The network directs attention from an unattended location to a target location or object (Posner & Badgaiyan, 1998, p.62). This process may be overt, when eye movements accompany movements of attention, or covert, without any eye movement (Posner & Rothbart). It can also be reflexive, a shift of attention to a location due to a sudden event, or voluntary, a conscious search for information in the visual field (Posner, 1980). Orienting can be manipulated by presenting a cue indicating where a target is likely to occur, thereby directing attention to the cued location (Posner). The frontal eye fields and posterior structures of the brain, including the parietal lobe, pulvinar of the thalamus and superior colliculus are the brain structures involved in the orienting network (Raz; Posner & Badgaiyan, p.62). Acetylcholine (cholinergic systems) arising in the basal forebrain is the neurotransmitter involved in orienting (Raz).

The executive network involves more complex mental operations engaged during monitoring and resolving conflict (Fan & Posner, 2004). The network becomes more active and is most needed during tasks that involve complex discrimination in processes such as conflict resolution, error correction, inhibitory control, and planning and resource allocation (Posner & Badgaiyan, 1998, p. 65; Raz, 2004). These processes are involved in variations of the flanker task and the Stroop task (Fan et al., 2002). These tasks activate anterior structures of the brain, such as the anterior cingulate cortex, lateral ventral prefrontal cortex and basal ganglia (Raz). The basal ganglia supply dopamine, the neurotransmitter of the executive control network, to the frontal lobe (Posner & Badgaiyan, p.65).

In 2002, Fan et al. set out to develop a behavioural task to measure the efficiency of each of the three networks in adults. By combining the cued reaction time test developed by Posner in 1980, and the flanker test created by Eriksen and Eriksen in 1974, the group developed the Attention Network Test (ANT; Fan et al., 2002). Their results indicate that the ANT produces reliable estimates of alerting (M = 47 msec, SD = 18), orienting (M = 51 msec, SD = 21), and executive control (M = 84 msec, SD = 25). Fan et al. also determined that the efficiencies of the three networks were uncorrelated and therefore assumed they work independently.

In a later study Callejas, Lupianez, and Tudela (2004), modified the ANT to introduce a short duration high frequency tone that would enable them to independently measure the three networks and the effect of each one on the other two networks. They were able to find interactions between all three networks. First, the executive control network is inhibited by the alerting network, whereas the orienting network raises the efficiency of the executive control network. Second, they found that the alerting network influences the orienting network by accelerating rather than enhancing its effect. Callejas et al. were able to conclude that, although the three attention networks are independent, and are subtended by different neural networks, the three attention networks act under the constant influence of one another in order to produce an efficient and adaptive behaviour.

The distinctions and overlaps between attention networks were replicated by Callejas, Lupianez, Funes and Tudela (2005) and Fan, McCandliss, Fossella, Flombaum and Posner (2005). Callejas et al. used a similar ANT to Callejas et al. (2004) but with a lengthened Stimulus

Onset Asynchrony (SOA), while Fan et al. used the original ANT and functional magnetic resonance imaging (fMRI).

The development of the attention networks has also been examined. Rueda et al. (2004) used both the ANT and the Attention Network Test for Children (ANT-C) on children and adults. The estimates of efficiency and standard deviation for the three attention networks for the age range studied are presented in Table 1. Rueda et al. determined that reaction time (RT) and accuracy improve at each age interval, and increases in efficiency were found for two of the three attention networks. The alerting network was found to develop up to and beyond the age of 10 years into adolescence and adulthood. The executive control network showed strong development from 4 to 7 years of age and stabilized after the age of 7 years. Finally, the orienting network seems to be formed by the age of 4, and therefore did not change in the age range studied (Fan & Posner, 2004; Raz, 2004; Rueda et al.).

Table 1
Estimates of network efficiency (msec) by age (Rueda et al., 2004)

Age (years)	Alerting	Orienting	Executive Control
7	100 (75)	62 (67)	63 (83)
8	73 (67)	63 (66)	71 (77)
9	79 (47)	42 (48)	67 (38)
10	41(47)	46 (44)	69 (44)
Group Mean	73.25	53.25	50.25

* Standard deviations for the RT data are presented between parentheses.

Konrad et al. (2005) were also interested in the development of the attention networks. They modified the ANT to present the stimuli peripherally, rather than centrally and also used fMRI with their adult and child participants. Their data agreed with the findings of Rueda et al. (2004), suggesting that there is a transition from functional yet immature systems supporting attention functions in children to more definitive, mature networks in adults.

Assessment of Attention. The Attention Network Test for Children (ANT-C) was adapted from the adult version, the ANT, by Rueda et al. (2004). The ANT-C, attempts to quantify the processing efficiency of the alerting, orienting and executive control networks of children (Fan et al., 2002; Raz, 2004). It was adapted with the intent of making the task more appealing for children by replacing the target arrows with swimming goldfish (Rueda et al.). The ANT-C uses the reaction time (RT) between conditions to measure efficiency of each network. Depending on the cue condition, each trial may or may not begin with a cue that informs the participant that a target will soon appear and of the potential location of the target (Posner, Sheese, Odludas & Tang, 2006). There are four warning cue conditions (no cue, centre cue, double cue, and spatial cue). Each is illustrated in Figure 1 (Fan et al.). In the no cue trials, the participant is not presented with a centre or spatial cue. They continue to see only the fixation point. In the centre cue trials, the participant is presented with an asterisk where the fixation dot is located. In the double cue trials, the participant is presented with two asterisks, one above and one below the fixation point. Finally, in the spatial cue trials, only one asterisk is presented to the participant, either above or below the fixation point. The spatial cues are always valid. In other words, the targets are always presented in the same location as the warning cue (Fan et al.).

+	*	* + *	* +	+ *
No Cue	Centre Cue	Double Cue	Spatial Cue (Up)	Spatial Cue (Down)

Figure 1. Warning conditions of the Attention Network Test for Children (Rueda et al., 2004).

The target is then presented to the participant. The participant must determine which direction the fish is swimming, left or right. The target appears above or below the fixation point, and is potentially accompanied by four flankers. The flankers surrounding the target either match the targets direction (congruent condition), are in the opposite direction (incongruent condition), or do not appear (neutral condition), as seen in Figure 2. When the researchers present the test instructions to their young participants, they ask for help with feeding the fish. The participant helps feed the fish by pressing the button corresponding to the direction in which the middle fish or single fish is swimming (Rueda et al., 2004).

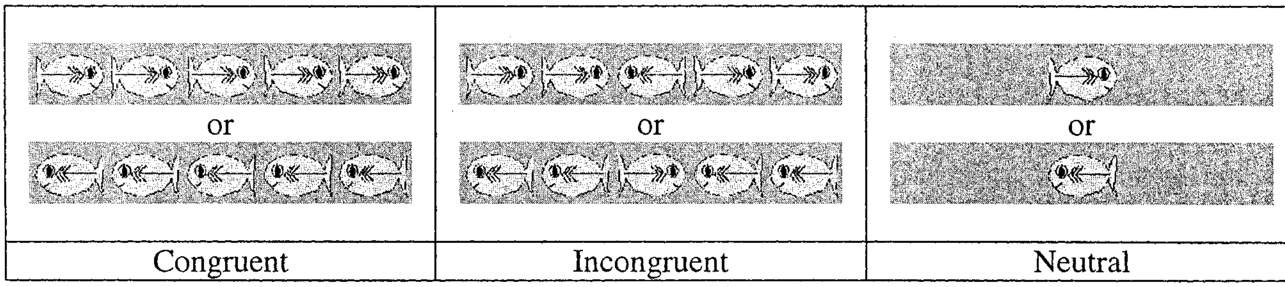

Figure 2. Target conditions of the Attention Network Test for Children (Rueda et al., 2004).

Each trial consists of five events, which are illustrated in Figure 3. The events include an initial fixation period of random duration varying from 400 msec to 1600 msec, followed by a warning cue for 150 msec. A second fixation period then appears for 450 msec, followed by the target and flankers, which stay on the screen until the participant responds or a time span of 1700 msec is reached. Finally, there is a feedback screen for 2000 msec if the correct response is given, followed by a constant post-target fixation period of 1000 msec. If the incorrect response is given, the feedback screen is skipped and the sequence continues with the post-target fixation period (Rueda et al., 2004).

+	* + *	+	 +	 +	+
Initial Fixation Period (400-1600 msec)	Warning Cue (150 msec)	Second Fixation Period (450 msec)	Target and Flankers (<1700 msec)	Feedback (200 msec)	Post-Target Fixation Point (1000 msec)

Figure 3. Sequence of events of each trial of the Attention Network Test for Children (Rueda et al., 2006).

The reliability and validity of the ANT-C have not been formally examined. However in the adult ANT, the test-retest correlations for the cognitive subtractions used to provide three numbers that describe the efficiency of each of the three attention networks are somewhat less reliable than that of the raw RT (r = 0.87). The alerting network appears to be the least reliable (r = 0.52), whereas the executive control network is the most reliable (r = 0.77) and the orienting network falls between the two (r = 0.61; Fan et al., 2002). To add to the reliability of the ANT-C, Rueda et al. (2004) tested a group of adults and a group of 10 year old children on both the adult ANT and the ANT-C. Neither version showed a significant difference between children and adults. However, the adult ANT provided conflict scores nearly twice as high as the ANT-C. This suggests the adult ANT is considerably more difficult.

Developmental Coordination Disorder and Attention

The etiology of DCD is unknown (Cermak & Larkin, 2002, p.16). To date, a single factor has not been identified to be the cause of DCD. However, various factors have been investigated. Factors considered over the years include brain damage or dysfunction, genetic predisposition, impairment in information processing, or an impoverished environment (Cermak & Larkin, 2002, p.16). In a meta-analysis conducted with some of the literature aimed at identifying the mechanisms responsible for DCD, Wilson and McKenzie (1998) suggested that relative to matched controls, children with DCD most consistently demonstrate a deficiency with respect to the processing of visuospatial information. This conclusion is not all that surprising, since one of the associated behaviours of DCD is difficulties in attention (Sugden & Chambers, 2005, p. 14). In a study by Dewey et al. (2002), the research team investigated the problems of attention experienced by children with DCD. The parents of the participants were asked to complete the Attention Problems Subscale of the Child Behaviour Checklist and the Hyperactivity Index from the Abbreviated Symptom Questionnaire (Achenbach, 1991). The results revealed that both children with DCD and children suspected of having DCD scored poorer on the measures of attention than the comparison children.

Based on the findings of the meta-analysis by Wilson and McKenzie (1998), Wilson and Maruff (1999) investigated children with DCD on their movement of attention through visual space to designated target locations using the Covert Orienting of Visuospatial Attention Task (COVAT). The COVAT provides a measure of an individual's ability to direct visuospatial attention to areas of the visual field without accompanying eye movements. In the voluntary mode, the RTs for both Children with DCD and the control children were faster when the stimulus appeared at the cued rather than the uncued location (spatial precue effect). More importantly, the magnitude of the effect was significantly greater for the children with DCD than for the control participants. Therefore, only the children with DCD demonstrated results consistent with a deficit in the disengagement operation of directing covert attention. These results confirmed the earlier findings of Wilson, Maruff and McKenzie in 1997.

It is also important to acknowledge that the attention deficit was not evident in all of the children with DCD. However, the RTs of most children with DCD were slower than those of the controls, which may be explained by the motor deficits that occur as a part of DCD, although it is unlikely that the motor disabilities led to the abnormal orienting response (Wilson & Maruff, 1999).

Mandich, Buckolz and Polatajko (2003) attempted to replicate Wilson and Maruff's (1999) findings, and continue the examination of the inhibitory function of children with DCD with respect to the movement of attention. Their intention was to clear up the uncertainty of whether the disengagement operation was volitional or whether it was affected by automatic factors. To do this they used a spatial precue task with both informative and uninformative precue conditions. Mandich and colleagues were successfully able to demonstrate that children with DCD exhibit a number of inhibitory deficits with respect to the intentional movement of attention through visual space. More specifically, the children with DCD took longer to disengage attention from a voluntary cued location, so that it could be moved to the target position.

The patterns of attention deficits exhibited by the children with DCD parallel those that have been observed in children with attention deficit hyperactivity disorder (ADHD). Both groups have been shown to perform within normal limits on COVAT in the reflexive orienting mode, but display abnormalities within the voluntary orienting mode (Wilson & Maruff, 1999). In addition to the orienting network, children with ADHD have been tested using a modified ANT to investigate the efficiency of the attention networks, alerting, orienting and executive control. Konrad, Neurfang, Hanisch, Fink and Herpertz-Dahlmann (2006) modified the ANT by having the arrow targets appear in a vertical row to either side of the fixation point, rather than in a horizontal row above or below the fixation point. The children with ADHD were boys between the age of 8 and 12 years. They demonstrated efficiency scores of 55 msec, 138 msec and 122 msec for the alerting, orienting and executive control, respectively. These results suggest a significant deficit in the executive control network when compared to their peers without ADHD.

The ANT has also been a convenient and effective tool in the evaluation of attention abnormalities associated with strokes and other brain injuries. It has also been used successfully to test a variety of clinical populations, including individuals with borderline personality disorder and schizophrenia. The findings from these studies may be useful in designing better interventions and determining the effectiveness of pharmacological and behavioural interventions (Fan & Posner, 2004). It would therefore be interesting to examine the results of children with DCD on the ANT-C.

Method

Procedure

Recruitment. After receiving ethical approval from the Ethics Review Board at Lakehead University, participants were recruited through the Thunder Bay Catholic District School Board, the Motor Development Clinic at Lakehead University, summer camps offered through the Athletic and Science departments at Lakehead University, local community groups, health care providers and day care centres, and word of mouth.

A proposal similar to that submitted to the Ethics Review Board at Lakehead University was submitted to the Thunder Bay Catholic District School Board. Approval was granted and a number of schools were identified to be contacted. Information packages, including cover letters and consent forms for the principal, teachers and participants along with a sample Motor Behaviour Checklist (MBC), were delivered to each school (refer to Appendices A through D). Upon confirmation of participation in the study, Teacher Cover Letters, Consent Forms and MBCs with instructions were delivered. Each teacher was asked to complete a checklist for each boy in his or her class. Once the checklists were completed by the teachers, participant information packages including a cover letter and consent form were dropped off for teachers to send home with students. At this time, the completed teacher consent forms and checklists were collected. It was then left to the parents of the children to contact the researcher to set-up a time for testing.

As well, past and present participants of the Motor Development Clinic were contacted by the researcher if they were the correct age for the study. Contact information was supplied by Dr. Jane Taylor, the coordinator of the program. Also, participants were recruited through referrals of an Occupational Therapist in Thunder Bay to the upcoming Motor Development Clinic.

In addition, the organizers of the Thunderwolves Basketball Camp and Superior Science Camp sent home participant information packages with their participants that met the age requirements. Again, it was left up to the parent of the child to contact the researcher if they were interested in participating. In addition, posters were hung at local community centres and a chiropractic office, an advertisement was published in a local skating club newsletter, and flyers were distributed at a local soccer complex and day care centre to children that fell into the identified age range (refer to Appendices E through G).

Finally, awareness of the study was passed around by word of mouth through the Kinesiology and Athletic Departments at Lakehead University. A number of participants who were recruited were children, relatives, or friends of faculty, staff and students.

Screening. The MBC was used as an initial screening tool for potential participants. The information provided by the checklist offered an early indication of group association. Children recruited from the Thunder Bay District Catholic School Board were the only group to be screened using the MBC. Past and present participants of the Motor Development Clinic and those referred for the upcoming clinic were screened using other assessment techniques by the occupational therapist that referred them. All participants were assigned to a group based on their percentile ranking on the MABC.

Participants. A sample of twenty-five males between the age of 7 and 10 years were recruited to participate in the study. All participants with a Total Impairment Score (TIS) on the MABC at or below the 15^{th} percentile were identified as the group with DCD. The remaining participants had a TIS at or above the 20^{th} percentile and formed the group without DCD. Both groups had normal or corrected to normal vision, an added requirement of the ANT-C.

Testing. Testing was completed in either one or two sessions. Most participants completed both the MABC and the ANT-C in a single session, approximately 1 hour in length. However, boys recruited through referrals for the upcoming Motor Development Clinic completed the testing in two sessions. The first session, roughly 1 hour in length, included the MABC test as well as other tests included in the initial assessment for the clinic. A second visit was requested to complete the ANT-C. This session was completed in approximately 30 minutes. All testing sessions took place in room 1028A in the C.J. Sanders Field House at Lakehead University.

Assessment of the MABC was completed according to the manual by Henderson and Sugden (1992). Refer to Appendix H for the protocol. The participant's parent or guardian was asked to complete an MABC Checklist to provide descriptive information on the child's behavioural problems related to motor difficulties. The MABC Checklist was adapted to include a question about medication related to Attention Deficit Disorder with or without Hyperactivity (see Appendix I). This information was collected to assist in the interpretation of the results and was not used as inclusion or exclusion criteria.

The ANT-C was programmed on the computer by the researcher. The appearance of the test and the procedure replicated the program guidelines used by Rueda et al. (2004). Refer to Appendices J and K for the developmental procedure and protocol.

Preliminary Evaluation. A preliminary examination of data using sixteen participants was completed and presented as a poster at the North American Federation of Adapted Physical Activity (NAFAPA) conference in Indianapolis Indiana, on September 6th, 2008 (see Appendix L). The review provided an opportunity to become familiar with the organization, analysis and interpretation of data, offered a good indication of what to expect when the entire sample was included, and identified factors to examine for interpretation of the results.

Analysis

The independent variable of interest is the two groups, boys with and with DCD, while the dependent variables are median reaction time (RT) on accurate trials and error rate. RT is recorded as the time from onset of the target to the time when the participant pushes the button on the keyboard. RTs from correct trials were trimmed to exclude outlying responses. The lower cut-off was set at 100 msec to exclude no responses and anticipatory responses, and the upper cut-off was set at 1500 msec (Callejas et al., 2005; Roberts et al., 2006). Incorrect trials, which included trials where the child responded by pushing the incorrect button on the keyboard were also excluded, but used to calculate the error rate and the overall error percentage (Van Donklear et al., 2005). The error rate is calculated as the percentage of incorrect trials within a condition (congruent, incongruent or neutral), or a percentage of all the trials (Van Donklear et al., 2005).

To determine the efficiency of each attention network, first the RTs are organized by their warning cue and target type. The median of each condition was then used to determine the median RTs for the no cue, centre cue, double cue, spatial cue, congruent and incongruent conditions (Rueda et al., 2004). Next, three simple calculations were computed to produce the network efficiency scores. First, subtracting the median RT obtained in the double-cue conditions from the median RT in the no cue conditions measures the alerting network due to the presence of a warning signal (Fan et al., 2002; Posner et al., 2006). Second, the orienting network is measured by subtracting the median RT of the spatial cues from the median RT of the central cues, since the spatial cue, but not the central cue, provides valid information on where the target will occur (Fan et al., 2002; Posner et al., 2006). Lastly, the executive control network is responsible for conflict resolution. It is measured by subtracting the median RT of the congruent target trials from the median RT of the incongruent trials (refer to Figure 4; Fan et al., 2002; Posner et al., 2006).

Alerting = median RT no cue condition – median RT double cue condition

Orienting = median RT centre cue condition – median RT spatial cue condition

Executive Control = median RT incongruent conditions – median RT congruent conditions

Figure 4. Network efficiency calculations (Fan et al., 2002).

Next, independent sample t-tests were performed on the no cue, double cue, centre cue, and spatial cue, as well as the alerting, orienting and executive control network scores to determine if there was a significant difference between the efficiency of the networks in boys with and without DCD. The percentage of error between target type (congruent, incongruent and neutral) and warning cue type (no cue, double cue, centre cue and spatial cue) were also examined using independent sample t-tests. Bonferroni corrections for inflated Type I error were applied to both analyses in order to control for the number of analyses conducted (Konrad et al., 2006). Due to the small sample size Cohen's d effect size calculations were also completed. Independent sample t-tests were also used to examine the difference between the overall median RT and error rate between groups (Van Donklear et al., 2005). Additional, pairwise t-tests were used to examine the difference between the no cue and the double cue, the centre cue and the spatial cue, and the incongruent and congruent target conditions within each group. Finally, bivariate correlations were computed to examine two types of relationships. The first correlation was used to investigate the relationship between the alerting, orienting and executive control networks within each group. The second correlation explored the relationship between the group with DCD and the group without DCD on each of the attention networks.

Interpretation of the ANT-C Scores

In general, higher network scores, or a greater difference between the warning cues or targets used in the network score calculations represent less efficient networks, while lower network scores, or a lesser difference between the conditions represent more efficient networks. In the alerting network, a higher network score would describe difficulty maintaining alertness without a cue. A high score in the orienting network indicates a difficulty disengaging from the centre cue where no target appears, whereas a high score in the executive control network suggests difficulty resolving conflict (Fan & Posner, 2004). If this interpretation were true, smaller network scores or a lesser difference between conditions would be considered more efficient.

Unfortunately, it is not always that straight forward. High network scores may also be considered efficient when a participant is making proper use of the cues or even expending increased effort. This explanation is more probable when the overall RTs are relatively quick. Similarly, the smaller network score described in the previous paragraph would only be efficient if associated with quicker overall RTs. Consequently, if the small network score or lesser difference was calculated using slow RTs, the network would be considered less efficient.

Hypothesis

Prior to performing all statistical analyses, it was expected that the overall reaction time of the boys with DCD would be slower than that of the boys without DCD, similar to the results of Wilson and Maruff (1999). In regard to the individual attention networks, it was expected that the children with DCD would demonstrate deficits in the orienting and executive control networks. Previously in the orienting network, both boys with DCD and those with ADHD were found to have a deficit on the voluntary condition of the COVAT (Wilson & Maruff, 1999). While in the executive control network, a deficit was found in children with ADHD using a modified ANT (Konrad et al., 2006). Similar results are expected for the boys with DCD based on the similarities on the COVAT and the additional attention difficulties associated with DCD (Sugden & Chambers, 2005, pg. 14). On the final attention network, alerting, it has been demonstrated that the network does not completely develop until the age of 10 years or beyond, therefore it could be speculated that 10-year-old boys with DCD might produce scores associated with the development of the alerting network (Fan & Posner, 2004). In addition, as previously mentioned, attention problems are an associated behaviour of some children with DCD (Sugden & Chambers). Consequently, some boys with DCD may also demonstrate a deficit in the development of the alerting network compared to boys without DCD of the same age, and similar to the deficit in performance of motor tasks (American Psychiatric Association, 1994, pg. 55).

Results

Group Characteristics

Initially, twenty-seven participants were tested on the MABC, however one did not complete the ANT-C test and a second was subsequently found to have Autism. Therefore, twenty-five participants were included in the data analysis. All of the participants were boys between the age of 7 and 10 years.

Fourteen boys were identified as, at risk or with DCD. Together, these boys formed the first group, boys with DCD. They had a mean age of 9 years (SD = 10.97). The group Total Impairment Scores (TIS) ranged from 10 to 27.5, which correspond with the 15th and below the 1st percentile. The group TIS mean was 16.3 (SD = 5.75), while the rank of the group mean was at the 6th percentile.

The remaining eleven boys were not identified with DCD, and therefore formed the second or control group, boys without DCD. The mean age of this group was 8.6 years (SD = 0.96). The individual TIS scores ranged from 1 to 8.5, or the 89th to the 20th percentile. The mean TIS was 4.6 (SD = 2.26), which is equivalent to the 51st percentile. An independent sample t-test revealed that the boys with DCD were not significantly older than the boys without DCD when age was examined ($t_{(23)} = 1.17, p > 0.05$). Therefore, the two groups were assumed to be the same chronological age.

In contrast, analysis of the MABC scores, also by independent sample t-tests, showed that on both the TIS and the percentile ranking, the two groups were significantly different. The boys without DCD scored significantly higher on the TIS ($t_{(23)} = 6.96, p < 0.05$), while scoring significantly lower on the percentile ranking ($t_{(23)} = -6.812, p < 0.05$; see Figures 5 and 6). Based on these two analyses, it was concluded that the two groups were of similar age, and the boys assigned to the group without DCD demonstrated significantly better overall motor abilities than the boys from the group with DCD. Complete individual scores on the MABC are available in Appendix M.

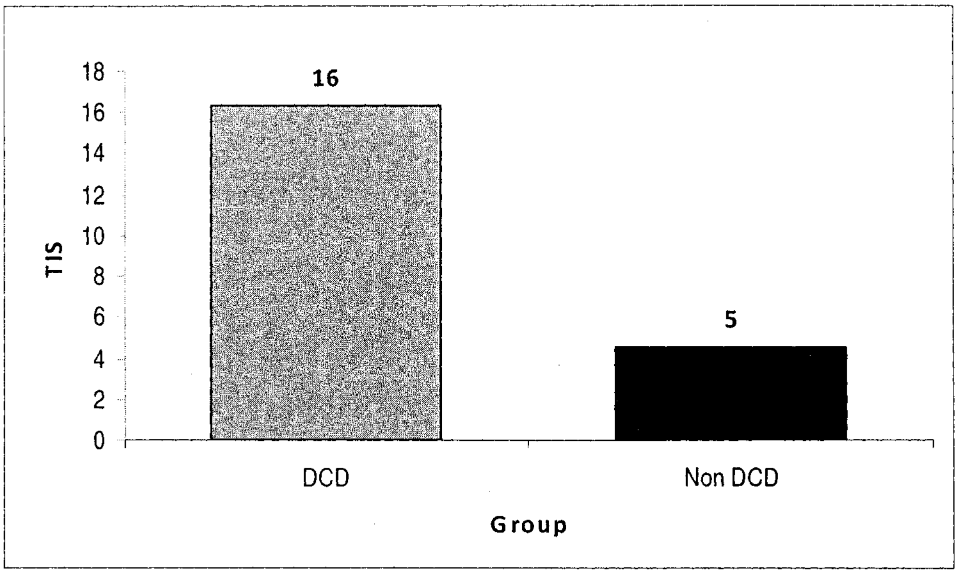

Figure 5. Comparison of Group means on the Total Impairment Score (TIS) on the Movement Assessment Battery for Children.

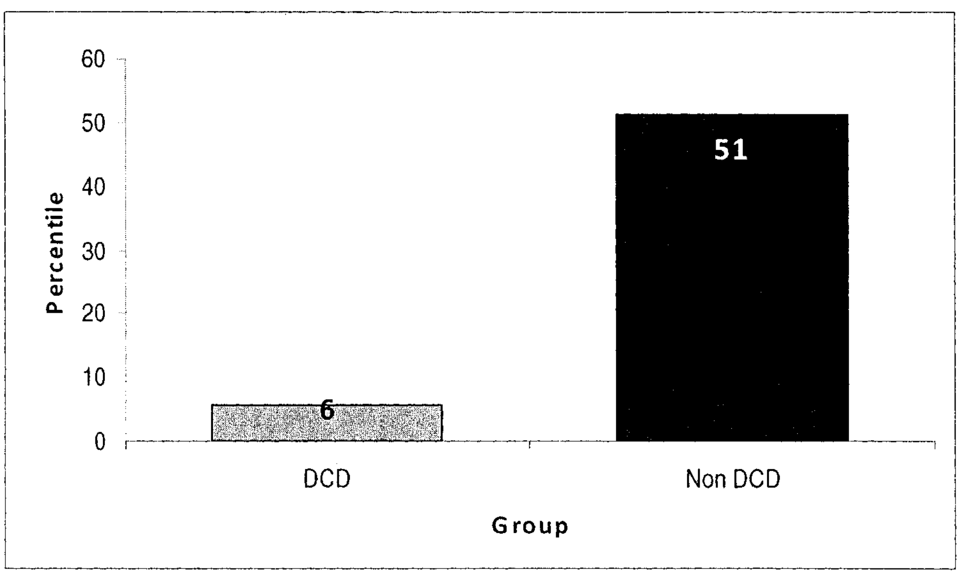

Figure 6. Comparison of group mean percentile scores on the Movement Assessment Battery for Children.

Finally, the results of the MABC Checklist identified only one participant taking medication for ADD or ADHD. From parent interviews for the Motor Development Clinic, eight of eleven boys with DCD who participated in the clinic were diagnosed or in the process of identification for ADD or ADHD.

Alerting Network

The efficiency of the alerting network is calculated by subtracting the median RT obtained in the double-cue conditions from the median RT in the no cue conditions (Fan et al., 2002). The median RT of no cue and the double cue conditions for boys with DCD were 833 msec and 789 msec, respectively (see Figure 8). The individual alerting scores for the group ranged from -65 msec to 141 msec, while the groups' mean alerting score was 44 msec with a standard deviation of 69 (see Figure 7 and 9). In comparison, the boys without DCD had a no cue median of 844 msec and a double cue median RT of 788 msec (see Figure 8). The individual alerting scores of the group ranged from -64 msec to 212 msec, while the groups' mean alerting score was 56 msec with a standard deviation of 72 (see Figure 7 and 9).

The difference between the alerting score of the boys with and without DCD was not found to be significant when an independent sample t-test with a Bonferroni correction was utilized ($t_{(23)} = -0.43$, $p = 0.51$). Further confirmation of this result is supported by the small effect size (d = -0.18). The two groups were also not significantly different on their no cue and double cue RT scores (No Cue, $t_{(23)} = -0.28$, $p = 0.78$; Double Cue, $t_{(23)} = 03$, $p = 0.98$). In contrast, a pairwise sample t-test determined a significant difference between the no cue and double cue conditions within each group (DCD, $t_{(13)} = 2.37$, $p = 0.03$; Non DCD, $t_{(10)} = 2.59$, $p = 0.03$).

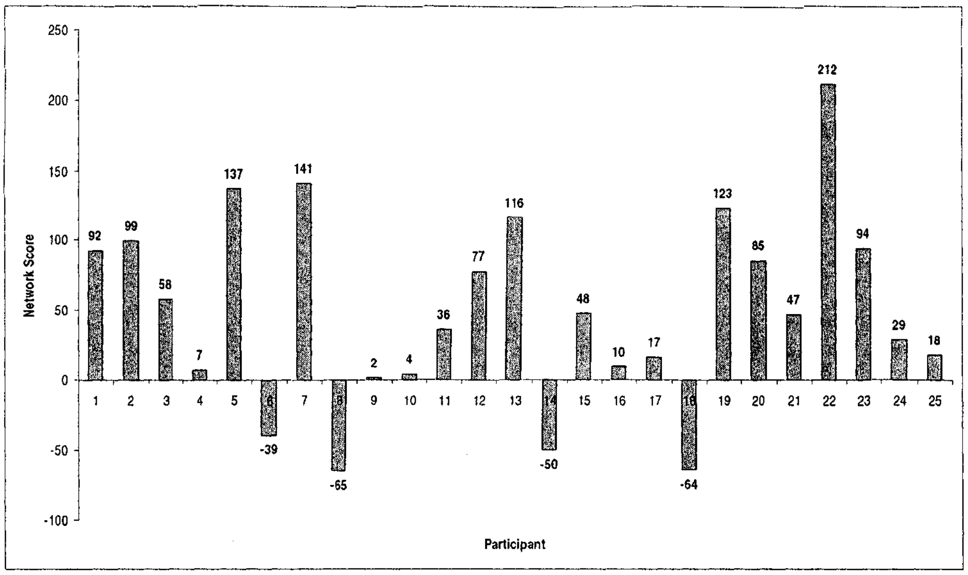

Figure 7. Individual alerting network efficiency scores.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

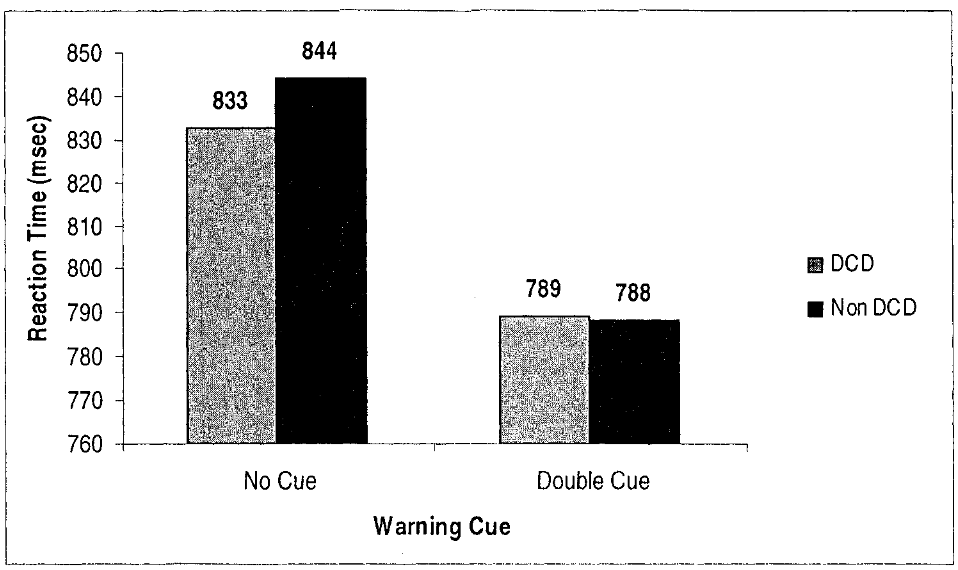

Figure 8. Comparison of group means on median reaction time in the no-cue and double-cue conditions.

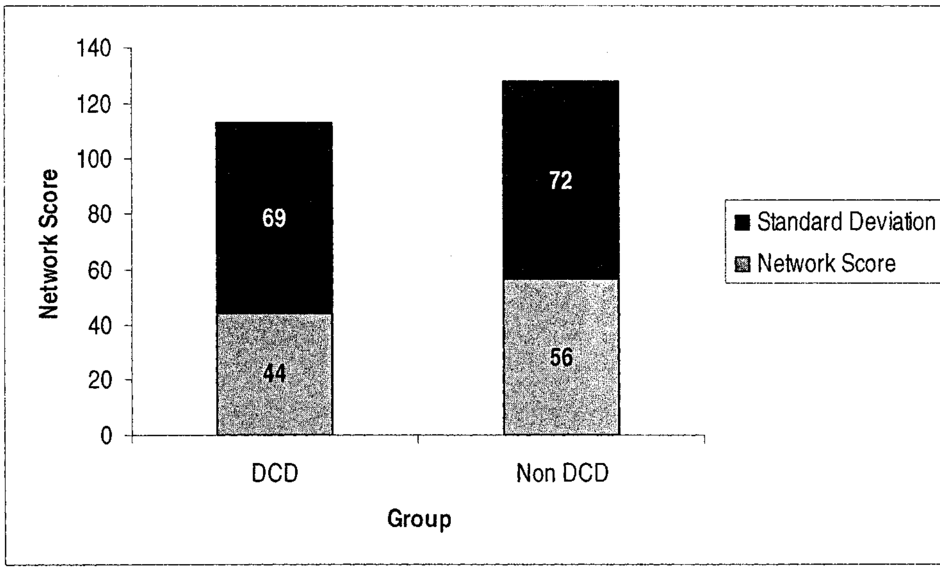

Figure 9. Comparison of group means and standard deviations on alerting scores.

Orienting Network

The boys with DCD had individual orienting scores that ranged from -89 msec to 154 msec and a group mean score of -2 msec with a standard deviation of 72 in the orienting network (see Figure 10 and 11). The boys without DCD had had individual orienting scores that ranged from -141 msec to 207 msec and a group mean score of 46 msec with a standard deviation of 100 (see Figure 10 and 11). The orienting score was calculated by subtracting the median RT of the spatial cue from the median RT of the centre cue conditions (Fan et al., 2002). The median centre cue values for the boys with and without DCD were 833 msec and 818 msec, respectively (see Figure 12). The boys with DCD had a spatial cue median RT of 835 msec and the boys without DCD had a median RT of 773 msec (see Figure 12).

Similar to the alerting network, the independent sample t-test also found no significant difference between the orienting scores of the boys with and without DCD ($t_{(23)} = -1.387$, $p = 0.18$). Although no difference was found between the groups, a medium effect size was revealed (d= -0.55). In addition, no significant difference was found on the RTs of the spatial cue and centre cue conditions between the two groups (Centre Cue, $t_{(23)} = 0.36$, $p = 0.72$; Spatial Cue, $t_{(23)} = 1.48$, $p = 0.15$), or within each group on the centre cue and spatial cue (DCD, $t_{(13)} = 0.\text{-}0.11$, $p = 092$; Non DCD, $t_{(10)} = 1.51$, $p = 0.16$).

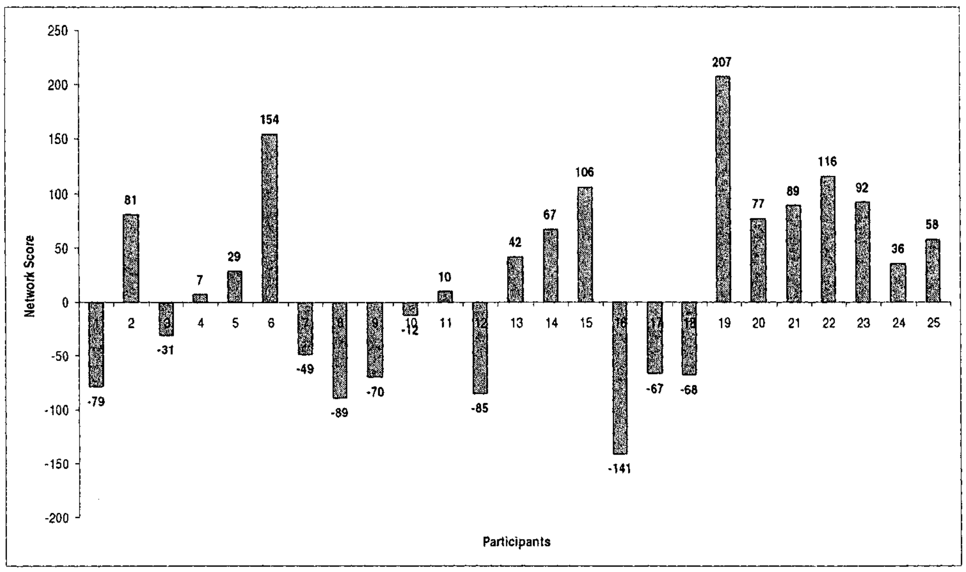

Figure 10. Individual orienting network efficiency scores.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

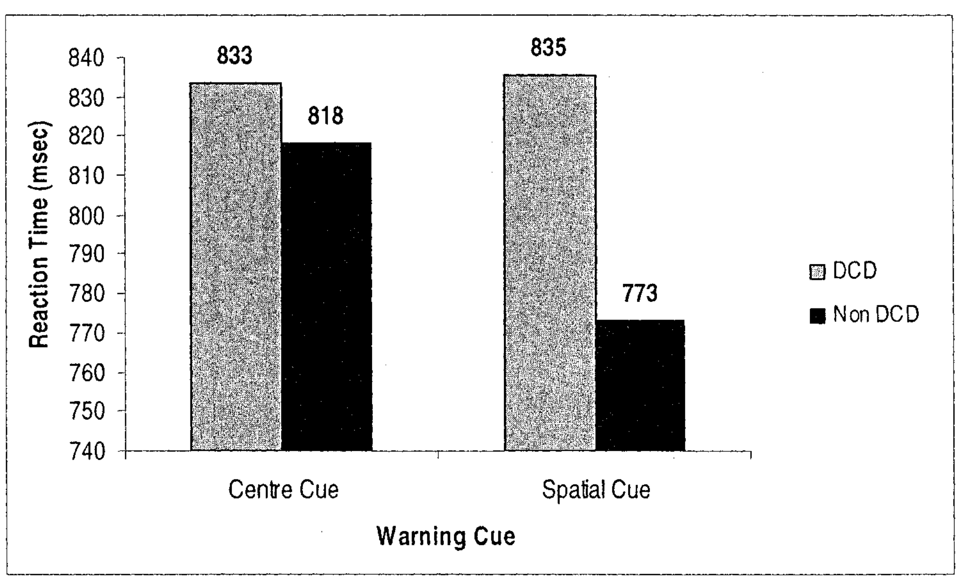

Figure 11. Comparison of group means on median reaction time in the center-cue and spatial-cue conditions.

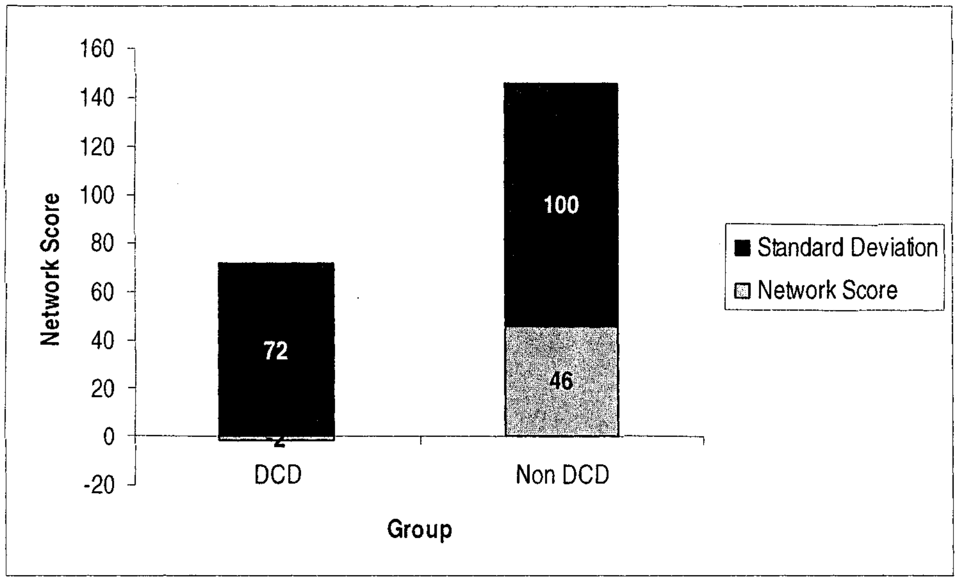

Figure 12. Comparison of group means and standard deviations on orienting scores.

Executive Control Network

The efficiency of the executive control network is found by subtracting the median RT of the congruent target conditions from the median RT of the incongruent target conditions (Fan et al., 2002). The group with DCD had an incongruent median RT of 934 msec and a congruent median RT of 799 msec, which yielded an executive score of 135 msec with a standard deviation of 76 (see Figure 14 and 15). The individual executive control scores of the group ranged from 7 msec to 252 msec (see Figure 13). The group without DCD had an incongruent median RT of 903 msec and a congruent median RT of 786 msec (see Figure 14). The executive control score was 117 msec with a standard deviation of 53 (see Figure 15). The individual executive control scores of the boys without DCD ranged from 22 msec to 200 msec (see Figure 13).

Once again, like the alerting and orienting networks, a significant difference was not found between the executive control scores of the boys with and without DCD ($t_{(23)} = 0.51$, $p = 0.67$) and a small effect size was recorded (d = 0.28). These results and the lack of significant difference between the incongruent and congruent target conditions further confirms the similarity of the two groups (Incongruent, $t_{(23)} = 0.68$, $p = 0.50$; Congruent, $t_{(23)} = 0.38$, $p = 0.71$). A difference was however found between the incongruent and congruent RTs of each group of boys (DCD, $t_{(13)} = 6.68$, $p = 0.01$; Non DCD, $t_{(23)} = 7.30$, $p = 0.01$).

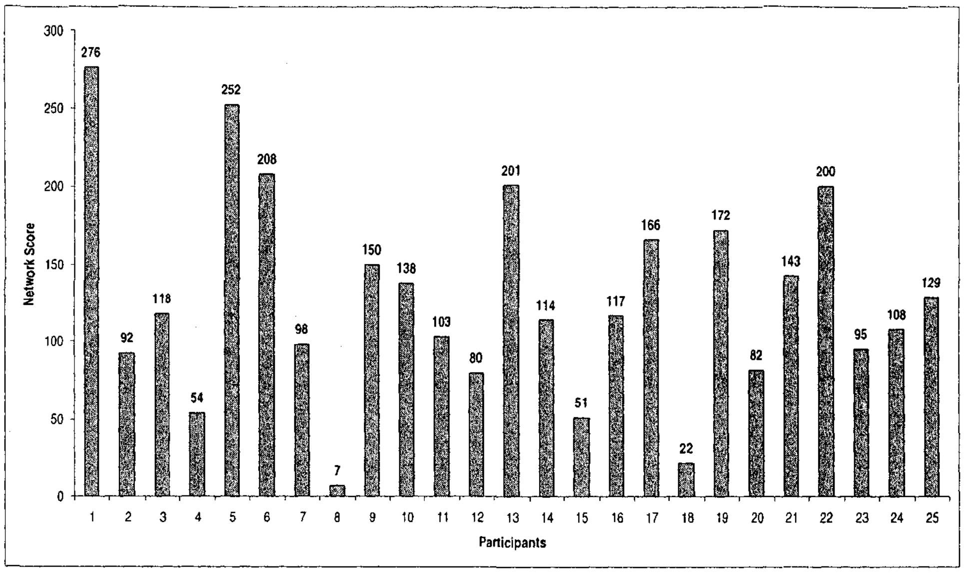

Figure 13. Individual executive control network efficiency scores.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

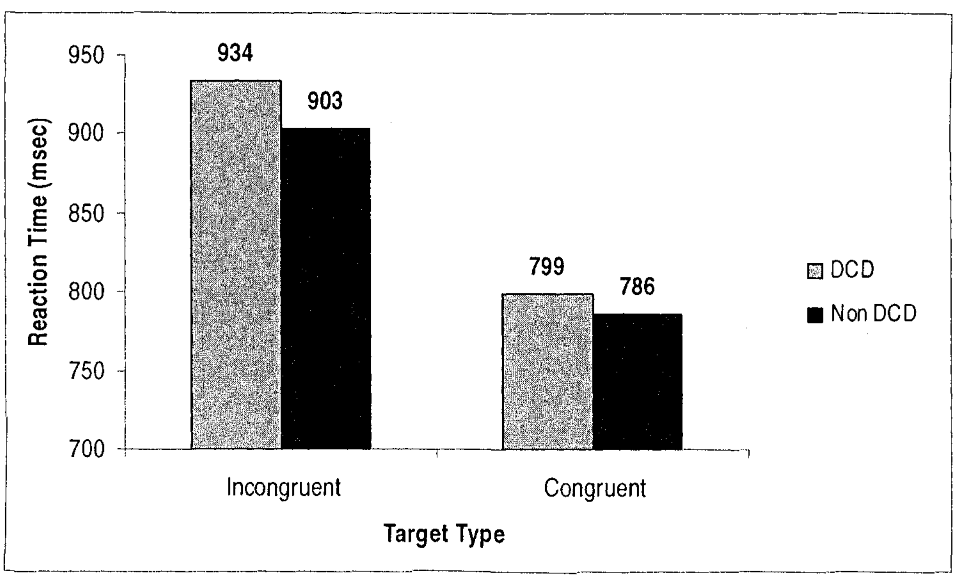

Figure 14. Comparison of group means on median reaction time in the incongruent and congruent conditions.

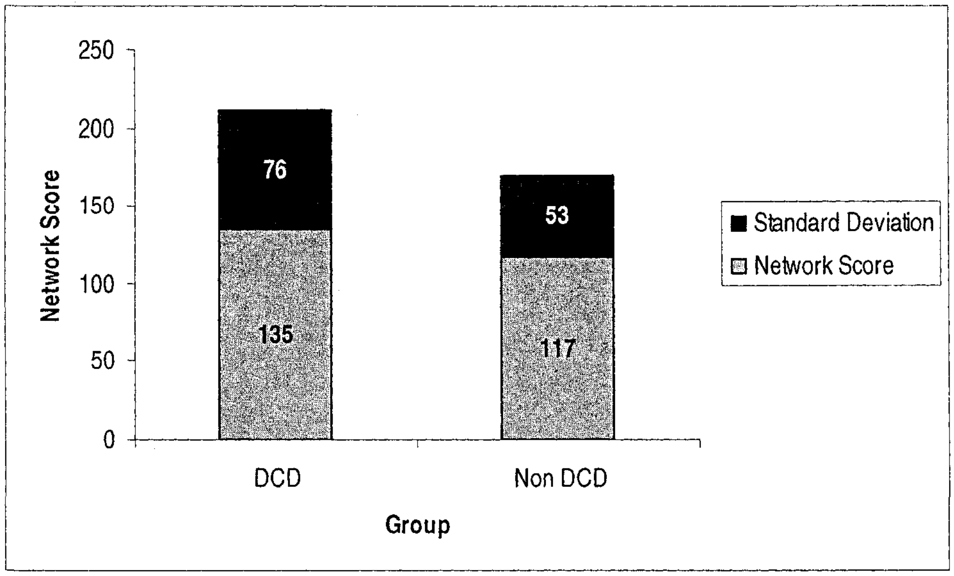

Figure 15. Comparison of group means and standard deviations on executive scores.

Error Rates

The error rates were examined by both target and warning cue condition. The error rates were determined by dividing the number of incorrect trials by the total number of trials in each specific target or warning cue type. As a review, the target conditions included congruent, incongruent and neutral. The group with DCD had an error percentage of five, eleven and seven, respectively. Where as, the group without DCD had equal or lower error percentages of five, seven and five for the congruent, incongruent and neutral warning cue types. Using an independent sample t-test with a Bonferroni correction, the two groups were not found to be significantly different in error rates on any of the target types (Congruent; $t_{(23)} = -0.11, p = 0.91$; Incongruent, $t_{(23)} = 1.07, p = 0.29$; Neutral, $t_{(23)} = 0.69, p = 0.5$; see Figure 13). Individual target type error rates are available in Appendix N. In addition, a one-way ANOVA was used to determine if there was a difference in responses to the target types themselves in each group. They too, were not significantly different in the DCD group ($F_{(39)} = 1.80, p = 0.18$), or the non DCD group ($F_{(43)} = 0.32, p = 0.81$).

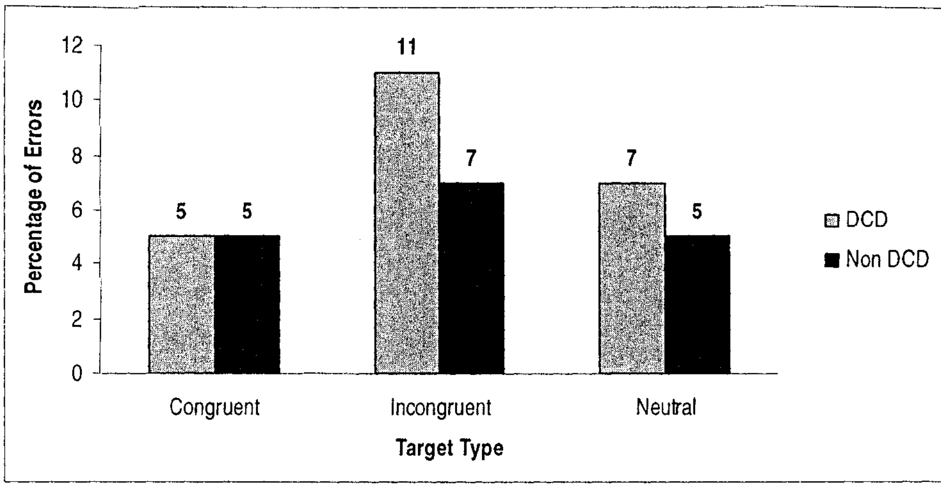

Figure 16. Comparison of percentage of error for target type illustrated by group mean.

Recall, there are four warning cue types, no cue, double cue, centre cue and spatial cue. The boys with DCD had a nine percent error in the no cue condition, an eight percent error for the double cue and centre cue conditions, and a seven percent error for the spatial cue condition. The boys without DCD were slightly more accurate with error rates of eight percent for the no cue, six percent for the double cue and spatial cue, and five percent for the centre cue conditions. When the difference between the two groups was examined using an independent sample t-test with a Bonferroni correction, there was no significant difference between the boys with DCD and the boys without (No Cue, $t_{(23)} = 0.30, p = 0.77$; Double Cue, $t_{(23)} = 0.77, p = 0.44$; Centre Cue, $t_{(23)} = 0.88, p = 0.39$; Spatial Cue, $t_{(23)} = 0.47, p = 0.66$; see Figure 14). Refer to Appendix N for individual error rates for warning cue conditions. Additionally, the difference between the target conditions themselves in each group was examined using a one-way ANOVA. Similar to the warning cue types, there was no significant difference in the DCD group ($F_{(53)} = 0.18, p = 0.91$), or the non DCD group ($F_{(32)} = 1.37, p = 0.26$).

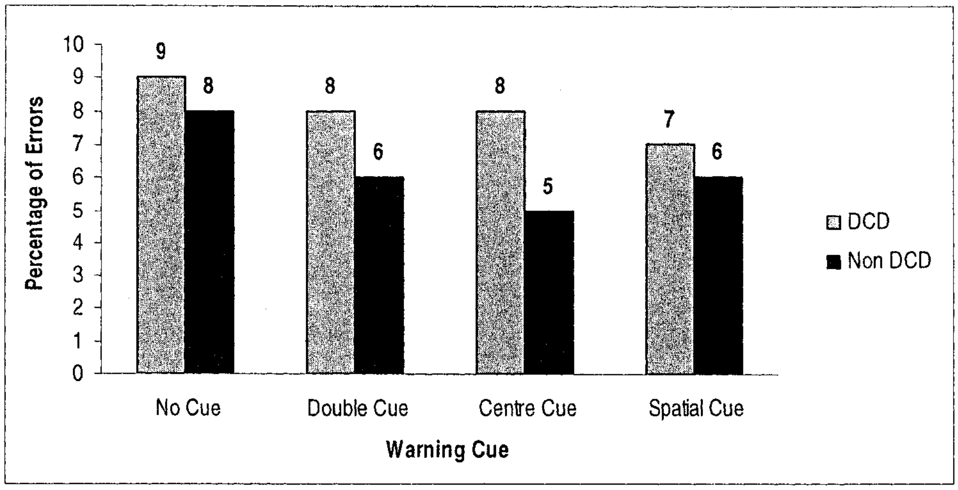

Figure 17. Comparison of group means percentage of error for warning cue conditions.

In addition to the target and warning cue condition error rates, an overall error rate was calculated for all trials in the ANT-C. Again, the total number of incorrect trials was divided by the total number of trials in the three experimental blocks. The boys without DCD had a slightly lower overall error percentage, at five percent, than the boys with DCD, at eight percent. There was no significant difference in error rates between the two groups, when inspected by an independent sample t-test, however ($t_{(23)} = 0.94$, $p = 0.36$; see Figure 15). Each participant's overall error rate can be located in Appendix N.

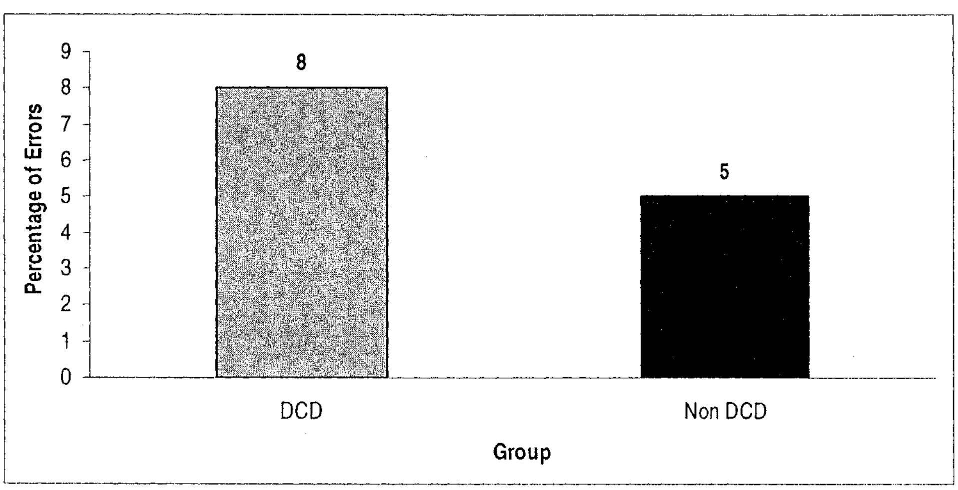

Figure 18. Overall mean percentage of error for boys with and without DCD.

Median Reaction Time

The median RT was calculated by taking the median of all correct trials during the ANT-C for each participant. Then the mean was computed for each group. The median RT for boys with DCD was 841 msec with a standard deviation of 110, while the median RT for boys without DCD was 818 msec with a standard deviation of 66. The RTs of the two groups were compared using an independent sample t-test and they were not found to be significantly different ($t_{(23)}$ = 0.61, p = 0.55; see Figure 16). Appendix N contains individual participant median RTs.

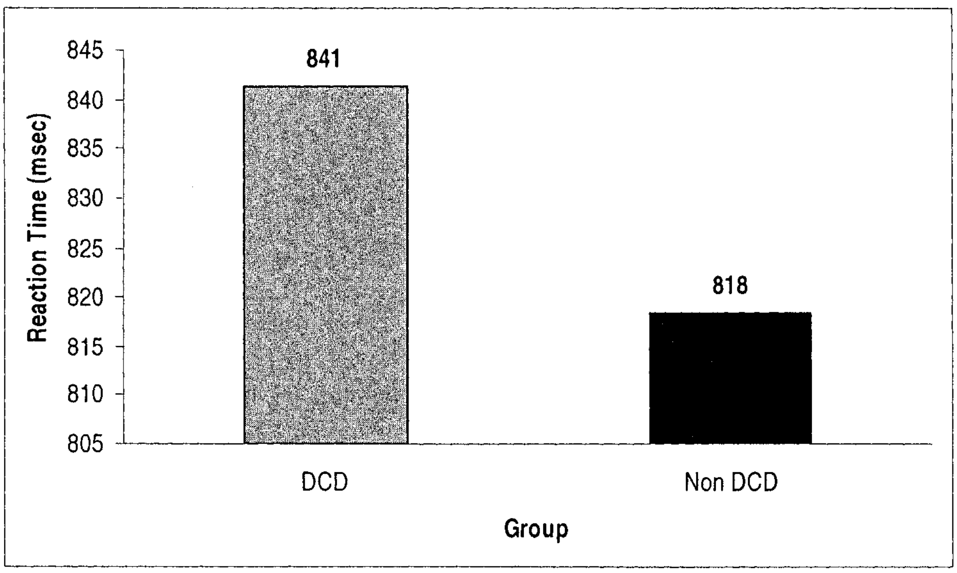

Figure 19. Overall median reaction times for boys with and without DCD.

Correlations

Initially, correlations were computed on the attention networks scores between participants within each group. This analysis did not show any significant relationship between the three attention networks (Alerting and Orienting, r = -0.12, p = 0.68; Orienting and Executive Control, r = 0.25, p = 0.39; Executive Control and Alerting, r = 0.39, p = 0.16) of the boys with DCD. On the other hand, both the alerting and orienting networks (r = 0.70, p = 0.02) and the alerting and executive control networks (r = 0.64, p = 0.04) of the boys without DCD were positively correlated. There was no significant relationship found between the orienting and executive control network (r = 0.29, $p = 0.39$), however.

A second group of correlations was calculated to examine the relationships between the boys with DCD and the boys without DCD on each network. There was no significant relationship found between the groups on the alerting (r = -0.27, $p = 0.42$), orienting (r = -0.26, $p = 0.44$), or executive control (r = -0.25, $p = 0.46$) networks.

Discussion

The purpose of the present study was to develop an attention profile for boys with and without developmental coordination disorder using the ANT-C and to determine if the two groups were different. The profile includes the efficiency scores of the alerting, orienting and executive control networks, an overall error rate, a median reaction time score, and a description of the relationships between the three networks. Initially, the boys with DCD were hypothesized to have a deficit in each of the attention networks in comparison to the boys without DCD (Fan & Posner, 2004; Konrad et al., 2005; Wilson & Maruff, 1999). However, the two groups were not found to be different from one another on any aspect of the attention profile, except the efficiency score of the orienting network and the relationships between network scores.

Alerting

Posner, Sheese, Odludas and Tang (2006) suggested the development of the alerting network, as well as the orienting and executive control networks begins in early infancy. The orienting network appears to be formed by the age of 4 years, while the executive control network displays strong development from 4 to 7 years of age and then plateaus (Raz, 2004). On the other hand, the alerting network continues to develop throughout adolescence and into adulthood (Raz). Children generally demonstrate much slower no cue and double cue RTs, and higher network scores or greater difference between cue RTs as evidenced by more brain activation than in adults (shown by an fMRI). This pattern suggests that children have trouble maintaining an alert state when not warned of the upcoming target (Posner & Rothbart, 2007; Konrad et al., 2005).

In view of the developmental pattern of the alerting network and the motor skill deficit that boys with DCD experience, it was hypothesized that boys with DCD would also show a less efficient alerting network demonstrated by a greater difference between the no cue and double cue conditions, or a higher network score compared to boys without DCD. The boys with DCD had a group mean alerting score of 44 msec, while the boys without DCD had a score of 56 msec. The two groups were not found to be significantly different using inferential statistics, which was also confirmed by a small effect size. The hypothesis may not have been observed due to a period of time that has been identified during middle childhood when there is little development of the alerting network. More specifically, this pause in development occurs between the ages of 6 and 10 years, the ages of our participants. Then after ten, the difference between the no cue and double cue lessens and the alerting scores significantly begin to decrease. Therefore, the network becomes more efficient as the boys develop into adulthood (Rueda et al., 2004).

In addition, the alerting score of the children in a previous study conducted by Rueda et al. (2004) was slightly larger at 73 msec. However, the positive alerting network score for all three groups demonstrated that the median RT for the no cue trials was faster than the median RT for the double cue trials. T-test comparisons confirmed that the no cue RTs were significantly slower than the double cue RTs for the boys with and without DCD in the present study. This result indicates that all of the participants took longer to respond in trials when no warning cue was presented, than in trials when a double cue preceded the target.

It could be suggested that prior to using the mental ability of attention, boys with and without DCD require assistance in achieving a vigilant state. Therefore, behavioural interventions with boys with and without DCD require the instructor to present a verbal, visual or physical warning cue, prior to instruction to gain the participant's attention. Once attention is achieved, it is also critical to continue providing stimuli in order to maintain attention until the instruction is complete (Cermak & Larkin, 2002, p.229). It is also essential to reduce distractions or additional warning cues in the environment in order to maintain attention.

Orienting

The predicted deficit in the orienting network was based on the results of Wilson and Maruff (1999) in their study of boys with DCD using the COVAT. In the current study, boys with DCD were found to have an orienting network score of -2 msec, while boys without DCD had a score of 46 msec. The negative score of the boys with DCD was the result of a slower spatial cue median RT than centre cue median RT. Although, they have a low orienting score or less difference between the spatial cue and centre cue RTs, the boys would be considered to have a less efficient network because of the slow RTs. It appears the boys with DCD do not benefit from the effect of the spatial cue. Either, the spatial cue does not assist in directing their attention to the target location, or the warning cue does not hold their attention to the target location and attention shifts back to the central fixation point. The similarity in response to either spatial or centre cue is further confirmed by the lack of significant difference between these RTs within the group of boys with DCD. In comparison, the responses of boys without DCD to spatial and centre cues were also not significantly different. However their RTs demonstrated a pattern that was similar to the participants in Rueda et al. (2004) who had a score of 53 msec. Both groups had a positive network score. A positive score is the result of a slower centre cue RT than spatial cue RT. It would suggest that the boys without DCD benefitted when the spatial cue directed their attention to the correct location on the target, and had more difficulty disengaging from the centre cue to the target location. But, since the RTs of the centre cue and the spatial cue of the boys without DCD in the current study were not significantly different from the boys with DCD the overall orienting network efficiency is the same.

An explanation for this result is that the ANT-C used by Rueda et al. (2004) and the COVAT used by Wilson and Maruff (1999) are measuring differing concepts of orienting. Initially, it was assumed the COVAT and the ANT-C were measuring the same concept of orienting because they both define orienting as the ability to attend or select relevant stimuli or information among numerous irrelevant sensory outputs (Wilson, Maruff & McKenzie, 1997; Fan & Posner, 2004). They are both associated with the same areas of the brain, the parietal cortex and the frontal lobes (Fan & Posner; Fan et al., 2002; Wilson & Maruff, 1999). And, they both require subjects to keep their eyes on a central fixation point and respond manually to the onset of a target in two peripheral locations (Rueda et al., 2004; Wilson, Maruff & McKenzie). However, there are more specific details of the tasks that reveal they are actually measuring differing aspects of orienting.

First, there are two conditions within the COVAT, voluntary and reflexive, but the ANT-C only has one, which can not be described as either voluntary or reflexive (Wilson & Maruff, 1999). Second, the two tasks differ in warning cue types. The COVAT only has two warning cue locations, central and spatial, while the ANT-C has four warning cue conditions, no cue, double cue, centre cue and spatial cue (Wilson & Maruff; Fan et al., 2002). Third, the cue to target probability is also dissimilar. In the COVAT, approximately 90% of the central cues are followed by a target, with a 50% chance of the target appearing at the cued location or contralateral. The remaining 10% are catch trials where no target appears following the warning cue. The spatial cues are similar. In approximately 80% of the trials, the target will follow the warning cue, with a 50% chance of appearing at the cued location or contralateral. The remaining 20% are catch trials (Wilson & Maruff). In contrast, only the spatial cues of the ANT, which represent 25% of the trials, predict the location of the target 100% of the time. While the double cue and the centre cue, which represent 50% of trials, do not predict the target location, and the remaining 25% are not cued and signify the no cue trials (Fan et al.). Fourth, the COVAT has a varying stimulus onset asynchrony of 150 msec or 850 msec, whereas the ANT-C has a constant cue to target time period of 450 msec (Wilson & Maruff, Rueda et al., 2004). Finally, the

COVAT measures an individual's ability to direct visuospatial attention to areas of the visual field without accompanying eye movements. The interpretation of the results examines the occurrence of facilitation and inhibition (Wilson & Maruff). The ANT-C in contrast, measures the efficiency of an individual's orienting network. The results are interpreted by calculating RT differences between various trial types (Fan & Posner, 2004, Fan et al.). With the number of differences between tasks, it appears that the ANT-C is a more general measure of orienting than the COVAT, and a rather weak measure of disengagement and re-orienting. Therefore, the deficit in the volitional disengagement of covert attention demonstrated by the children with DCD using the COVAT would not be evident using the ANT-C.

On the other hand and more importantly, the orienting network was the only network to have a meaningful effect size measure (d = -0.55). The effect size can be interpreted in terms of the percent of nonoverlap between the boys with DCD and the boys without DCD (Cohen, 1998). The effect size between the groups indicates that the distribution of orienting scores between the two groups has a 38.2% of non overlap. In the realm of effect size measures this suggests there is a noteworthy difference between the two groups. This difference may not have been revealed in the inferential statistics because of the high variability between and within each group. The standard deviations for both groups were high. The boys with DCD had a standard deviation of 72 and the boys without DCD had a standard deviation of 100. The scores between groups, as well as within each group were also quite variable. The boys with DCD had orienting scores that ranged from -89 msec to 154 msec. Similarly, the boys with DCD had orienting scores that ranged from -141 to 207 (see Figure 10). The difference between the groups is evident in the skewness of the individual scores. The group with DCD had 7 boys out of 14 with a negative score, while the group without DCD had 8 boys out of 11 with positive scores.

This information is useful when developing behavioural interventions for boys with and without DCD. In general, it is recommended to break down a skill into its most basic components or focus on one body part at a time. Therefore, emphasis may be placed on the most relevant aspects of the skill or the environment. More importantly for the boys with DCD, it is critical to decrease the amount of time between instruction or feedback and practice of the skill. The less time spent between, the less time the boys with DCD have to reorient their attention to another source of stimuli. As with alerting, decreasing the amount of distractions in the environment will also assist in decreasing the number of stimuli present.

Executive Control

When examining the executive control network, Konrad et al. (2006), uncovered a deficit in children with ADHD on a modified ANT. A group of children with ADHD also demonstrated similar results on the COVAT to children with DCD. Therefore, it was hypothesized that the boys with DCD would have a higher executive control score or a greater difference between the incongruent and congruent RTs than the boys without DCD, which would indicate a less efficient network.

However, the executive control score of 135 msec for boys with DCD was not significantly different from the 117 msec score of the boys without DCD. This result was also supported by a small effect size. Similarly when the RTs for the incongruent and congruent target conditions were examined for a significant difference between the two groups, one was not found. The pattern of response within each group to the target conditions was also similar. In other words, both groups had a significantly slower median incongruent RT than median congruent RT. Therefore, when the flanker fish were swimming in the opposite direction of the middle fish, the boys had more difficulty distinguishing the direction of middle fish, than when the flanker fish were swimming in the same direction as the middle fish.

Although the results of the present study do not support the hypothesis, when the executive control scores of both boys with and without DCD were compared to those of the children in the study by Rueda et al. (2004), there appeared to be a difference. Rueda's sample had a lower network score or less difference between target type RTs. They had an executive control score of 50 msec. A smaller score generally indicates that the incongruent flankers provided less conflict for the participants than a higher score. This result suggests that the children in Rueda's study have more efficient and more mature executive control networks than all the boys in the present study.

In addition, it looks as if the boys, with DCD, in the present study and the children with ADHD in the Konrad et al. (2006) study demonstrate a similarity in executive control network scores. Unfortunately, a direct comparison of these two sets of data is not possible because each study used a different variation of the ANT (Fan et al., 2002). Konrad et al. modified the task to make it more comparable with other cueing paradigms and to include a condition that requires attention reorienting. They achieved this by having the targets appear peripherally and vertically rather than centrally and horizontally. The targets were arrows and 20% of all spatially cued trials were invalid. The present study, which replicated that of Rueda et al. (2002), replaced the centrally presented target arrows with fish, but continued to present spatially cued targets in a valid location 100% of the time. In order to directly compare the two groups, they would both need to be reassessed on one test. Then it might be possible to determine if there is a resemblance in the executive control network efficiency of the two groups.

On the whole, boys with and without DCD in the present study, have difficulty with the mental operations of monitoring and resolving conflict among stimuli (Cermak &Larkin, 2002, p.225). While using the mental ability of attention, it is suggested that boys with DCD require assistance in selecting the important or relevant stimuli within a given environment. This information may be applied in behavioural interventions by initially practicing a skill in a closed environment. As the participant becomes comfortable with a skill, choices can be added by making the environment more open (Cermak & Larkin, 2002, p.226). Again, it is important to minimize the distractions in the environment. The fewer competing stimuli, the greater the amount of focus they can place on the task at hand.

Overall Error Rate

In regard to overall error rate, the boys with DCD had a mean error rate of eight percent. Whereas the boys without DCD in the present study and the children in the Rueda et al. (2004) study were in the same range with an overall error rate of five and four percent, respectively. Therefore, when only two response options are obtainable, as in the ANT-C, the two groups of boys are equally successful when choosing the correct response based on environmental stimuli.

Median Reaction Time

It was initially expected that the overall reaction time of the boys with DCD would be slower than that of the boys without DCD, similar to the results of Wilson and Maruff (1999) using the COVAT. The boys with DCD had an overall median RT of 841 msec. Their RT was not different from the boys without DCD and the children in the previous Rueda et al. (2004) study. The boys without DCD had a median RT of 818 msec, while the children from the Rueda et al. study had a median RT of 789 msec. As previously discussed, the two groups of boys were equally successful in choosing the correct response with two options. It can also be stated that they are equally as quick to choose the response. Since the two groups were not significantly different from one another on either aspect, it appears neither group showed a preference for the speed versus accuracy trade off. In other words, neither group demonstrated a tendency to respond slower to improve their accuracy, or in contrast, display a tendency to give up accuracy for quicker response times (Wilson, Maruff, Butson, Williams, Lum & Thomas, 2004).

Correlations

The alerting, orienting and executive control network scores did not demonstrate any relationships between one another in the boys with DCD. Previously, Rueda et al. (2004) had a similar outcome with their participants. They interpreted this result as independence between the networks. Independence would indicate that each network worked alone, without inference or assistance from either of the remaining networks. Despite their results, Rueda et al. suggested it would not be reasonable to consider the networks as totally independent, since brain areas involved in each network undoubtedly communicate with each other.

Subsequently, Callejas et al. (2004) found the interactions between the networks hypothesized by Rueda et al. They determined that even though the three attention networks are anatomically and functionally different, they act under the constant influence of each other in order to produce an efficient and adaptive behaviour. The interactions found between the networks by Callejas et al. were similar to the correlations found in the boys without DCD in the present study. Relationships were found between the alerting and orienting networks and the alerting and executive control networks. No relationship was found between the orienting and executive control networks, however.

It would appear that the boys with DCD use the three networks independently from one another to achieve similar network efficiency as the boys without DCD who use the three networks in conjunction with one another. In the overall scheme of attention, it could be suggested that the strategies the boys with DCD use to select stimuli, responses, memories and thoughts are different from the boys without DCD. This difference may occur in how each group interprets their environment. The boys with DCD may use strategies that are narrow. They may view the environment as separate stimuli, responses, memories and thoughts independent of one another, similar to the independence of their attention networks. The boys without DCD on the other hand, may use strategies to view the environment in a broader sense. Like the relationships found in their attention networks, they can use the relationships between the stimuli, responses, memories and thoughts to help them interact in the environment. With that said, further investigation is required to confirm this idea.

Summary

From the analysis of the alerting, orienting and executive control networks, it appears that boys with DCD are not all that different from boys without DCD in their network efficiency, but differ on how they make use of them. The group means on the MABC clearly showed there were two distinct groups of boys, one with movement difficulties and one without, thereby resolving any question of overlap. The participants' individual scores on the ANT-C were again combined to reveal no significant difference on any measurement examined.

Overall, there appears to be a high amount of variability between and within both groups when the network efficiency scores are examined. This appears to be the reason for the lack of significance in the network scores, especially the orienting. In the alerting network, both groups of boys demonstrated a similarity to the children studied by Rueda et al. (2004), while both groups had greater executive control scores than the children in the previous study (Rueda et al.). In the orienting network, only the boys without DCD demonstrated a similarity to the children studied by Rueda and colleagues. The value of the group mean of the boys with DCD was negative, which indicates they are not as influenced by the spatial cue as the boys without DCD, who had a positive group mean value (Fan & Posner, 2004). In addition, the orienting network was the only network to produce a meaningful effect size measure.

Although the boys did not differ on the efficiency of each network, it looks like they used differing strategies to achieve similar RTs, error and efficiency scores. The boys without DCD used the three networks in combination with one another and were synchronized. Whereas, the boys with DCD used the alerting, orienting and executive control networks independently.

As previously stated, the two groups of boys took different approaches to produce similar network efficiency scores. From previous studies, it is apparent that children with DCD have difficulties with attention (Dewey et al., 2002; Wilson & Maruff, 1999; Wilson, Maruff &

McKenzie). The similarities found between the present two groups may suggest that the level of attention measured by the ANT-C is too general to evaluate the differences that are evident in the behaviour of boys with DCD. The intent of this study was to search for answers, but it has opened the door to more questions that may be answered by future studies.

Limitations and Recommendations

It is clear that further research is needed in order to draw conclusions on the efficiency of attention networks in boys with and without DCD. Limitations of the present study may be used to form recommendations for future studies. The first limitation of the study was the response tool used. The computer keyboard for most participants was a suitable implement; however, there were a number of boys who had some difficulty using the keys. One individual used the "." key for the entire third block, while five boys hit the windows button. Luckily, the SuperLab 4.0 program records which buttons were pressed to respond, so correct and incorrect trials were distinguishable. For that reason, no data were lost. Unfortunately, when the windows button was pressed the program menu opened on the screen and the program no longer recognized the boys' responses. The experimental block had to be stopped and restarted. For that reason, the use of a responding device with less buttons and larger buttons, or something like a video game controller may solve the issue.

A second limitation of the study was the inability to confirm that each participant was focusing on the centre fixation point and not moving their eyes to the target. This was also a limitation of the Rueda et al. (2004) study. The use of a webcam focused on the participants' eyes or a decrease in the second fixation period to less than 200 msec would solve this problem.

A final set of recommendations for future studies would be to increase the number of participants in each age category to compare means with the original data collected by Rueda et al. (2004). Also, participants should be asked to complete additional trials of the ANT-C. This method would establish a baseline for each participant that would allow calculation of the reliability of his scores and provide the option of comparison as individuals as well as designated groups. Finally, children with ADHD and DCD should be tested on the same version of the ANT to examine similarities between the two groups. Children with ADHD were found to have a deficit on a modified ANT by Konrad et al. (2006) and demonstrated similar results on the COVAT to children with DCD (Wilson & Maruff, 1999). The researcher had hypothesized that the boys with DCD would show a similar deficit in the executive network, however a deficit could not be concluded from the results of the present study.

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Appendix A – Principal Cover Letter and Consent Form

Cover Letter

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

Dear Principal,

My name is Laura Anne Sheehan and I am a graduate student at Lakehead University in the School of Kinesiology. I am in the process of completing my research thesis under the supervision of Dr. Jane Taylor.

Over the past 15 years, students from the Thunder Bay Catholic District School Board with Developmental Coordination Disorder (DCD) have been referred to and have attended the Motor Development Clinic. Participants have routinely included students from Holy Cross, Our Lady of Charity, St. Bernard, St. Elizabeth, St. Francis, St. Martin, and others. These students and their parents have been involved in research related to balance, fitness, and the long term benefits of intervention. Many of the students who come to the clinic also have attention difficulties. Up to now, we have addressed these difficulties with teaching strategies in the clinic.

This year we would like to investigate attention difficulties associated with DCD with a new organ system approach using the Attention Network Test for Children (ANT-C). This test measures the efficiency of the three attention networks, alerting, orienting, and executive control. Two recent studies have shown that children with DCD have attention difficulties in the orienting network, but the other two networks have not been studied. The information from this study will better define the attention profile of boys with DCD and therefore help us address these problems more efficiently.

In order to perform this study we are looking to gather a group of approximately 30 male children aged 7 or 8, with and without DCD. We would like to ask for permission to invite the teachers at your school to participate in the screening and recruitment process.

The teachers will be asked to complete a Motor Behaviour Checklist (MBC) for each male student who is 7 or 8 years of age who does not have a diagnosed physical or cognitive disability. The MBC is a quick, 10 question checklist devised to screen children with motor performance difficulties. Initially, the teacher answers yes or no to the statement, "I am concerned about the motor development of this child". If concern is indicated, then the teacher completes 10 additional questions. The questions describe general motor abilities, performance of simple everyday activities, and behavioural patterns of each student. For example, This child dresses quickly and efficiently before recess: (1) Rarely, (2) Sometimes, (3) Usually, or (4) Always. The completion of the questionnaire should not take longer than 20 minutes for all the boys in the class. On the other hand, if there is no concern, the teacher is finished with the questionnaire and can move on to the next child. This particular tool has been used successfully in previous studies involving a screening process of school children with motor difficulties.

The students screened by the teachers will take home an information package, including cover letter and consent form, and be asked to take part in the study. I will pick up the completed consent forms and invite the participants to come to the study. They will be asked to complete two assessments, the Movement Assessment Battery for Children on one day and the Attention Network Test for Children on a second day. The MABC includes 8 tasks involving the use of manual dexterity, ball and balance skills. The test will take approximately 40 minutes to complete. The ANT-C is a reaction time test that measures the efficiency of the attention networks. The child pushes a button on a keyboard in response to the appearance of fish on a computer screen. The test is roughly 30 minutes in length.

The participant's parent will also be asked to complete an Adapted Movement Assessment Battery for Children Checklist. The information gathered from this questionnaire is descriptive information on the child's behaviour related to different motor contexts. It is adapted to ask if the child is taking any medication for attention difficulties, which may have an affect on the efficiency of the networks. The checklist should be completed in 20 minutes.

If you are interested in providing your teachers and students an opportunity to participate in this study, or if you have any questions or concerns related to the study, please contact me, Laura Anne Sheehan at (807) 343-8182 or my advisor, Dr. Jane Taylor at (807) 343 8752. You are also welcome to a summary of the project once the study is complete.

Any information contained in the questionnaire is strictly confidential, and may not me released without a written consent of the child's parents.

Sincerely,

Laura Anne Sheehan
lasheeha@lakeheadu.ca

Consent Form

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

I have read the cover letter and give my permission for Laura Anne Sheehan, under the supervision of Dr. Jane Taylor, to proceed with the recruitment process identified in the study, "An Investigation into the Attention Profile of Children With and Without Developmental Coordination Disorder" under the following circumstances:

1. Only the Teachers identified at the bottom of the page will be contacted.

2. The teachers, students and parents must consent to their participation in the study prior to their involvement.

3. There is no more risk of physical or psychological harm than would be involved in a regular physical education class.

4. The teachers, students and parents are volunteers and can withdraw from the study at any time.

5. They may choose not to answer any question or participate in any task they prefer to leave out.

6. The information that they provide will be confidential and will be stored for a minimum of five years at Lakehead University's School of Kinesiology.

7. They will receive a summary of the project if they check off the box on their consent forms or if they later request it during the period of the study.

8. All data collected during the study will be coded and participants' names will not be released in the report at any time and the school board will remain anonymous in any publication of the study.

9. The results of the research will be used in the completion of Laura Anne Sheehan's M.Sc. thesis project and will be presented at the North American Federation of Adapted Physical Activity Conference in September 2008 at the University of Indiana.

Teachers that may be included in the study:

____

____

____

Please return this form as soon as possible.

Signature of Principal ______________________________ Date ____________

School: ______________________________

☐ I wish to receive a summary of the results of this study following completion of this study

Laura Anne Sheehan, M.Sc. in Kinesiology Candidate
(807) 343-8182

Jane Taylor, Ph.D., Associate Professor, School of Kinesiology
(807) 343-8752

Appendix B – Teacher Cover Letter and Consent Form

Cover Letter

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

Dear Teacher,

My name is Laura Anne Sheehan and I am studying the attention networks of children with and without DCD for my M.Sc. in Kinesiology at Lakehead University under the supervision of Dr. Jane Taylor.

The purpose of the study is to investigate the attention profile of children with and without Developmental Coordination Disorder (DCD), by examining the efficiency of the three attention networks, alerting, orienting, and executive control. In recent years, research has shown that children with Developmental Coordination Disorder have attention difficulties in the orienting network. It is important to study all three networks because the findings of the study may be useful in designing better interventions for children with attention problems.

In order to perform this study, a group of children with and without DCD is required. Considering the age group that the study is focused on, we would be interested in using children from your class. You will be required to complete a Motor Behaviour Checklist (MBC) for each child in your class. The MBC is a quick, 10 question checklist devised to screen children with motor performance difficulties. The process of checklist administration will be explained to you by myself or Dr. Taylor. This particular tool has been used successfully in previous studies involving a screening process of school children with motor deficiencies. The completion of the questionnaire should not take longer than 20 minutes.

If you are interested in participating in this study, please mail your signed consent form today, in the envelope attached. Any questions or concerns related to the content of the questionnaire, or to the information based on it, please contact me, Laura Anne Sheehan at (807) 343-8182 or my advisor, Dr. Jane Taylor at (807) 343 8752. You are also welcome to a summary of the project once the study is complete.

Any information contained in the questionnaire is strictly confidential, and may not me released without a written consent of the child's parents.

Sincerely,

Laura Anne Sheehan
lasheeha@lakeheadu.ca

Consent Form

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

I have read the cover letter and I understand the following information:

1. I agree to participate and assist Laura Anne Sheehan in the recruitment process of her study by completing the Motor Behaviour Checklist for students in my class.

2. I am a volunteer and can withdraw my recruitment from the study at any time.

3. I may choose not to answer any question.

4. The information that I provide will be confidential and will be stored for seven years at Lakehead University's School of Kinesiology.

5. I will receive a summary of the project if I check off the box underneath my signature on this page or if I later request it during the period of the study.

6. All data collected during the study will be coded and my name or my students' names will not be released in the report at any time.

7. The results of the research will be used in the completion of Laura Anne Sheehan's M.Sc. thesis project and will be presented at the North American Federation of Adapted Physical Activity Conference in September 2008 at the University of Indiana.

Please return this form as soon as possible.

Signature of Teacher ______________________________________ Date ______________

Phone Number of Teacher ____________________

_☐_ I wish to receive a summary of the results of this study following completion of this study

Laura Anne Sheehan, M.Sc. in Kinesiology Candidate
(807) 343-8182

Jane Taylor, Ph.D., Associate Professor, School of Kinesiology
(807) 343-8752

Appendix C – Parent and Participant Cover Letter and Consent Form

Cover Letter

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

Dear Parent of Potential Participant,

My name is Laura Anne Sheehan and I am studying the attention networks of children with and without DCD for my M.Sc. in Kinesiology at Lakehead University under the supervision of Dr. Jane Taylor.

The purpose of the study is to investigate the attention profile of children with and without Developmental Coordination Disorder (DCD), by examining the efficiency of the three attention networks, alerting, orienting, and executive control. In recent years, research has shown that children with Developmental Coordination Disorder have attention difficulties in the orienting network. It is important to study all three networks because the findings of the study may be useful in designing better interventions for children with attention problems.

If your child is a boy, 7 or 8 years of age with or without a motor difficulty he can be part of this study. Motor difficulties may include trouble performing skills such as handwriting or drawing, tying shoelaces, using utensils, running, catching and throwing. He must also be willing to complete a series of tests.

The tests will be conducted at the School of Kinesiology in the C.J. Sanders Field House at Lakehead University. The tests include the Movement Abilities Battery for Children (MABC), the Adapted Movement Assessment Battery for Children Checklist (Adapted MABC Checklist) and the Attention Network Test for Children (ANT-C). The tests will be broken into two sessions. It will take about an hour to complete the MABC and the Adapted MABC Checklist in the first session, and the ANT, in the second session will take about half an hour.

Your son is a volunteer in this study and therefore may refuse to participate in any part of the study or withdraw from the study at any time. He may decline to answer any questions you do not wish to answer.

There is no potential harm or risks, physical or psychological. The testing procedure does not pose any psychological or physical harm. The physical requirements are no greater than those required in a regular physical education class.

All information that you provide will be coded and your name will not appear in any reporting of the results. Only the researchers involved in the study will have access to the data. Please understand that all information will be securely stored at Lakehead University's School of Kinesiology in the Motor Development Clinic Lab for seven years. If you would like, the results of this study will be made available to you at your request. The results will only be used for the purpose of this research and will be presented at the North American Federation for Adapted Physical Activity Conference in September 2008 at the University of Indiana.

If you have any questions, please feel free to contact me, Laura Anne Sheehan at (807) 343-8182 or my advisor, Dr. Jane Taylor at (807) 343-8752. The Research Ethics Board may also be reached at (807) 343-8283.

Sincerely,

Laura Anne Sheehan
lasheeha@lakeheadu.ca

Consent Form

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

We have read the cover letter and my son and I understand the following information:

1. My son and I agree to participate and be tested by Laura Anne Sheehan on the Movement Abilities Battery for Children (MABC), the Attention Network Test for Children and the Adapted MABC Checklist.
2. There is no more risk of physical or psychological harm than would be involved in a regular physical education class.
3. He is a volunteer and can withdraw from the study at any time.
4. We may choose not to answer any question or participate in any task we prefer to leave out.
5. The information that we provide will be confidential and will be stored for a minimum of five years at Lakehead University's School of Kinesiology.
6. We will receive a summary of the project if I check off the box underneath my signature on this page or if I later request it during the period of the study.
7. All data collected during the study will be coded and my son's name will not be released in the report at any time.
8. The results of the research will be used in the completion of Laura Anne Sheehan's M.Sc. thesis project and will be presented at the North American Federation of Adapted Physical Activity Conference in September 2008 at the University of Indiana.

Please return this form as soon as possible.

Signature of Participant ___________________________________ Date ______________

Signature of Participant's Parent/Guardian ___________________ Date ______________

Phone Number of Participant _____________________

☐ I wish to receive a summary of the results of this study following completion of this study

Laura Anne Sheehan, M.Sc. in Kinesiology Candidate
(807) 343-8182

Jane Taylor, Ph.D., Associate Professor, School of Kinesiology
(807) 343-8752

Appendix D – Motor Development Checklist

Motor Behaviour Checklist

Teacher's Name ____________________ Student's Name ____________________

School ____________________________ Birthdate __________________ Sex ___

Age ______ Grade ______

PLEASE ANSWER THE FOLLOWING QUESTION.

I am concerned about the motor development of this child. YES NO

If you answered YES, please complete the rest of the form.

1. When running this child is usually:

Very uncoordinated Uncoordinated Coordinated Very coordinated

2. This child dresses quickly and efficiently before recess:

Rarely Sometimes Usually Always

3. This child uses playground equipment:

Rarely Sometimes Usually Always

4. This child usually catches a ball:

Awkwardly Fairly well Easily Very easily

5. This child participates in ball games:

Rarely Sometimes Usually Always

6. This child enjoys playing on climbing equipment:

Rarely Sometimes Usually Always

7. This child tires easily and needs frequent rest:

Rarely Sometimes Usually Always

8. This child seems to be:

Very unfit Unfit Fit Very fit

9. This child avoids participating in games with his/her peers:

Rarely	Sometimes	Usually	Always

10. This child avoids participating in physical education classes:

Rarely	Sometimes	Usually	Always

Appendix E - Poster

Attention Profile of Boys With and Without Developmental Coordination Disorder

What is the study about?

- We are conducting a study to determine if the way boys with DCD attend to visual information is different from the way boys without DCD attend

Who is eligible to participate?

- Males aged 7, 8 and 9 with AND without motor ability difficulties, such as handwriting, tying shoe laces, using utensils, running, catching, and throwing

What will be required of the participant?

- Participants will be asked to:
    - Attend approx. 30 minutes of movement ability assessment
    - Attend approx. 30 minutes of attention network assessment
- Participant's parents will be asked to:
    - Attend the assessment sessions with their child
    - Complete a checklist regarding their child's movement abilities

Where does the Study take place?

- In the multi-purpose lab in the CJ Saunders Fieldhouse, which is part of the School of Kinesiology at Lakehead University

Interested?

- Please contact
    - Laura Anne Sheehan at 343-8182 or lasheeha@lakeheadu.ca
    - Dr. Jane Taylor at 343-8752 or jtaylor@lakeheadu.ca

Appendix F – Newsletter Advertisement

ATTENTION STUDY

Hello Skaters and Parents,

I am a graduate student in the Kinesiology Department at Lakehead University. Together my advisor, Dr. Jane Taylor and I are researching the attention profile of boys with and without Developmental Coordination Disorder. We are looking for boys aged 7-9 who would be interested in participating in our study. Each participant will be asked to attend a session of movement ability and attention network assessment, approximately an hour in length, at the C.J. Saunders Fieldhouse. If you, or know someone who may be interested in participating and would like more information, please contact me at 343-8182 or lasheeha@lakeheadu.ca.

Thanks so much,

Laura Anne Sheehan

Former Member and current Program Assistant

Appendix G - Handout

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

Dear Parent of Potential Participant,

My name is Laura Anne Sheehan and I am studying the attention networks of boys with and without DCD for my M.Sc. in Kinesiology at Lakehead University under the supervision of Dr. Jane Taylor.

We are looking for **10 boys** aged **8 or 9 years without a motor difficulty** to participate in our study.

The purpose of the study is to investigate the attention profile of boys with and without Developmental Coordination Disorder (DCD), by examining the efficiency of the three attention networks, alerting, orienting, and executive control. In recent years, research has shown that children with Developmental Coordination Disorder have attention difficulties in the orienting network. It is important to study all three networks because the findings of the study may be useful in designing better interventions for children with DCD.

Your son's participation will include the completion of the Movement Abilities Battery for Children (MABC) and the Attention Network Test for Children. Also, as the parent, you will be asked to complete the Adapted MABC Checklist. The tests will be conducted at the School of Kinesiology in the C.J. Sanders Field House at Lakehead University and will take approximately one hour to complete.

If you are interested in having your son participate in the study and/or would like more information, please contact me, Laura Anne Sheehan by **November 14, 2008**. I can be reached by phone at **(807) 343-8182** or by email at **lasheeha@lakeheadu.ca**. You may also contact my advisor, Dr. Jane Taylor at (807) 343-8752 or jtaylor@lakeheadu.ca for more information as well. Thank you for your consideration.

Sincerely,

Laura Anne Sheehan

Appendix H – Movement Assessment Battery for Children Protocol

Prior to the commencement of the formal assessment, the examiner must determine the handedness of the participant. A pencil and record sheet should be placed in front of the child so that he can print or write his name on the space provided. The examiner should record the hand that was used and ask the child if he uses that hand to do all tasks. A note should be made beside the preferred hand with a check mark if gross motor tasks are also performed with this hand.

The test begins with the assessment of manual dexterity, followed by ball skills, concluding with balance. There are eight items in total. The items included in Age Band 2, used for 7 and 8 year olds are, placing pegs, threading lace, the flower trail, one-hand bounce and catch, throwing a bean bag into a box, the stork balance, jumping in squares and heel-to-toe walking. For 9 and 10 year olds, Age Band 3 is used. The items include shifting pegs, by rows, threading nuts on bolt, flower trail, two-hand catch, throwing bean bag into box, one-board balance, hopping in squares and ball balance.

In general, the test begins by the examiner setting up the test materials according to the directions for the item. Next, the examiner provides a demonstration of the task form for the child. Each task includes specific features that should be emphasized to the child about what is required of him. The child is then provided an opportunity to practice the task. It is important the examiner correct the child as soon as possible if an incorrect procedure is adopted. After the practice trials, the child is given one or more opportunities to formally complete the task to the best of his abilities. As soon as a score of zero is achieved, the testing of the item can be stopped, and the next item may begin. If the child obtains any other score and the instructions permit it, additional trials of the task are administered until the maximum number of trial is reached or a score of zero is achieved. During a trial, the examiner may not help the child in any way. If the child does commit an error, the tester may remind the child of the error between trials as the child may have forgotten the instruction. The test is finished once all eight tasks are completed. The length of the test is approximately 1 hour.

To score each item, the raw data obtained from a 'good' attempt is recorded in the appropriate box. This will vary from task to task, but will be a score such as the number of seconds, steps, catches or goals, an 'F' indicating the child has failed to complete task, an 'I' indicating that the task is inappropriate for the child, or an 'R' indicating the child refused to perform the task. Once the child has obtained a zero, or reached the maximum number of attempts, the best score is used to assign the appropriate scale and item score between one and five on the mini table. If on all attempts at the task the child fails by performing it incorrectly or unable to begin, then a point score of five is awarded. Some tasks in this part of the test are performed by both, the preferred and non-preferred hands or legs. To obtain the item score that contributes to the total on these items ensure that the raw data has been entered in the correct box and read off the scaled scores from directly underneath. The child's scale scores on the two hands or legs should then be summed and divided by two to produce the final item score.

To describe the child's profile, the child's scores on the Test are summarized. Three subgroup scores for manual dexterity, ball skills, and balance are produced by summing the items scores in each section. A Total Impairment Score can then be generated by summing the subgroups scores. This TIS is then interpreted as a percentile norm.. The crucial TISs for this study are 13.5-14, 10 and 8.5, which are associated with the 5th, 15th and 20th percentiles, respectively.

Appendix I – Adapted Movement Assessment Battery for Children Checklist

Movement Assessment Battery for Children

Checklist

Compiled by Sheila E. Henderson and David A. Sugden

Name .... Gender .... Date of test ....

Home address .... Date of birth ....

.... Age .... Grade/year ....

School .... Assessed by ....

Section 1	Section 2	Section 3	Section 4	Total	Section 5	Full Movement ABC assessment required	
.... +	....	.... +	.... =	....	L M H (circle one)		yes no (circle one)

Does your child take medication for attention difficulties? yes no

Section 1: Child Stationary/Environment Stable

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Put on and take off articles of clothing without assistance (shirt, sweater, socks). ....
2. Stand on one leg in a stable position (when putting on trousers, skirt). ....
3. Tie shoelaces, buckle belt, fasten a zipper/buttons. ....
4. Demonstrate competence in personal hygiene (wash hands, brush/comb hair). ....
5. Demonstrate good posture when sitting or standing (at a desk/table, on a chair, in line). ....
6. Hold instruments using proper tension and grasp (scissors/pencil/pen/paintbrush). ....
7. Cut/draw/trace with precision/accuracy. ....
8. Form letters, numbers and basic geometric shapes that are accurate and legible. ....
9. Pick up small objects (blocks, beads, puzzle pieces). ....
10. Use blocks, beads, puzzle pieces to complete appropriate task. ....
11. Turn the pages of a book, hand out individual sheets from a stack of paper. ....
12. Recognize own body parts and differentiate between left and right. ....

Section 1 Total [ ]

Section 2: Child Moving/Environment Stable

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Walk around the classroom/school avoiding collision with stationary objects/persons. ....
2. Carry objects around the classroom/school avoiding a collision with stationary objects/persons. ....
3. Run and then stop to avoid stationary objects/persons. ....
4. Skip or gallop a distance of 15 feet (4.5 m). ....
5. Hop in a controlled manner on either foot. ....
6. Jump across/over obstacles that might be found in the play environment (blocks, low hurdles, ropes). ....
7. Use fixed playground/gymnasium apparatus such as climbing frame, slide and/or low balance beam. ....
8. Manoeuvre through/around an obstacle course appropriate to age and ability. ....
9. Throw an object (ball, bean bag, ring) into a container using an underarm action, while on the move. ....
10. Throw an object (ball, bean bag, ring) into a container using an overarm action, while on the move. ....
11. Run to kick a large stationary ball. ....
12. Demonstrate an understanding of directional commands by moving forward/backward; over/under; around/through; in/out; to the left/right. ....

Section 2 Total [ ]

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Pass objects down a line from one child to the next (passing books or pencils along the row). ....
2. Maintain a stable position within a physical group activity (leap-frog, holding a hoop steady for others to throw a bean bag through). ....
3. Intercept and stop a moving object (toy train or car, ball) as it approaches/enters the field of reach. ....
4. Catch a large approaching ball (bouncing or in flight) using two hands. ....
5. Catch a small approaching ball (bouncing or in flight) using one hand. ....
6. Kick an approaching ball using the foot rather than the shin. ....
7. Hit/strike a moving ball using a bat, racket or stick. ....
8. Roll a ball for a moving child to stop or catch. ....
9. Throw a ball/bean bag for a moving child to catch. ....
10. Continually bounce a large playground ball while standing still. ....
11. Turn a rope with sufficient force and accuracy to allow another child to jump or skip. ....
12. Keep time to a musical beat by clapping hands or tapping foot. ....

Section 3 Total [ ]

Section 4: Child Moving/Environment Changing

0	1	2	3
Very Well	Just OK	Almost	Not Close

The child can:

1. Move around the classroom/school while avoiding collision with other moving persons. ....
2. Use non-stationary playground/gymnasium apparatus such as swings unassisted. ....
3. Ride moving vehicles such as pedal cars, tricycles, scooters and bikes (as appropriate for age). ....
4. Push/pull wheeled vehicles such as wagons, library and mat trolleys. ....
5. Participate in chasing games (tag, Mr. Wolf). ....
6. Run to catch an approaching ball. ....
7. Run to kick an approaching ball. ....
8. Run to hit/strike an approaching ball using a bat, racket or a stick. ....
9. Use skills of striking, kicking, catching and/or throwing to participate in a team game. ....
10. Move around keeping control of a bouncing ball. ....
11. Move to enter a turning jump rope. ....
12. Move in a variety of directions, styles and speeds while keeping time to a musical beat. ....

Section 4 Total [ ]

Section 5: Behavioral Problems Related to Motor Difficulties

0	1	2
Rarely	Occasionally	Often

The child is:

1. Overactive (squirms and fidgets; moves constantly when listening to instructions; fiddles with clothes). ....
2. Passive (hard to interest; requires much encouragement to participate; seems to make little effort). ....
3. Timid (fearful of activities like jumping and climbing; does not want to move fast; constantly asks for assistance). ....
4. Tense (appears nervous, trembles; fumbles with small objects; becomes flustered in a stressful situation). ....
5. Impulsive (starts before instructions/demonstrations are complete; impatient of detail). ....
6. Distractible (looks around; responds to noises/movement outside the room). ....
7. Disorganized/confused (has difficulty in planning a sequence of movements; forgets what to do next in the middle of a sequence). ....
8. Overestimates own ability tries to change tasks to make them more difficult; tries to do things too fast). ....
9. Underestimates own ability (says tasks are too difficult; makes excuses for not doing well before beginning). ....
10. Lacks persistence (gives up quickly; is easily frustrated; daydreams). ....
11. Upset by failure (looks tearful; refuses to try task again). ....
12. Apparently unable to get pleasure from success (makes no response to feedback; has a blank facial expression). ....

Section 5's overall estimated contribution to movement difficulties (High, Medium or Low) [ ]

Appendix J – Development of the Attention Network Test for Children

To begin the process of building the ANT-C program, the stimuli were downloaded from the Sackler Institute for Developmental Psychobiology webpage. The stimuli were opened in Paint and saved as a 256 Color Bitmap file. Microsoft Power point was then used to form 42 slides, one for each possible screen used in the ANT-C. To be specific there were six instruction slides, one blank, one break, one central fixation, four cue (up, down, double and center), four single fish targets (up left, up right, down left and down right), four congruent targets (up left with flankers left, up right with flankers right, down left with flankers left and down right with flankers right), and four incongruent targets (up left with flankers right, up right with flankers left, down left with flankers right and down right with flankers left). In addition, there were 12 feedback slides, one for each target.

The background colour of each slide was a blue-green colour, while the targets were yellow fish, either a single fish or a horizontal row of five fish. Each fish subtended 1.6° of visual angle and the contours of the adjacent fish were separated by 0.21°. The five fish subtended a total of 8.84°. The target was presented either about 1° above or below the central fixation (Rueda et al., 2004).

Once the slides were complete, each was individually saved as a Device Independent Bitmap. They were then uploaded into SuperLab 4.0 as an event. They had to be uploaded in the order of appearance on the screen and the central fixation had to be uploaded three times for its multiple appearances in each trial. When all the events were loaded, the formation of the 48 trails began using the events. With the trials formed, it was then possible to build the blocks. In addition to the three experimental blocks, an instruction block, practice block and 3 breaks were also included. The randomization of trials, timing and feedback were set into the program according to the specifications of Rueda et al. (2004), once the events, trials and blocks were formed.

Appendix K – Attention Network Test for Children Protocol

The participant will be directed to sit 53 cm away from the desktop computer loaded with the ANT-C program. The child will place one finger of their left hand on the 'z' key and one finger of their right hand on the '/' key. It is not specified which finger must be on the keyboard, other then the most comfortable, however the child should be instructed to use the same finger for the whole session.

The instruction block begins by the researcher telling the child that a hungry fish will appear on the screen and he is instructed to feed the fish by pressing the key on the keyboard that matches the direction the fish is swimming. Next, it is explained that sometimes the hungry fish is alone, or sometimes it will be swimming with others. The child is instructed to pay attention to the middle fish and feed that fish using the keyboard. The child is also instructed to maintain fixation on the cross in the center of the screen throughout the task and to respond as quickly and accurately as possible. Finally, a practice trial from the participant will conclude the instruction block.

The practice block begins when it is clear the child understands the instructions. The practice block consists of 24 trials, which takes about 3 minutes to complete. To ensure the child understands the task, the researcher will supervise, and provide feedback and encouragement if needed. Once the practice block is complete, the child can take a break, if needed, prior to beginning the first experimental block. Each experimental block, includes 48 trials. There are three experimental blocks, which individually take about 5 minutes respectively. A break is provided if needed between each block. Each trial in an experimental block represents one of 12 conditions in equal proportions presented in random order. Each trial begins with a fixation period of random duration varying from 400 msec to 1600 msec, followed by a warning cue for 150 msec. a second fixation period then appears for 450 msec, followed by the target and flankers, which stay on the screen until the child responds or a time span of 1700 msec is reached. The child indicates his or her responses via the ‘z’ and ‘/’ keys on the keyboard. A correct response will initiate a simple animation sequence showing the target fish blowing bubbles. The feedback screen will last for 2000 msec. Incorrect responses will show no animation of the fish and move on to the next trial.

Appendix L - North American Federation of Adapted Physical Activity 2008 Poster

An Investigation into the Attention Profile of Boys With and Without Developmental Coordination Disorder

Laura Anne Sheehan & Dr. Jane Taylor   School of Kinesiology Lakehead University, Canada

Background

- DCD is a motor-based performance problem that limits a child's ability to fully participate in the everyday activities of childhood (Polatajko & Cantin, 2005; American Psychiatric Association, 1994).

- There are a variety of factors that have been identified in an attempt to determine the cause of DCD, however it is still unknown (American Psychiatric Association, 1994). One factor that has been identified is a deficit in visual-spatial processing (Wilson & McKenzie, 1998). This theory has led to an investigation into the orienting attention network of children with DCD. The orienting network is responsible for directing attention from an unattended location to a target location or object (Posner & Badgaiyan, 1998, pg. 62). Children with DCD have been identified with a deficit in the voluntary disengagement of attention, while reflexive orienting is not implicated in the disorder (Wilson & Maruff, 1999).

- In addition to the orienting, there are two other attention networks, alerting and executive control. Alerting is responsible for achieving and maintaining a vigilant state to incoming stimuli (Fan, McCandliss, Sommer, Raz & Posner, 2002), while executive control is responsible for more complex mental operations engaged during monitoring and resolving conflict among stimuli (Fan et al.). Most recently, attention has been viewed through a neurological approach (Fan et al.) in which attention is perceived as an organ system with its own anatomy and circuitry (Fan & Posner, 2004). Together the three networks form the organ system of attention.

- Attention problems have been identified as an associated problem in children with DCD (Sugden & Chambers, 2005, pg. 14; Dewey, Kaplan, Crawford & Wilson, 2002). As no research presently exists, it is of interest that the efficiency of the alerting, orienting and executive control networks be examined using the ANT-C in children with DCD (Reuda et al., 2004). The findings from this study may be useful in designing better behavioural interventions (Fan & Posner, 2004).

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Purpose

- To investigate the attention profile of boys with DCD by examining the efficiency of the three attention networks, alerting, orienting, and executive control, using the Attention Network Test for Children (ANT-C; Reuda et al., 2004)

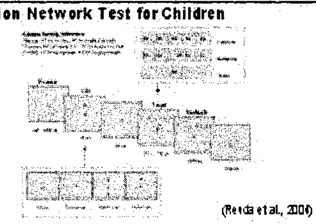
Method

- Participants
  - The sample included 16 boys, 8 with DCD and 8 without, between the ages of 7 and 10 years (mean = 8.8 years).
    - With DCD identified by an MABC Composite Score at or below the 3rd percentile (mean = 1st percentile) and a Manual Dexterity Score at or below the 15th percentile (mean = below 5th percentile).
    - Without DCD identified by an MABC Composite Score at or above the 20th percentile (mean = 38th percentile) and a Manual Dexterity Score at or above the 15th percentile (mean = above 15th percentile).

- Recruitment
  - Participants with DCD were recruited through the Motor Development Clinic at Lakehead University, while participants without DCD were recruited through local schools and summer camps.

- Data Collection
  - Parents of the participants completed an Adapted MABC Checklist.
  - Participants completed the MABC and the ANT-C

Attention Network Test for Children



(Reuda et al., 2004)

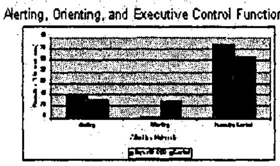
Acknowledgements

- Dr. Jim McAuliffe, Nipissing University
- Professor Eryk Przysucha, Lakehead University
- Professor Carlos Zerpa, Lakehead University

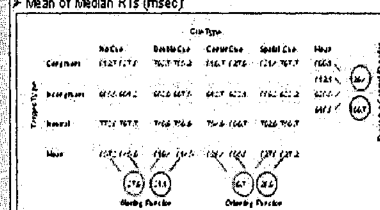
NAFAPA 2008 Indianapolis, Indiana

Results

- Mean Alerting, Orienting, and Executive Control Function



- Mean of Median RTs (msec)



Discussion

- Using an Independent Sample T-Test with Bonferroni correction, there was no significant difference found between boys with and without DCD in their scores on network efficiency for alerting ($t_{(14)}$ = -0.296, p = 0.772), orienting ($t_{(14)}$ = 0.826, p = 0.826) and executive control ($t_{(14)}$ = -0.885, p = 0.391).

- The effect sizes for alerting (d = 0.14), orienting (d = -0.41) and executive control (d = 0.44) were also small.

- Although it appears that there are differences in the orienting and executive control networks, the variation within the network scores may contribute to the lack of significant difference between groups. The alerting, orienting and executive control standard deviations for the DCD and control groups are 48.9 and 43.6, 51 and 81.1, and 53.2 and 49.3, respectively.

- In addition, the overall number of errors committed by participants did not demonstrate a difference between groups ($t_{(14)}$ = 0.591, p = 0.564). Also, no significant differences were found between groups when congruent ($t_{(14)}$ = 0.467, p = 0.655), incongruent ($t_{(14)}$ = 0.646, p = 0.529) and neutral ($t_{(14)}$ = 0.926, p = 0.833) target types were examined.

- Therefore, the hypothesis of an orienting deficit in boys with DCD, which was previously suggested by Wilson and Maruff (1999) using the COVAT, was not confirmed.

Appendix M – Participant Performance on the Movement Assessment Battery for Children

Table 2

Individual characteristics including age and Movement Assessment Battery for Children Scores

Participant Number	Group	Age	Manual Dexterity Score (MD)	Ball Skills Score	Balance Score	Total Motor Impairment Score (TMIS)	MD Percentile	TMIS Percentile
6	1	7.17	9	1.5	0	10.5	<1	13
1	1	8	2.5	4	4	10.5	>15	13
4	1	8.67	3	2.5	7.5	13	>15	6
7	1	8.25	8.5	4	8	20.5	<1	0
9	1	8.42	8.5	1	0.5	10	<1	15
17	1	8.17	10	2.5	4	16.5	<1	2
10	1	9.58	9.5	0	7	16.5	<1	2
13	1	9.67	7.5	0	5.5	13	<1	6
14	1	9.5	9.5	3	2	14.5	<1	4
16	1	9.33	14.5	7	3	24.5	<1	<1
18	1	9.33	8	0	2	10	<1	15
22	1	9.33	10.5	9	8	27.5	<1	<1
19	1	10.58	14	1	3	18	<1	1
21	1	10.58	9.5	5	8.5	23	<1	<1
2	2	7.75	3	0	0	3	>15	65
8	2	7.5	1	0	0	1	>15	89
27	2	7.75	4	1.5	0	5.5	>15	40
3	2	8.17	1.5	0	1.5	3	>15	65
5	2	8.42	4	0	0	4	>15	54
11	2	8.92	1	1.5	2	4.5	>15	49
12	2	8	2	0	0	2	>15	79
24	2	8.08	2	1	3	6	>15	36
25	2	9.75	3	0	3	6	>15	36
26	2	9.92	4	0	3	7	>15	29
20	2	10.17	5	1	2.5	8.5	15	20
23	3	8	4.5	4	8.5	17	>15	2
15	3	9.3	13	8	10.5	21.5	<1	<1

Appendix N – Individual Scores on the Attention Network Test for Children

Table 3

Individual alerting, orienting and executive control scores

Participant #	Participant Number on Figures	Group	Alerting	Orienting	Executive Control
6	1	1	92	-79	276
1	2	1	99	81	92
4	3	1	58	-31	118
7	4	1	7	7	54
9	5	1	137	29	252
17	6	1	-39	154	208
10	7	1	141	-49	98
13	8	1	-65	-89	7
14	9	1	2	-70	150
16	10	1	4	-12	138
18	11	1	36	10	103
22	12	1	77	-85	80
19	13	1	116	42	201
21	14	1	-50	67	114
2	15	2	48	106	51
8	16	2	10	-141	117
27	17	2	17	-67	166
3	18	2	-64	-68	22
5	19	2	123	207	172
11	20	2	85	77	82
12	21	2	47	89	143
24	22	2	212	116	200
25	23	2	94	92	95
26	24	2	29	36	108
20	25	2	18	58	129

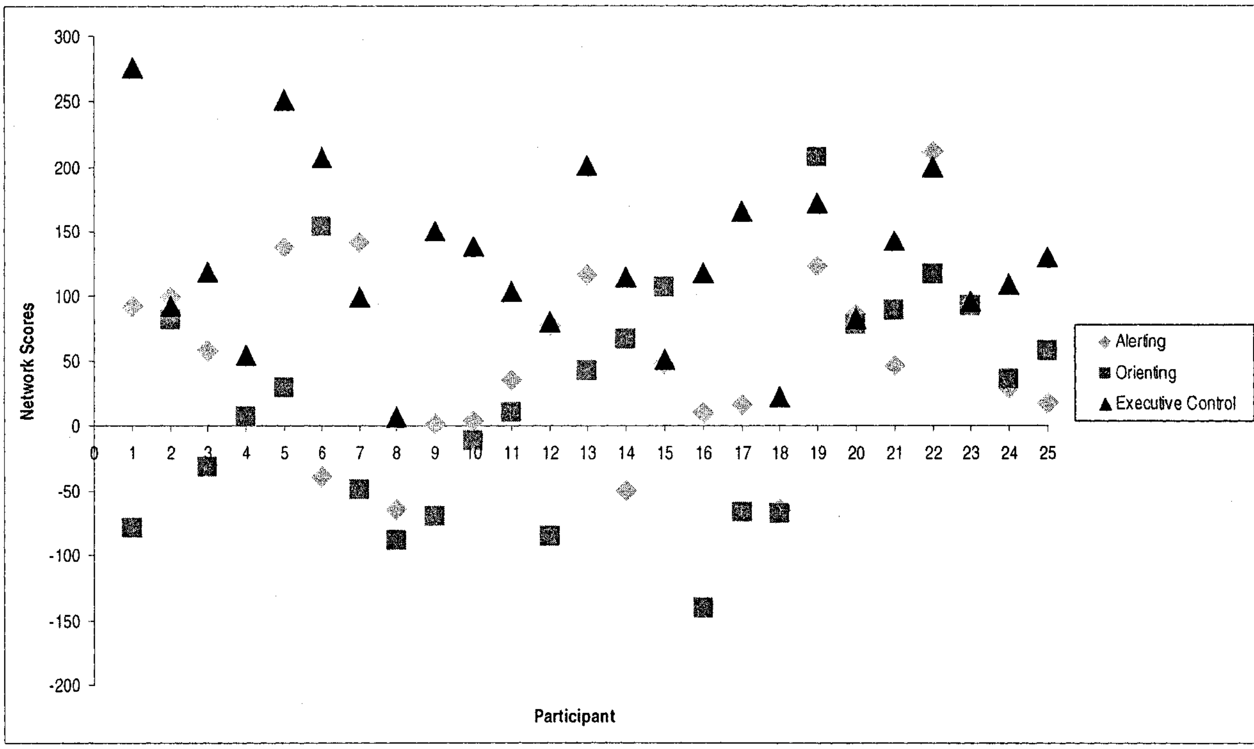


Figure 20. Individual alerting, orienting and executive control scores.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

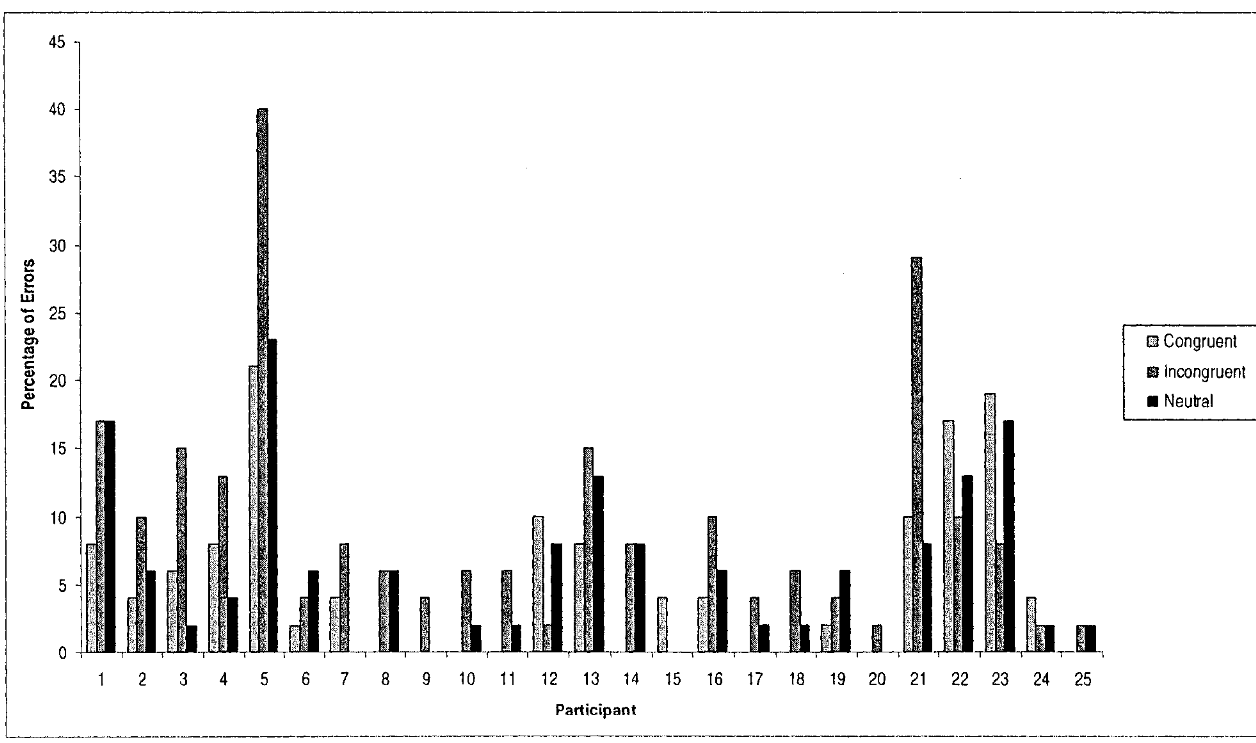


Figure 21. Individual error rate by target type.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

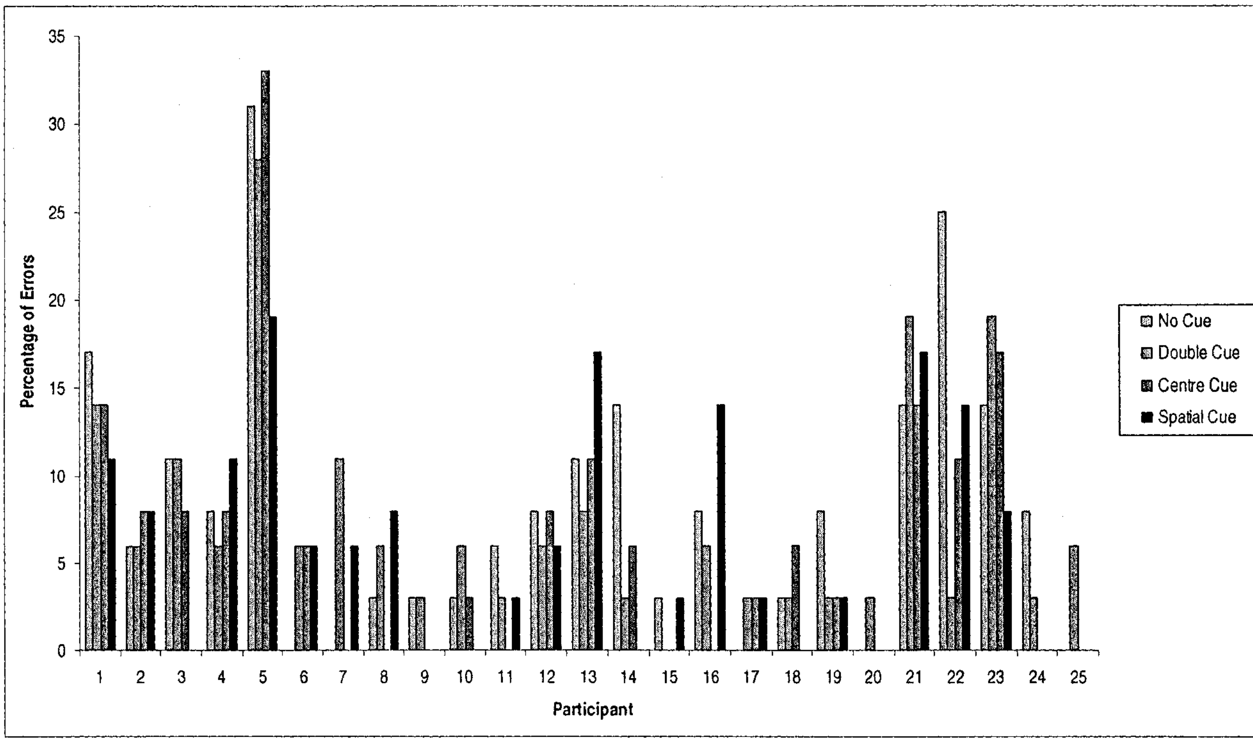


Figure 22. Individual error rate by warning cue condition.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

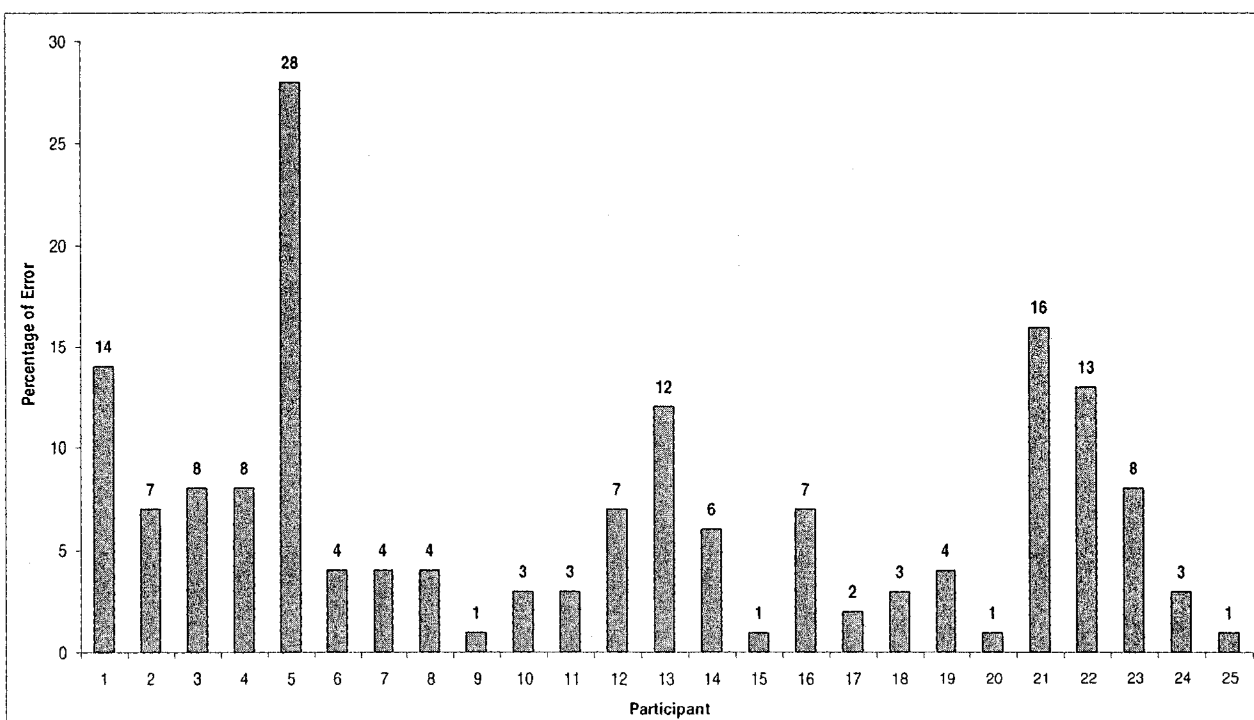


Figure 23. Individual total error rate.
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD

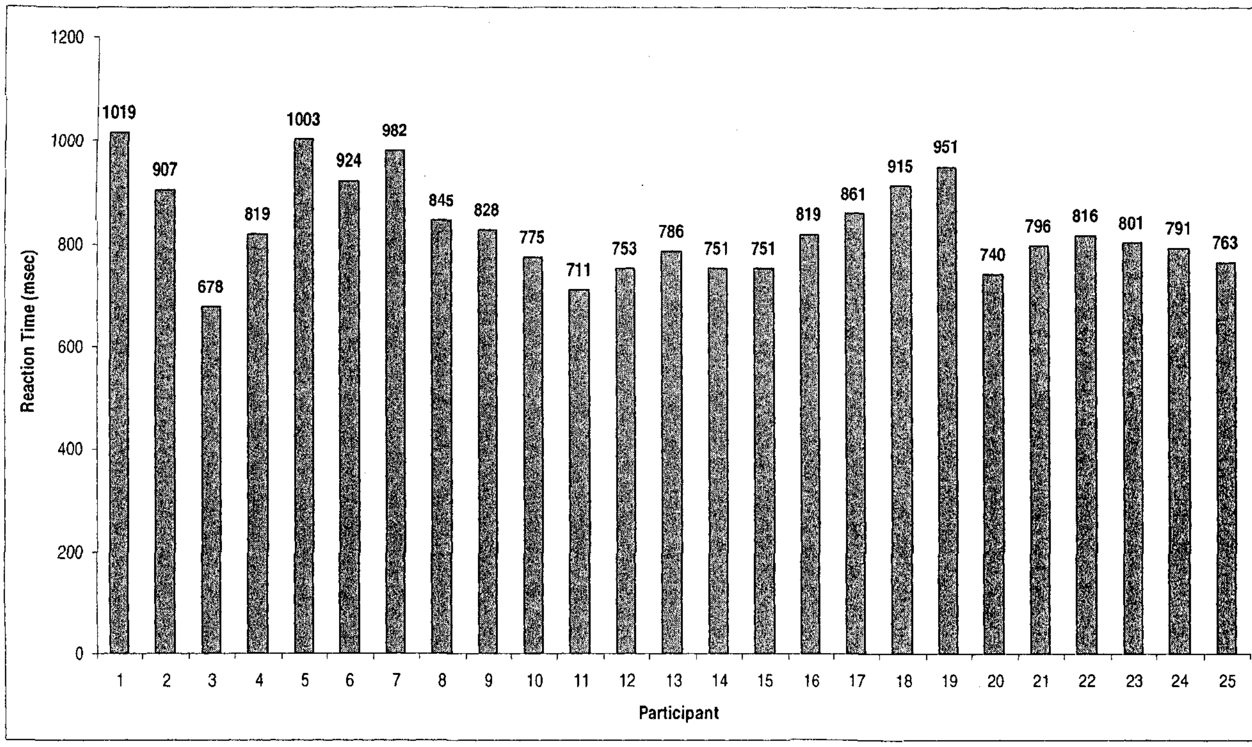


Figure 24. Individual overall median reaction time (msec).
* Participants 1-14 are boys with DCD, participants 15-25 are boys without DCD