Chapter 1

Thesis Overview

1.1 Background

This thesis is presented as an investigation into the movement integration, performance processes and effects of anxiety on the skill acquisition of individuals diagnosed with Down syndrome or DS as it will be referred to in this thesis (a full description of this genetic condition is presented in the thesis introduction). The investigation of several features of motor control and performance pressure in individuals with DS is carried out through several related research projects which will be rationalised and outlined throughout.

In both everyday life and in sporting situations, people are required to perform tasks quickly and accurately and these tasks vary in complexity. Some of these actions consist of one segment movements (e.g. turning on a light switch), whilst other actions have multiple segments (e.g. making a cup of tea) and the need to be fast whilst maintaining a high degree of accuracy is very important. Therefore understanding the basic principles behind these actions in individuals with DS and how performance pressure may affect speed and accuracy of movements will not just have theoretical implications, but also practical importance such as designing practice protocols to enhance functional independence. Motor skill control, learning and performance are imperative for everyday activities such as signing one's name, dressing oneself and personal hygiene. The capability to perform these motor skills with or without support is of the upmost importance for individuals with DS. Discovering new channels of enhancement in motor skill control, learning and performance for individuals with DS is extremely important and vital step on the pathway to improving functional independence for personal and professional gains.

1.2 Outline of thesis

This thesis attempts to investigate the issues relating to the programming of movements and the affects of anxiety on the motor skill learning of individuals with DS. The first experimental chapter focuses on the underlying mechanisms responsible for the planning, control and integration of multiple target aiming extension movements in individuals with DS. The aim of this chapter was utilise to the One Target Advantage (OTA) phenomenon in sequential extension movements to see if individuals with DS utilise similar movement planning and control strategies to typically developing (TD) individuals and individuals with an undifferentiated intellectual disability (UID). The second experimental chapter was designed to further understand the control of multiple directional movement actions in the DS population and the possible central and peripheral movement deficits. This experimental chapter aims to examine both the directional requirement of the second movement together with the effects of practice on the OTA phenomenon in persons with DS. Specifically, as in the first experimental chapter, we compare single-target movements with two-target extension sequences when the two-target responses are performed with a single arm and when there is a switch between the arms used to execute the first and second movement segments. However, in this chapter we also include sequences where the second movement in the sequence requires a reversal in direction to that of the first movement. The purpose of the third experimental chapter was to investigate the effects of environmental characteristics outside of those associated with the number of targets within a sequence. Specifically, the effects of performance pressure on the speed and accuracy of the movements of persons with DS.

1.3 Thesis format

This thesis consists of a review of the literature, three research papers and a general discussion. All three manuscripts were written as stand-alone research articles and have been or are currently being prepared to be submitted for publication in international disability research journals. For consistency, all manuscripts have been written in the style of the

American Psychological Association Publication Manual (Deckers, 2001) and the current recommendations adopted by the School of Sport, Health and Exercise Sciences, Bangor University for thesis preparation. For this purpose, all illustrations are numbered consecutively and citations are included in a single section at the end of this thesis. For ease of reading, all abbreviations are defined at their first appearance within each chapter of the thesis. Any contribution of co-authors is detailed in the 'acknowledgements' section of this thesis. All experimental chapters of this thesis are independent but linked, therefore at times there may be a necessary overlap in content between chapters.

Chapter 2

General Introduction

2.1. Background

The clinical characteristics of Down syndrome (DS) were first described by English physician Dr. J. H. Langdon Down in 1866, although the syndrome has been reportedly observed since the 9th century (Anson, 1992; Patterson, 1987). Subsequently the genetic pathology was determined by Lejeune, Gautier and Turpin (1959) and a contemporary definition of the syndrome resulted bearing the name Down (or Down's) syndrome and is now commonly used in both the research, clinical and general public domains (Anson & Mawston, 2000). The prevalence of DS is about 1 in 1000 births with 60,000 people in the UK currently diagnosed with the condition. It affects people of all ages, races, religious and economic situations (Down Syndrome Association, 2013). DS is one of the most prevalent and one of the most globally recognised chromosomal abnormalities and causes of intellectual disability (ID) (Selikowitz, 2008; Silverman, 2007). The level of cognitive delay in individuals with DS can vary from moderate to profound (Carr, 1985; Menghini, Costanzo & Vicari, 2011).

DS is a genetic condition involving chromosomal abnormality, specifically extra genetic material is carried on chromosome 21 between segments 21q22.1 and 22.3. This extra chromosomal material is found between the first and third parts of the 22nd segment on the long arm of chromosome 21. DS generally occurs due to Trisomy 21 which involves the non-disjunction of the chromosomes at the reduction division and this detachment may arise during the first or second meiotic division (Newton, 2004). This genotype results in individuals with DS demonstrating distinguishable atypical physiological, anatomical and neurological features to those of the typically developing (TD) population. There is considerable variability in the attainment of motor milestones within this population (Sacks & Buckley, 2003). For example, individuals with DS experience discrepancies in motor learning that can be attributed to deficits in programming, execution and control and these delays can limit the motor experiences and motor exploration which leads to proficient movement learning (Guazzo, 2007; Virji-Babul, Jobling, Elliot & Weeks, 2011).

In both everyday life and in sporting situations, people are required to perform tasks quickly and accurately and these tasks vary in complexity. Some of these actions consist of one segment movements (e.g. turning on a light switch), whilst other actions have multiple segments (e.g. making a cup of tea) and the need to be fast whilst maintaining a high degree of accuracy is very important. Therefore understanding the basic principles behind the movement integration and these actions in individuals with DS and how performance pressure may affect speed and accuracy of movements will not just have theoretical implications, but also practical importance such as designing practice protocols to enhance functional independence. Motor skill control, learning and performance are imperative for everyday activities such as signing one's name, dressing oneself and personal hygiene. The capability to perform these motor skills with or without support is of the upmost importance for individuals with DS. Discovering new channels of enhancement in the motor skill control, learning and performance for individuals with DS is extremely important on the pathway to improving functional independence for personal and professional gains.

2.2 Down Syndrome: An Issue with Motor Skill and Motor Control

Guazzo (2007) states that when studying movement one should focus not only on the body but also on the context in which the movement takes place and the possible stages that may occur in the process of motor learning. The physiological, anatomical and neurological abnormalities arise from the genotype mutation impacts both physical and cognitive development in individuals with DS (Simon, Elliot & Anson, 2003). Poor motor coordination and a perceived clumsiness in motor performance have long been associated with individuals with DS (Frith & Frith, 1974; Vimercati, Galli, Rigoldi, Ancillao &

Alberttini, 2012; Virji-Babul, Llyod & Van Gyn, 2003). It is proposed that individuals with DS exhibit difficulties in speed and efficiency in relation to the performance of precision goal directed movements (Elliot, Hansen, Grierson, Lyons, Bennett & Hayes, 2010). Researchers have highlighted differences between individuals with DS and TD individuals in the form of longer movement onset and reaction times (Arisi et al., 2012; Davis, Sparrow & Ward, 1991; Henderson, Illingworth & Allen, 1991; Masumoto, Abe, & Inui, 2012), longer movement times, and greater movement errors for individuals with DS compared to TD individuals (Elliott, Hansen, Mendoza & Tremblay, 2004; Hodges, Cunningham, Lyons, Kerr & Elliot, 1995).

Despite these motor behaviour issues in individuals with DS, there is a modest base of research which looks at the motor control issues for this population (Anson, 1992; Henderson, 1985). Previous research has proposed varying hypotheses to try and explain the motor behaviour disparities of individuals with DS. Latash, Kang & Patterson (2002) conducted a study using a force production task investigating finger coordination and the effects of practice in individuals with DS. They proposed that these issues with motor behaviour could be attributed to participants with DS having a notably slower initiation speed for movement commencement. Research investigating a range of motion task with 3D movement analysis measurements on individuals with DS demonstrated less efficient patterns of movement coordination for individuals with DS compared to the performance of TD participants (Galli et al., 2010). Meegan, Maraj, Weeks & Chua (2006) assessed gross motor skill performance by applying both visual and verbal instructions to participants and concluded that atypical patterns of brain organisation are one of the main explanations for motor behaviour disparities in this population. That is, individuals with DS use the left hemisphere of the brain for the organisation and control of sequential movement and the right hemisphere for speech perception. Therefore, in tasks that require both the perception of speech, and the organisation and control of limb and/or oral movement can lead to specific information processing difficulties for individuals with DS (Bunn, Roy, & Elliott, 2007).

As well as observed differences in brain organisation between the DS and TD populations, differences in sensorimotor organisation have also been proposed (Virji-Babul et al., 2011). Research by Virji-Babul et al (2011) investigating spatial localisation and functional connectivity during right index finger voluntary movements has provided evidence for potential motor representation issues. Incomparable physiological characteristics to their TD peers such as lower muscle tone, hypotonia and higher ligamentous laxity can potentially lead to weaknesses in the voluntary muscle control, spatial awareness and movement quality for individuals with DS. This may potentially be an additional contributing factor to the aforementioned motor behaviour decrements (Berg, Becker, Martian, Primrose & Wingen, 2012; Smith, Kubo & Ulrich, 2012).

In addition to the deficits highlighted above, research has proposed that people with DS possess problems with movement planning and feed forward control (for a review see Elliot et al., 2010). Hodges, Cunningham, Lyons, Kerr, & Elliott (1995) investigated aiming accuracy in individuals with DS. Specifically, they investigated the use of visually based online correction processes (i.e., adjustments to limb trajectories during movement that are conducted to produce a more accurate movement endpoint). They found that regardless of visual condition participants with DS exhibited longer movement times but were less affected by the elimination of visual feedback compared to the nondisabled participants. Therefore a dependence on visual feedback for the control of goal-directed movement is not a specific characteristic of DS. It is suggested that individuals with DS have issues modelling a stable representation of a potential motor action (Bunn, Simon, Welsh, Watson & Elliot, 2002; Elliot et al., 2010; Zoia, Pelamatti & Rumiati, 2004). It is perceived that these deficiencies in movement planning and feed-forward processes potentially lead to individuals with DS making greater use of feedback-based corrections during movement execution in order to reduce potential discrepancies between the position of the limb and the target (Almedia, Coros and Hasan, 2000; Hodges et al., 1995).

Perceptual-motor impairments in individuals with DS have been attributed to both central processes (i.e., Frith & Frith, 1974; Hodges et al., 1995; Inui, 2007; Lam, Hodges, Virji- Babul & Latash, 2009) and peripheral anatomical characteristics (Henderson et al., 1991; Latash, 2007; Morris, Vaughan & Vaccaro, 1982). Anson (1992) advised that there is a complex relationship between central and peripheral mechanisms in individuals with DS and that future research with a focus on investigating the specific underlying central and peripheral mechanisms should be conducted. Since research utilising single movement aiming tasks have concluded that individuals with DS experience problems with movement planning (Hodges et al., 1995) one might expect that this deficit would affect more ‘real-life relevant’ two movement responses.

Past research looking at the motor performance of individuals with DS has predominantly been conducted on single target directed movements. The purpose of this thesis is to improve the understanding of ‘how individuals with DS plan and execute the more complex responses involved in multiple target movements?’ As previously suggested, the majority of personal and professional everyday tasks are not performed by single upper limb aiming movements but rather by the coordinated actions of dual upper limbs. Therefore, we wanted to embark on novel research designed to investigate how people with DS plan to integrate movements both within and across limbs and if this is done in a similar fashion to that observed in the TD population and by individuals with an unidentified intellectual disability (UID)[1]. We also wanted to investigate the potential effects of practice on these multiple target movements in this population. In regards to practice and potential motor skill advances within the DS population, it has been indicated that task-specific practice sessions can modify and improve motor skills of persons with DS over a period of days or weeks. In addition, it has been suggested that individuals with DS have the potential to reach the same levels of motor skill proficiency as their TD peers with adequate practice (Latash, 2007; Smith et al., 2007). It has been noted that 1100 practice trials was enough to show dramatic improvements in the kinematics of a simple target aiming movement performed by individuals with DS and having this amount of practice can lead to performance reaching levels comparable to that of TD participants (Almeida, Corcos & Latash, 1994).

2.3 Down Syndrome: An Issue with Cognitive Functioning

The vermis is located in the midline of the cerebellum and is involved in the regulation of affect and cognitive processes (Yucel et al., 2012). A strong correlation between a reduced cerebellar vermis volume and the quality of motor performance in individuals with DS has been proposed and linked with deficits in cognitive functioning such as planning (Menghini, Costanzo & Vicari, 2011). This reduced celebellar volume leading to a reduced capacity combined with the previous findings that individuals with DS are susceptible to neuropsychological conditions such as anxiety as a response to pressure/stressful situations (Lufi, Okasha & Cohen, 2004; Frazer & Nolan, 1994; Kerins, Petrovic, Bruder & Gruman, 2008) gives rise to a very important research topic regarding the effects of performance pressure on the speed and accuracy of the movements in individuals with DS.

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[1] Whilst the individuals with an UID were classified as having a high functioning intellectual disability from local service departments and parent(s)/guardian(s), this disability was not syndrome specific (i.e., Down syndrome, Williams syndrome, Prader Willis).

The potential effects of environmental characteristics outside of those associated with the number of targets within a sequence have to our knowledge thus far not been investigated in individuals with DS. Limitations have been noted in the executive functioning, attentional capacity and information processing speed of people with DS (Borella, Carretti & Lanfranchi, 2012; Guazzo, 2006; Norman & Shallice, 1986; Silverman, 2007) with some studies observing discrepancies associated with memory impairments (Baddeley & Jarrold, 2007), working memory (Baddeley & Hitch, 1974; Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010), verbal short term memory (Marcell & Amstrong, 1982; Silverman, 2007; Vicari, Marotta & Carlesimo, 2004) and explicit long term memory (Carlesimo, Marotta & Vicari, 1997; Jarrold, Baddeley & Philips, 2007). Lanfranchi et al (2010) investigated executive functioning in individuals with DS and concluded that notable deficits were observed for executive functioning in tasks assessing set shifting, planning and working memory as well as greater errors and less strategy use in a sustained attention task. Optimal executive functioning and particularly working memory are essential for the regulation and control of goal directed behaviour (Gioia, Isquith, & Guy, 2001). Therefore, taking into account the aforementioned limitations of this population, the effects of performance pressure on the speed and accuracy of the movements of persons with DS is a relevant and very crucial enquiry.

Working memory and attentional capacity are essential features for effective learning and the production of relevant movement patterns. Working memory is required to maintain and utilise the relevant information required to complete the skill and attention is required to ensure focus is optimal whilst performing the skill (Fougnie, 2008). Working memory is a limited capacity system which temporarily stores information for future use and management. It consists of the central executive system which temporally stores and processes information from numerous sources, whilst the limited capacity system is an overflow mechanism for the central executive system and can temporarily store and rehearse information from a single source (Baddeley, 1986; Baddeley, 2000). The articulatory loop component of working memory has been extensively investigated in the DS population yet few studies have investigated visual spatial processing in individuals with DS (Vicari, Bellucci & Carlesimo, 2005; Virji-Babul et al., 2011). A relative limitation in visual-spatial memory with respect to visual-object memory has been found for people with DS (Ellis, Woodley-Zanthos & Dulaney, 1989) and in a study by Vicari et al (2005) it was noted that persons with DS have difficulty in learning visual-object material with a substantial reduction in visual-spatial learning.

Inconsistency in motor learning and the quality of learning in individuals with DS are said to be due to discrepancies with attention (Guazzo, 2006). Attention is directed to irrelevant stimuli and it is diverted from one relevant aspect of the task to another irrelevant entity during learning (Guazzo, 2007). Chiviacowsky, Wulf, Machado & Rydberg (2012) state that individuals with DS have 'fewer attentional resources available to process additional information, as more attentional capacity is needed to monitor basic aspects of motor performance as a result of less optimal movement control'. In light of this, one could expect larger performance decrements in individuals with DS compared to a population of TD peers due to the overloading of attentional and memory capacity when anxiety or worries are experienced. The rationale being that, the evident discrepancies in attentional control and working memory for individuals with DS suggest a reduced processing efficiency which is essential for coping with pressure and thus maintaining performance levels under stressful environments. This would potentially have an additional effect on the perceived poor motor behaviour within this population. In order to examine the effects of anxiety on the skill performance of individuals with DS, another aim of the present thesis is to examine whether individuals with DS and UID are affected by anxiety in a similar fashion to their TD peers.

2.4 Movement Integration

The One-Target Advantage (OTA): Considering the aforementioned issues with motor skill performance in individuals with DS, one of the purposes of this thesis is to investigate how this population plan and execute the more complex responses involved in multiple target movements. Researchers have adopted numerous approaches to understanding how multiple segment movements are prepared and executed in the TD population in order to investigate whether movements are performed independently of each other or grouped together (chunked) as a single response. Primarily research investigated the relationship between reaction time (RT) and the number of response segments/elements (e.g., Henry & Rogers, 1960; Klapp, Wyatt, & Lingo, 1974; Sternberg, Monsell, Knoll, & Wright, 1978). However, more recently, research has been devoted to examine the time it takes to execute movements (e.g., Adam et al., 2000) with results revealing a one-target advantage (OTA); movement time to an initial target is slowed when subjects are required to make a subsequent movement (Chamberlin & Magill, 1989; Adam et al., 2000; Adam, Helsen, Elliot & Buekers, 2001; Helsen, Adam, Elliot, & Buekers, 2001; Khan, Mottram, Adam & Buckolz, 2010, Khan, Sarteep, Mottram, Lawrence & Adam, 2011). This OTA implies interference during the first movement due to the characteristics of the second and thus highlights that individual elements in a response are not functionally independent. This OTA has shown it to be a robust phenomenon since it occurs under both left and right hand conditions (Helsen, Adam, Elliott, & Buekers, 2001; Lavrysen et al., 2003) and is both resistant to practice (Lavrysen et al., 2003) and the occlusion of vision (Lavrysen, Helsen, Elliott, & Adam, 2002).

Several movement planning and execution hypotheses have been put forward to explain the OTA (Khan et al., 2010). Fischman & Reeve (1992) proposed that the movement to the first target is performed in a controlled manner to provide an optimal starting position for the start of the second movement. This movement constraint hypothesis (MCH) is based on the assumption that the variability of movement endpoints accumulates from one target to the next. Hence, in order to be accurate at a second target, movement to the first target must be constrained so that the accuracy demands at the second target are met. In support for this hypothesis, Sidaway, Sekiya & Fairweather (1995) have shown that the accuracy demands of the second target affect variability at the first target. Specifically, when accuracy demands are higher at the second target, variability at the first is reduced. Similarly, Khan, Sarteep, Mottram, Lawrence & Adam (2011) have showed that when vision is available over the first segment of a two segment response, movements are adjusted as the limb approaches the first target thereby reducing endpoint variability.

An alternative interpretation of the OTA is the movement integration hypothesis (MIH) (Adam et al., 2000). The MIH suggests that the OTA uses a combination of processes related to advance planning and on-line control. Specifically, both segments are planned in advance of movement initiation and stored in a buffer. Then the neuromuscular organisation of the second movement is retrieved from this buffer and partially implemented during execution of the first movement. Thus, the assumption of the hypothesis is that the motor program is constructed prior to response initiation, but the implementation of the second element is performed on-line in conjunction with the execution of the first movement. Therefore, there is an overlap in processing between movements causing interference during movement one which leads to the OTA.

The presence of the OTA can distinguish between two possible loci of interference when movement times to the first target in single and two limb tasks are compared. There are two possible loci of interference at a central level (retrieval of a motor program from a motor buffer) and/or a peripheral level (muscular organisation of the performing limb which is adjusted and prepared to produce the second movement). However, the MIH does not make any specific assumptions about the nature or location of this interference effect (Adam et al., 2000). A reduction or potentially an elimination of interference at the peripheral level would seem to occur when a two-limb movement condition is utilised as the two movements are implemented by largely distinct and separate neuro-anatomical effectors. Therefore in a two-limb condition, if the OTA failed to materialise this would limit the concept of the movement integration hypothesis and imply that it only holds for single limb sequential movements. If the OTA materialised in the two-limb condition and magnitude of OTA was similar for the one- and two-limb movements, this would lend support for a purely central locus of interference. Evidence in support of the two-loci interference would be evidenced by a significant but smaller OTA for two-limb compared to one-limb movements. This would suggest both a limb-independent central locus (retrieval of a motor program from a motor buffer) and a limb-dependent peripheral locus of interference.

Until recently, the OTA had been exclusively demonstrated for aiming tasks in which movements were performed with a single limb. To address this, Khan et al. (2010) investigated whether the one-target advantage would emerge when there was a transfer between limbs in sequential aiming movements. A three condition design was utilised: a one-target movement condition, a two-target movement condition performed by a single limb, and a two-target movement condition where the first movement was performed with one limb and the second movement performed with the other limb. Novel results revealed that the OTA appeared in all conditions; therefore the processes involved in the movement integration hypothesis (Adam et al., 2000) occur at a central level. The two-limb condition would eliminate the possibility of interference occurring at the peripheral level (i.e., limb mechanics) as the two movements are implemented by largely distinct and separate neuro-anatomical effectors.

Direction of the second segment: When a second movement involves a change (reversal) in direction the OTA fails to materialise. Under these conditions research has demonstrated either the elimination of the OTA (Adam et al., 2000; Ketelaars, Garry and Franks, 1997; Khan et al, 2010) or significant reductions in MTs to the first target compared to those in one target conditions; a two-target advantage (TTA) (Khan, Lawrence, Buckolz & Franks, 2006) Researchers have accounted for this two-target movement advantage in terms of the underlying muscle activity patterns. In single target movements, the muscle activity patterns are characterised by a tri-phasic EMG pattern of activation. Initially, the agonist muscle accelerates the limb towards the target followed by an antagonist muscle burst to decelerate the limb. A second agonist then acts to serve the purpose of dampening the mechanical oscillations at the end of the movement (Adam et al., 2000; Almeida, Freitas, & Marconi, 2006; Enoka, 1988; Hallett, Shahani, & Young, 1975; Hannaford & Stark, 1985; Khan et al, 2006; Wierzbicka, Wieger & Shahani, 1986). In a two-target reversal movement the elastic properties of the antagonist muscle can be exploited to save energy in repositioning the limb in the reverse direction (Khan et al., 2006). Therefore, there is no requirement for the second agonist burst since the antagonist used to decelerate the limb at the first target also acts as the agonist on the second movement. This dual purpose of activity allows for optimal integration between elements, resulting in the TTA.

Previous research has looked at whether reversal movements are organised as a single unit of action rather than two discrete movements (Khan, Tremblay, Cheng, Luis & Mourton, 2008). Findings revealed that MTs were shorter when two targets were presented compared to when a single target appeared at stimulus onset. This also showed that the TTA emerges from the execution of processes prior to response initiation or during movement execution. It was expected that if two-target reversal movements are grouped as a single unit of action, then the ability to inhibit the movement to the second target would be difficult once the movement was initiated. Their findings of an inability to inhibit a second target provided support for the hypothesis that reversal responses are prepared as a single unit rather than two separate movements.

It is an aim of this thesis to examine the possible OTA and TTA effects in the DS population when two target movements require an extension movement or reversal in direction at target 1 together with a potential condition when there is a switch between limbs at the same target. This may assist in the understanding of the underlying control mechanisms of how people with DS plan and execute movements and if there are any similarities to the processes used by the TD population.

2.5 The Effects of Performance Pressure on Speed and Accuracy of Movements.

The effects of performance pressure on the speed and accuracy of the movements of persons with DS has to our knowledge never been examined, yet the effects of anxiety on performance continues to be an area of major interest within psychology research (Baumeister, 1984; Janelle, 2002; Eysenck, Deraksham, Santos, & Calvo, 2007; Hardy, Mullen & Martin, 2001; Mullen & Hardy, 2000; Williams, Vickers & Rodrigues, 2002; Wilson, Smith, Chattington, Ford & Marple-Hovart, 2006; Woodman & Hardy, 2001, 2003). When a person experiences state anxiety they may fail to perform to their normal ability due to the pressure to perform, this is refered to a ‘choking’ (Beaumeister, 1984; Lawrence, Beattie, Woodman, Khan, Hardy, Gottwald & Cassell, *in press*; Lawrence, Hardy and Khan, 2012, Mullen & Hardy, 2000; Oudejans & Pijpers, 2010).

The ‘choking’ phenomenon, has been attributed to the influence of two somewhat competing theoretical viewpoints. Self focus theorists such as Baumeister (1984) and Masters (1992) state that anxiety causes performers to focus their conscious attention on the process of performance resulting in a disruption in the normal automatic processes of skilled action.

Whereas, distraction theorists propose that the pressure an individual is subjected to can cause attention to be directed towards dealing with task irrelevant stimuli (e.g., anxiety/worry) and therefore this reduces the performance outcomes of the primary task (Eysenck et al., 2007; Wine, 1971).

Eysenck et al's. (2007) distraction based Attentional Control Theory (ACT) proposes that anxiety is resource intensive and results in attention being allocated to task irrelevant cues such as detecting the cause of the threat/anxiety and deciding how to cope with it. A noted increase in the influence of the stimulus-driven system (i.e., the resources devoted to coping with the threat) is experienced and a reduction in efficiency of the goal-directed system (i.e., the resources devoted to the primary motor or cognitive task). As a result, when anxiety is experienced the resources available are reduced within the central executive component of working memory for control of the primary task. Therefore, the use of attentional control to prevent interference from task-irrelevant cues is inhibited and the use of attentional control to maintain focus on the task-relevant cues is shifted. This affects the functions of the central executive component of working memory in a harmful way leading to decrements in performance (Lawrence et al., 2012). Wilson, Vine & Wood (2009) found that anxiety caused impaired goal-directed attentional control and this was apparent due to a significant increase in visual saccades just prior to movement production (i.e., reducing quiet eye) for participants. The principles of ACT extend from the earlier processing efficiency theory (Eysenck and Calvo, 1992) (PET), the reduction in processing efficiency will only result in task performance decrements if applying additional attentional resources (e.g., effort) cannot compensate for the imbalance between the stimulus and goal driven systems. As such, the adverse effects of anxiety on task performance are predicted to become stronger for tasks that require greater working memory capacity (i.e., conscious, effortful and non automated tasks) (for a review see Wilson, 2008).

An alternative explanation of the anxiety-performance relationship is the Conscious Processing Hypothesis (CPH) (Masters, 1992) which proposes that an individual experiences elevated levels of anxiety when in a stressful or pressured situation which causes the individual to become self-conscious about performing successfully (Masters, 1992; Wilson, Smith & Holmes, 2007). If performers have accumulated accessible and conscious task-relevant knowledge used to control movement then tasks are more likely to break down under pressure (Masters & Maxwell, 2008). This interference with normally automatic processes causes decrements in performance, as a skill that was previously performed automatically and proficiently is executed in a step-by-step manner using conscious control of movement parameters. 'The capacity to perform some complex tasks depends critically on the ability to retain task-relevant information in an accessible state over time (working memory) and to selectively process information in the environment (attention)' (Fougnie, 2008 pg 1). The discrepancies in attention and working memory for individuals with DS highlighted earlier in the writing may suggest a potential detrimental reduction in processing efficiency for this population in comparison to those of the TD. As processing efficiency is essential for coping with anxiety, we would expect greater performance decrements to occur in the DS population (compared to the TD population) due to the overloading of attentional and memory capacity when anxiety is experienced. Anxiety has been documented to affect people with DS in relation to 'test anxiety' and 'performance anxiety' (Wachelka & Katz, 1999; Lufi et al., 2004; Wheeler, 2010), yet to our knowledge no conclusive evidence has been put forward regarding the effects of anxiety on skill learning in this population. The present thesis proposes to examine and fill the research void gauging whether individuals with DS are affected by anxiety in the same way as the TD population.

2.6 Purpose of Thesis

The purpose of this thesis is three-fold. Firstly, in Chapter 3 a comparison is made between single limb sequential aiming movements and two limb movements in which the hand was switched at the first target. We wanted to investigate whether, like their TD peers, the OTA would emerge when there is a transfer between limbs in sequential aiming movements for individuals with DS. Single target movements, along with two target movements using both single and two limbs were utilised in this thesis. The majority of past research into the motor performance of the DS population has been conducted on single target directed movements. Therefore, the purpose of Chapter 3 is to fill the research lacuna surrounding the question of 'how individuals with DS plan and execute the more complex responses involved in multiple target movements?' Furthermore, since the majority of everyday tasks such as food preparation, personal hygiene and computer use are not performed by single upper limb aiming movements but rather by the coordinated actions of dual upper limbs, we wanted to investigate for the first time whether the DS population plan to integrate movements both within and across limbs in a similar fashion to that observed in the TD population.

Chapter 4 further examines the OTA in individuals with DS, additionally examining the possible TTA effects in this population when two target movements require a reversal in direction at target 1, together with situations where there is a switch in limbs at the same target. We propose that the OTA will emerge in both the single and dual arm responses when the second movement in the two target action is an extension of the first. However, for the reversal movements, it is expected that the OTA will not emerge in the single arm condition and rather be replaced by a TTA due to the pattern of muscle activation responsible for this advantage. Additionally, in the two-target dual arm reversal condition we expect the switch in arms at the first target will result in the removal of the bi-phasic pattern of muscle activation and therefore the TTA would not emerge. If the TTA is revealed for the two arm reversal movements this would indicate that the TTA is influenced by central rather than peripheral processing since the within arm peripheral muscle benefits proposed to be responsible for the TTA are removed in conditions where arms are switched at the first target.

An additional aim of the thesis detailed in chapter 4 was to explore the effects of practice on both the OTA and TTA in persons with DS. Research within the DS population has indicated that motor skills can be modified over a period of days or weeks through task-specific practice sessions, and that individuals with DS have the potential to reach the same levels of motor skill proficiency as their TD peers with adequate practice (Almeida et al., 1994; Latash, 2007; Smith et al., 2007). Thus, in order to further investigate the possibility that the reaction times and movements times of individuals with DS can improve across practice to be in line with those of their TD peers we included the independent variable of practice into this thesis chapter.

Chapters 3 and 4 are designed to investigate the underlying mechanisms responsible for the planning, control and integration of multiple target aiming movements. The purpose of Chapter 5 was to investigate the effects of environmental characteristics outside of those associated with the number of targets within a sequence. Specifically, the effects of performance pressure on the speed and accuracy of the movements of persons with DS. Whereas research examining the influence of anxiety and the 'choking' phenomenon on performance continues to be an area of major interest within the TD population, this chapter focuses on the effect of anxiety and pressure on the processing efficiency and skill performance of individuals with DS. Participants performed a football dribbling task as quickly and as accurately through a slalom course. Testing consisted of a pre-test, succeeded by an anxiety induced acquisition stage and two counter balanced transfers: a high anxiety transfer and a low anxiety transfer. Given the previously mentioned reduced cognitive attentional resources available to persons with DS, we predict that individuals with DS will be affected in a detrimental way by anxiety and they will experience greater choking like effects to their TD peers.

As previously stated DS is one of the most prevalent and one of the most globally recognised chromosomal abnormalities and causes of ID. Therefore, if we are able to understand the underlying mechanisms responsible for the planning, control and integration of multiple target aiming movements as well as the basic principles behind the effects of performance pressure on the speed and accuracy of the movements of persons with DS, this information will be beneficial for developing and improving protocols to enhance functional independence for personal and professional gains.

Chapter 3

Sequential aiming movements and the one-target advantage in individuals with Down syndrome

Experiment 1 of this study was presented at the World Down Syndrome Congress in Capetown, South Africa on 15/08/12.

It has also been submitted for publication as a research article in Research in Developmental Disabilities:

Lawrence, G. P., Reilly, N. E., Mottram, T. M., Khan, M. A., & Elliot, D. (*in press*). Sequential aiming movements and the one-target advantage in individuals with Down Syndrome.

3.1 Introduction

DS is a genetic condition involving chromosomal abnormality, specifically an additional 21st chromosome (full or partial) occurs in every cell of the body. This genotype results in individuals with DS demonstrating different physiological, anatomical and neurological features to those of the TD population. Researchers have highlighted differences between the DS and TD populations in the form of longer reaction times (Davis et al., 1991; Henderson et al., 1991), longer movement times, and greater movement errors for DS compared to TD (Elliott et al., 2004; Hodges et al., 1995). These perceptual-motor impairments have been attributed to both central processes (i.e., Frith & Frith, 1974) and peripheral anatomical characteristics (Henderson et al., 1991; Morris, Vaughan & Vaccaro, 1982).

In target directed aiming, Hodges et al. (1995) reported that movement times were approximately twice as long for those with DS and that the acceleration profiles of the DS participants contained significantly more discontinuities (indicative of online movement adjustment) than those observed in the movements of TD participants. Similarly, Almedia, Coros and Hasan (2000) have reported that individuals with DS spend proportionally more time in target regions compared to TD individuals. In both Hodges et al. (1995) and Almedia et al. (2000) movement time differences between DS and TD were attributed to participants with DS making greater use of feedback-based corrections during movement execution in order to reduce discrepancies between the position of the limb and target that emerged due to deficiencies in movement planning and feed-forward processes.

The majority of past research on motor performance in children and adults with DS has been conducted using single target directed movements. The purpose of this thesis chapter was to investigate how individuals with DS plan and execute the more complex responses involved in multiple target movements. Researchers have adopted numerous approaches to understanding how multiple segment movements are prepared and executed. Following from an extensive body of research that has investigated the relation between reaction time (RT) and the number of response segments/elements (e.g., Henry & Rogers, 1960; Klapp, Wyatt, & Lingo, 1974; Sternberg et al., 1978; Vidal, Bonnet, & Macar, 1991), researchers have recently directed their efforts towards examining the time it takes to execute movements (e.g., Adam et al., 2000; Helsen et al., 2001; Khan et al., 2006). The typical finding has been that movement time (MT) to an initial target is slowed when subjects are required to make a subsequent movement (Adam et al., 2000; Chamberlin & Magill, 1989; Helsen et al., 2001; Khan et al., 2010; Khan et al., 2011). This one-target advantage (OTA) suggests that individual elements in a response are not programmed or executed independently. Furthermore, research has shown the OTA to be a robust phenomenon since it occurs under both left and right hand responses (Helsen et al., 2001; Lavrysen et al., 2003), with and without vision (Lavrysen, Helsen, Elliott, & Adam, 2002) and is resistant to practice (Lavrysen et al., 2003).

Several hypotheses have been proposed to explain the OTA. The movement integration hypothesis (MIH) (Adam et al., 2000) explains the one-target advantage by combining the notion of advance planning and on-line control processes. Specifically, the hypothesis poses that all movement programming is completed before movement initiation and, in order to facilitate a smooth and efficient transition between segments, the implementation of the second segment is performed online, concurrent with the execution of the first movement. The increased cognitive control associated with the implementation of the second segment during the production of the first segment in two target responses leads to interference. This interference results in a lengthening of MT to the first target.

Other researchers have proposed movement constraint based explanations for the OTA (Sidaway et al., 1995). Because spatial variability increases as movement progresses

(Schmidt, Zelaznik, Hawkins, Frank & Quinn, 1979; for a review see Khan et al., 2006), the movement constraint hypothesis (MCH) proposes that movements to the first target in two element responses must be performed in a more constrained manner in order to ensure the accuracy requirements of the subsequent movement are met. That is, constraining the accuracy of the first movement has the knock on effect of providing a less variable starting position for the second movement, leading to less need to adjust the movement parameters of the second element. This results in a more integrated and efficient overall response program.

Although the OTA had been exclusively demonstrated for aiming tasks in which movements were performed with a single arm, Khan et al. (2010) recently investigated whether the OTA would emerge when there was a transfer between arms in sequential aiming movements. They compared three movement conditions; a single target movement, a two-target movement performed by a single arm, and a two-target movement where the first movement was performed with one arm and the second movement was performed with the other arm. Results revealed the OTA occurred in both the single and dual arm 2-target responses. As such, Khan et al. (2010) concluded that the processes underlying the OTA likely occur at a central level (i.e., the retrieval or initiation of motor programs). The rationale here being that if the interference occurred at the peripheral level (i.e., limb mechanics) then the OTA would not have been observed when there was a switch between the arms involved in production of the first and second movement sequences (i.e., the dual arm condition). Furthermore, Khan et al. (2010) proposed that the MCH could not explain the OTA in the two-arm condition where there was a transition between arms at the first target. This is because in the two-arm condition, the starting position of the second segment is fixed and hence does not depend on endpoint variability of the first movement.

Since there is debate about whether motor deficits in individuals with DS are primarily due to central process impairments involved in the planning of motor responses

(Frith & Frith, 1974; Hodges et al., 1995; Inui, 2007; Lam et al., 2009) and/or the peripheral issues related to anatomical and neural drive characteristics associated with DS (Henderson et al, 1991; Latash, 2007; Morris et al., 1982), the present investigation examined this further by adopting the experimental design of Khan et al. (2010). Specifically, we compared single-target movements with two-target sequences both when the two-target responses were performed with a single arm and when there was a switch between the arms used to execute the first and second movement segments. The presence of the OTA for individuals with DS would first reveal that, similar to the TD population, sequential aiming movements are not functionally independent and that the control processes underlying the production of the second segment influence the execution of the first segment. Secondly, by comparing movement times to the first target between the single and dual arm two-target conditions, inferences could be made regarding whether movement planning and control deficits associated with DS occur at the central or peripheral level. For example, a significant OTA in the single-arm but not the two-arm two-target movements would point to interference at the peripheral but not the central level. The rationale here is that the two movements in a dual-arm condition are controlled by separate and distinct effectors. Hence, the switch between arms during a response removes the possible interference and movement deficit effects associated with functional dependencies between muscles, effectors and their organisation. Further, an OTA that is present and of similar magnitude for both the single and dual arm conditions would support a central locus of interference. Finally, a significant but smaller OTA in the dual-arm compared to single-arm two-target responses would provide support for both central and peripheral interference suggesting the deficits in movement control of those with DS reside in a combination of both central and peripheral processes.

3.2 Method

Participants

24 adult volunteer participants were recruited; 8 DS (3 males and 5 females; mean age = 24 yrs, *SD* = 6.2, range= 18-37), 8 individuals with an undifferentiated intellectual disability (UID)[2] (5 males and 3 females; mean age = 26 yrs, SD = 7.1, range = 20-37) and 8 TD (4 males and 4 females; mean age = 22 yrs, SD = 4.5 yrs, range = 18-30). The DS and UID groups were recruited from Mencap Cymru support groups across North Wales and the TD group were recruited from the research institution's student body. Of the 16 participants with an ID, all lived in either a group home or with a parent/caregiver and were involved in some form of physical activity (e.g. Athletics, football etc) at least once a week. In addition, 4 (DS) and 3 (UID) were in full time education and 4 (DS) and 5 (UID) were involved in part time employment. All participants volunteered for the study, were naive to the experimental hypothesis, were right-hand dominant and reported normal or corrected to normal vision. Accessible and easy read information sheets about this experiment were given to all participants (see appendix 1). More in-depth information sheets about the study were also supplied for support workers and parents/guardians (see appendix 2). All participants were assessed for Mental Capacity (under the guidelines for the Mental Capacity Act 2005) prior to consent (see appendix 3). Specifically, participants were provided with accessible information (both verbally and visually) about the experiment and

[2] All participants completed the British Vocabulary Peabody scale as a measure of mental age and intellectual functioning (Dunn & Dunn, 1997). Whilst the individuals with an UID were classified as having a high functioning intellectual disability from local service departments and parent(s)/guardian(s), this disability was not syndrome specific (i.e., Down syndrome, Williams syndrome, Prader Willis syndrome). Although the participants in the two ID groups exhibited similar patterns of day to day adaptive functioning, participants in the UID group scored slightly higher on the Peabody scale than participants in the DS group.

then asked a series of questions related to this information. Responses were graded for understanding by an individual trained in Mental Capacity assessment through Mencap Cymru and in line with the procedures for consent to psychological research by people with an ID (see Arscott, Dagnan, & Kroese, 1998). Accessible consent forms (see appendix 4) were signed before the start of the experiment[3]. The study was carried out according to the ethical guidelines laid down by the institutions Ethics Committee for research involving human participants.

Apparatus

Participants were seated in front of a horizontal table top upon which was situated a wooden frame with six microswitches mounted under square keys (25mm x 25mm). The keys were positioned in 3 sets of pairs along the participants' midline (see Figure 1). The lateral distance between each key in a pair was 35mm (centre to centre) whilst the horizontal distance between each key pair was 150mm (centre to centre) resulting in an Index of Difficulty of 3.6 bits (Fitts, 1954). Participants were positioned so that each key could be easily reached and pressed with their index fingers. The start positions were the most distal keys, the middle keys were designated as Target 1 and the most proximal keys as Target 2.

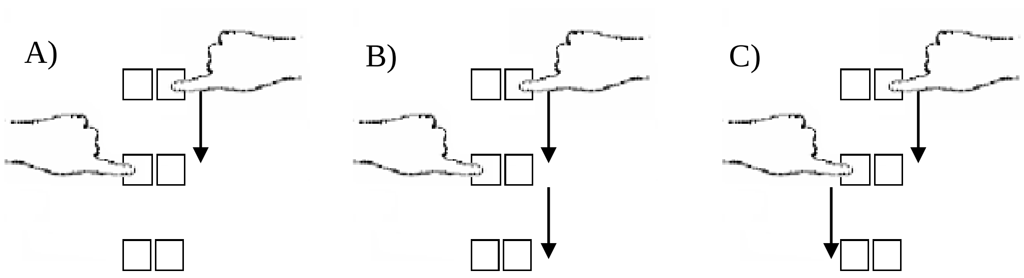

Figure 1. Starting position of fingers for the 3 conditions used in the study. A) Single target (1T); B) Two-target, single limb (2T1L); C) Two-target, two limbs (2T2L).

[3] All participants with an ID were deemed to have the sufficient mental capacity to consent themselves.

Task and Procedure

At the start of each trial, the right index finger was placed on the start position (right key) while the left index finger was placed on target 1 (left key). Participants performed three aiming tasks. In the one target (1T) task, participants moved their right index finger from the start position to target 1 (see Figure 1a). The other hand remained stationary on target 1. In the two target, single limb (2T1L) task, participants moved their right index finger from the start position to target 1 and then to target 2, pressing both targets with the same index finger (see Figure 1b). The other hand remained stationary on target 1. In the two target, two limb (2T2L) task, participants moved their right index finger from the start position to target 1 and then moved their left index finger from its position on target 1 to target 2 (see Figure 1c). Participants were told not to start the second movement until the first had been completed (complete depression of the target 1 key), but to make this changeover as quickly as possible.

At the beginning of each trial, participants were presented with a warning tone, followed by a movement initiation tone after a 1500-2500 ms variable foreperiod. Participants were instructed to react and perform the movement(s) as quickly as possible in response to the onset of the movement initiation tone.

Each participant completed three blocks of trials, one for each aiming task (1T, 2T1L and 2T2L). At the start of each block, instructions were given about the task and the movement was demonstrated three times. Each participant was then given five practice trials prior to performing 25 test trials. The three blocks of trials were counterbalanced between participants.

Statistical Methods

Dependent measures consisted of reaction time (RT), movement time to the first target (MT1), pause time at target 1 (PT) and movement time from the first target to the second target (MT2).

RT was the interval from the presentation of the stimulus (auditory tone) to the release of the key press at the starting position. MT1 was measured from the release of the key press at the starting position to the pressing of the target 1 key. PT was the time between the pressing of target 1 and the release of the key press to perform the second movement. Finally, MT2 was the time from the release of the key press at target 1 to the pressing of target 2.

A 3 Group (DS, UID, TD) x 3 Task (1T, 2T1L, 2T2L) ANOVA with repeated measures on the second factor was performed on RT and MT1, whilst a 3 Group (DS, UID, TD) x 2 Task (2T1L, 2T2L) ANOVA with repeated measures on the second factor was performed on PT and MT2. As suggested by Stevens (2002, p 509), any significant main effects and interactions involving more than two means and where Epsilon was below .7 were further investigated using Bonferroni post hoc procedures ($p < .05$ with appropriate adjustments for multiple comparisons applied). In situations where Epsilon was above .7, main effects and interactions were further investigated using Tukey's (HSD) procedures ($p < .05$).

2.3 Results

Trials in which RT was less than 100ms or greater than 800ms and in which participants missed any of the required targets or initiated the second response element prior to completing the first were omitted from the analysis. This accounted for less than 5% of trials in any one participant.

Means and SDs for all dependent measures are reported in table 1.

	DS			UID			TD		
	1T	**2T1L**	**2T2L**	**1T**	**2T1L**	**2T2L**	**1T**	**2T1L**	**2T2L**
RT	348	346	352	331	337	374	205	224	223
	52	*77*	*80*	*102*	*75*	*113*	*33*	*35*	*38*
MT1	409	418	470	276	300	297	221	252	243
	112	*80*	*112*	*145*	*140*	*112*	*65*	*81*	*90*
PT	---	256	146	---	304	121	---	103	30
		69	*113*		*97*	*45*		*23*	*41*
MT2	---	347	466	---	255	281	---	220	253
		111	*204*		*117*	*80*		*63*	*68*

Table 1. Means and *SDs* (ms) for reaction time (RT), movement time to the first target (MT1), pause time (PT), and movement time to the second target (MT2) for group (Down syndrome, DS; higher functioning undifferentiated intellectual disability, UID; and typically developing, TD) and condition (one-target, 1T; two-target, one-limb, 2T1L; and two-target, two-limb, 2T2L).

Analysis of RT data revealed only a significant main effect for group; ($F_{(2,21)} = 10.96$, $p < .001$, $\eta^2 = .51$) with RTs in the TD group (217 ms) being significantly faster than those of the UID (347 ms) and DS (349 ms) groups (see Figure 2). There was no significant main effect for condition and no significant group × condition interaction.

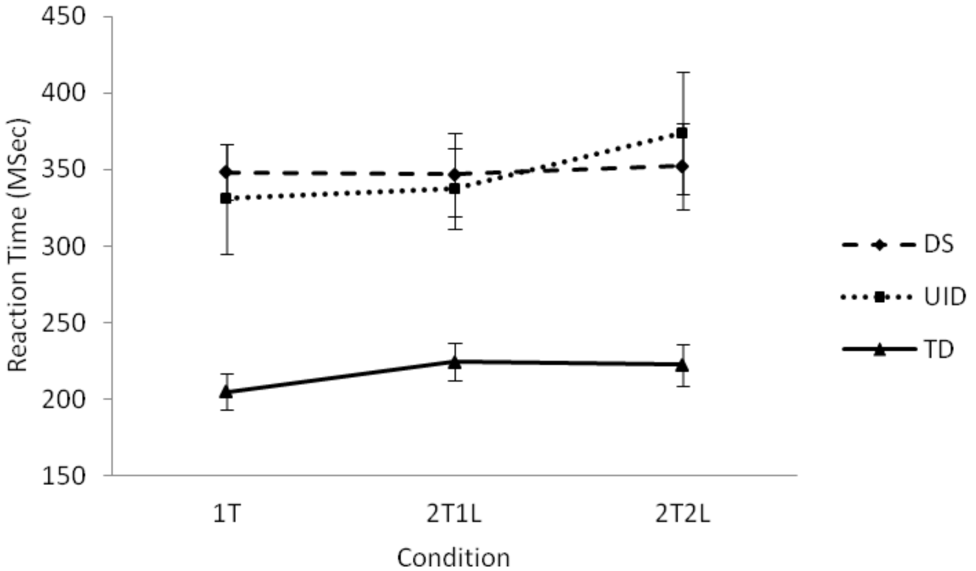

Figure 2: Reaction time as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and condition (1T = one-target; 2T1L = two-target, one limb; and 2T2L = two-target, two limbs).

MT1 data revealed a significant main effect for group ($F_{(2, 21)} = 7.68$, $p < .05$, $\eta^2 = .42$) and condition ($F_{(2, 42)} = 3.77$, $p < .05$, $\eta^2 = .15$), but no significant interaction between these two factors. Specifically, MT1 was significantly longer in participants with DS (432 ms) compared to the UID (291 ms) and TD (239 ms) groups. The UID and TD groups were not significantly different from each other. Furthermore, the 1T condition had shorter MT1s (302 ms) than both the 2T1L (323 ms) and 2T2L (337 ms) conditions, which were not different from each other (see Figure 3).

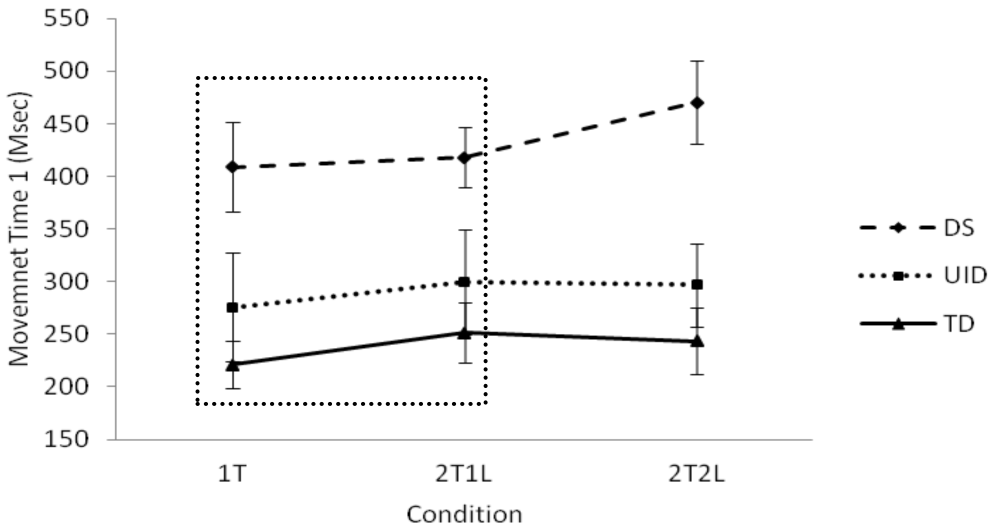

Figure 3: Movement time to the first target as a function of group and condition. The box encapsulating the data from all groups within the 1T and 2T1L conditions highlights the significant OTA observations.

The analysis of PT data revealed only a significant main effect for condition ($F_{(1, 21)} = 9.74$, $p < 0.05$, $\eta^2 = .31$) with PTs in the 2T2L condition (99 ms) being significantly less than the 2T1L condition (221 ms).

Analysis of MT2 data revealed a significant main effect for group ($F_{(2, 21)} = 6.45$, $p < .05$, $\eta^2 = .38$) and condition ($F_{(1, 21)} = 5.81$, $p < .05$, $\eta^2 = .22$). Specifically, MT2s were significantly longer in participants with DS (407 ms) compared to the UID (268 ms) and TD (237 ms) groups. Additionally, participants had longer MT2's under 2T2L (333 ms) compared to 2T1L (274 ms) conditions. The group × condition interaction was not significant.

3.4 Discussion

Research has revealed that individuals with DS are slower in initiating (Anson and Mawston, 2000; Davis et al., 1991; Henderson et al., 1991) and executing (Elliott et al., 2004; Hodges et al., 1995) target directed movements because they rely more readily on afferent information to correct movement trajectories (Elliott et al., 2004; Elliott et al., 2010; Hodges et al., 1995). These patterns of results have often been attributed to both central processes (Frith & Frith, 1974) and peripheral anatomical characteristics (Henderson et al, 1991; Morris et al., 1982) associated with DS. However, much of the research investigating DS has been conducted on single arm single sequence movements. As such, the present study investigated the planning and execution of multiple target sequential aiming movements to determine whether participants with DS use similar control strategies to the TD population. Specifically, we compared two target movements performed with a single arm to those in which there was a switch between arms at the first target in order to investigate whether perceptual-motor deficits in the DS population are due to central or peripheral issues.

The results of the present investigation revealed that individuals with DS produced significantly longer RTs and MTs than their TD and UID peers. Also, consistent with past research conducted on TD adults (Adam et al., 2000; Helsen et al., 2001; Khan et al., 2010; Lavrysen et al., 2003); we found that increasing the number of response segments in a manual aiming movement produced an increase in the time taken to execute the first segment in a sequence. This OTA was observed regardless of whether the participants had an intellectual disability (DS and UID) or no intellectual disability (TD). The OTA was present regardless of whether sequential movements were performed with one or two arms. Hence, similar to TD and UID participants, the existence of the OTA for individuals with DS implied that movements within a sequence are not prepared and executed independently.

Past literature has offered two explanations for the OTA; the MIH (Adam et al., 2001) and the MCH (Sidaway et al., 1995). According to theMIH, the first movement is carefully monitored so that the parameters of the second movement can be implemented at a time that enables optimal integration between the two movements. Since the implementation of the second segment is performed online, concurrent with the execution of the first, the increased cognitive control associated with this overlap leads to interference and hence the lengthening of MT to the first target. The MCH on the other hand, proposes that the OTA occurs because movements to the first target in two element responses must be performed in a more constrained manner in order to ensure the accuracy requirements of the already planned subsequent movement are met. Research has revealed that both the movement integration and movement constraint hypotheses play a role in the control of single arm sequential aiming movements (Khan et al., 2011). However, it is unlikely that the MCH can explain the emergence of the OTA in the dual arm condition of this thesis chapter. The rationale being that, because the starting point of the second movement is fixed in the dual arm condition, the endpoint variability of the first movement is not relevant to the production of the second movement when there is a switch in arms between the two movements. Hence there is no requirement to constrain the variability of the first movement in the two-target dual arm condition. Consequently, the emergence of the OTA in the dual arm condition of the present investigation lends support for the movement integration explanation for the OTA rather than that of the MCH.

Based on research that has involved single arm aiming movements, Adam et al. (2000) suggested that the loci of interference underlying movement integration could occur at either a central level (i.e., the retrieval or initiation of motor programs) or peripheral level (i.e., interference/alterations in muscle recruitment patterns associated with the first movement when a second movement is required). Consistent with Khan et al. (2010), the results of this thesis chapter revealed that the OTA emerged for single arm aiming movements and when there was a switch in arms at the first target. Furthermore, for the TD, DS and UID groups, the magnitude of the OTA was similar for single and dual arm conditions. Since the presence and magnitude of the OTA was not effector dependent, these findings extend the results of Khan et al (2010) to individuals with DS, suggesting a central rather than a peripheral locus of interference.

Although the magnitude of the OTA did not differ between the single- and dual-arm responses, there was a tendency for the OTA to be greater in the dual arm condition than the single arm condition for individuals with DS (see Figure 3).[4] It is possible that this increase in movement time to integrate movement segments across arms is due to the involvement of the non-dominant left hand in the dual arm responses. Research has revealed that RTs are slower in the left hand compared to the right hand of individuals with DS suggesting that the motor programs required to initiate movement of the left arm require greater cognitive processes than that of the right arm (Elliott, 1985; Elliott & Chua, 1986). Hence, the increase in the OTA for the dual arm responses suggests that participants with DS needed to apply greater cognitive resources than their TD and UID peers when attempting to integrate movements when there was a switch to the non-dominant hand. This increased cognitive control involved in implementing the second segment involving the non-dominant hand would lead to greater interference during the first segment and hence an increased OTA in the dual compared single arm responses.

[4] Separate paired samples *t*-tests performed between the single-and dual arm MT1 group data revealed that the OTA of the DS group was significantly greater in the two arm (61 ms) compared to single arm (9 ms) condition ($t(7) = -2.49$, $p < .05$). Both the UID and TD groups did not reveal significant differences between the single- and dual arms conditions ($p > .05$).

Alternatively, the larger OTA found under the dual-arm conditions for participants with DS could reflect the need for interhemispheric integration when both the right and left arm are involved in the aiming sequence. This suggestion is consistent with the finding that anomalies in the development of the corpus callosum in persons with DS negatively impacts communication between the left and right cerebral hemispheres (Wang, Doherty, Hesselink & Bellugi, 1992; see also Heath, Grierson, Binsted & Elliott, 2007). This type of communication is for the precise coordination of right and left-sided limb movements.

Whilst the results of this thesis chapter revealed a significant OTA, there was no significant difference in RT between responses that required only the single movement (1T) or the more complex multiple movements (2T1L or 2T2L). It is possible that all movement programming was completed during the foreperiod (i.e., the time interval between the warning signal and movement initiation stimulus of each trial) thus eliminating any increase in RT as a result of increasing the number of elements within a response. However, previous research has revealed increases in simple RT with increases in the number of response elements (Khan et al., 2006; Klapp, 1995, 2003). An alternative explanation is that participants were programming the movement parameters of the second movement online during the execution of the first (see Chamberlin & Magill, 1989; Khan et al., 2006). Under these circumstances, the complex two-movement sequences would not have been programmed in their entirety during the RT interval. Rather, participants would have adopted a strategy of programming the first segment of the response during RT and then completed the programming of the later segment during the execution of the first. The additional programming requirements associated with preparing the second movement during the execution of the first segment would have required increased cognitive processing and resulted in an increase in the time required to perform the first movement. It is important to note that regardless of whether the OTA occurred due to the processes involved in the MIH

(Adam et al., 2000) or the online programming hypothesis (Chamberlin & Magill, 1989; Khan et al., 2006) both hypotheses propose central processes as being responsible for the increase in movement time.

In conclusion, for DS, UID and TD individuals, MT1 data was longer in two-target sequential movements compared to single-target movements. The presence of the OTA implies that similar to the TD population, individuals with DS do not prepare and control segments of multiple target aiming sequences independently. Furthermore, the OTA emerged regardless of whether the entire movement sequence was performed with a single arm or when the arm was switched at the first target. This implies that the processes underlying the OTA are not arm specific. Similar to TD individuals, it appears that for individuals with DS, central rather than peripheral processes underlie the cause of the OTA. According to the MIH (Adam et al., 2000), in order to ensure a smooth transition between segments, the second segment is implemented during execution of the first segment. This overlap of processes during the execution of the first segment causes interference and hence the lengthening of movement time to the first target. Khan et al. (2010) have suggested that when participants prepare two-target movements, the first segment is monitored through visual and/or proprioceptive feedback to determine when the second segment should be implemented. Hence, individuals with DS likely treat movements within a sequence as functionally dependent and it is perhaps the central processes associated with the timing of the implementation of the second element that are responsible for the interference that leads to the OTA.

Chapter 4

Reversal and extension sequential aiming movements with additionally practice in individuals with Down syndrome

This experimental chapter was presented at the International Association for the Scientific Study of Intellectual and Developmental Disabilities (IASSID) conference in Halifax, Canada on 14/07/12.

4.1 Introduction

Consistent with previous research on upper limb sequential aiming movements in the TD population, the results of the previous chapter revealed that the OTA also emerges in the DS and UID populations. These results are novel in the field of ID research and indicate that individuals with DS treat movements within a sequence as functionally dependent actions. Furthermore, since the magnitude of OTA was similar in both one and two-arm sequential aiming movements it appears that the theoretical explanation for this increase in movement time to the first target resides in the movement integration hypothesis (Adam et al., 2000) rather than the movement constraint hypothesis (Sidaway et al., 1995). This is because there was a switch between arms in the two target dual arm condition and thus the starting point of the second movement was fixed and not dependent on the terminal endpoint of the first movement. Consequently, the need to constrain the first movement in order ensure an accurate and known movement start position for the second movement was not required due to the two movements being controlled by separate effectors (arms). Since research has revealed that the locus of interference responsible for the OTA resides at a central origin (i.e., the retrieval or initiation of motor programs) within the movement integration hypothesis and a peripheral origin (i.e., interference/alterations in muscle recruitment patterns associated with the first movement when a second movement is required) within the movement constraint hypothesis (Adam et al., 2000, Khan et al., 2010) the results of the previous chapter lend support for a central rather than peripheral locus of interference in the DS population.

In order to further the understanding of the control of multiple movement actions in the DS population and the possible central and peripheral movement deficits, the current investigation examined both the directional requirement of the second movement together with the effects of practice on the OTA phenomenon in persons with DS. Specifically, similar to the previous thesis chapter, we compared single-target movements with two-target extension sequences when the two-target responses were performed with a single arm and when there was a switch between the arms used to execute the first and second movement segments. However, we also included sequences where the second movement in the sequence required a reversal in direction to that of the first movement. With regard to the directional requirement of the second movement, past research (Adams et al., 2000; Larysen et al., 2003; Khan et al, 2010) together with the findings of the previous chapter have demonstrated the OTA phenomenon in two target movements where the second movement of the sequence involved an extension. However, exceptions to the OTA have been observed when the second movement involves a reversal in direction from that of the first. Under these conditions research has demonstrated either the removal of the OTA (Adam et al., 2000; Ketelaars, Garry and Franks, 1997; Khan et al, 2010) or significant reductions in MTs to the first target compared to those in one target conditions; a two-target advantage (TTA) (Khan et al., 2006). This reduction in OTA, or the TTA, has been explained by the different underlying muscle activation patterns of the single movement and the two movement reversal actions. In a single target movement, the muscle activation follows a tri-phasic pattern. That is, the agonist muscle group accelerates the limb towards the target, an antagonist muscle burst decelerates the limb upon nearing the target and a final second firing of the agonist muscle is used to dampen the mechanical fluctuations at the end of the first movement (Adam et al., 2000; Almeida, Freitas, & Marconi, 2006; Enoka, 1988; Khan et al, 2006; Wierzbicka et al., 1986). However, in a two-target reversal movement the elastic properties of the antagonist muscle group used to decelerate the first movement are also utilised to accelerate the limb in the second reversal movement and therefore there is no need to dampen the mechanical fluctuations at the end of the first movement. This bi-phasic pattern of muscle activation allows for optimal integration between movements by reducing the muscle activation processes involved (compared to single target movements) and results in the TTA (Adam et al., 2000; Khan et al., 2006; 2010). If this TTA is a result of the peripheral processes involved in the control of motor responses then we can expect to find this advantage in the single arm reversal condition but not the dual arm reversal condition. The rationale being that there is a change in effectors (arms) in the two arm condition and thus the removal of the bi-phasic pattern of muscle activation proposed to be responsible for the TTA in single arm reversal conditions i.e., the antagonistic muscle (responsible for the deceleration of the movement) of the arm used to produce and control the first movement is not the agonist muscle used to accelerate the arm towards the second movement since there is a switch in arms at the first target. Furthermore, if the movement deficits associated with DS reside at the peripheral level then one would expect the TTA phenomenon to be reduced or removed in the DS compared to TD populations. That is, individuals with DS would not utilise the peripheral movement strategies that reside at mechanical level to allow for optimal integration and transition between movements.

The primary aims of this thesis chapter were; 1) to replicate the seminal OTA findings of the previous chapter and; 2) to examine the possible TTA effects in the DS population when two target movements require a reversal in direction at target 1 together with situations where there is a switch in limbs at the same target. As discussed above (and based on the findings of the previous chapter), it was hypothesised that the OTA would emerge in both the single-and dual-arm responses when the second movement in the two target action was an extension of the first. However, for the reversal movements it was expected that the OTA would not emerge in the single-arm condition and rather be replaced by a TTA. This is due to the previously discussed pattern of muscle activation proposed to be responsible for the TTA. Furthermore, it was hypothesised that this TTA would not emerge in the two-target dual arm reversal conditions because there was a switch in arms at the first target resulting in the removal of the bi-phasic pattern of muscle activation proposed to be responsible for the TTA in single arm reversal conditions. If the TTA was revealed for the two arm reversal movements this would indicate that the TTA is influenced by central rather than peripheral processing since the within arm peripheral muscle benefits proposed to be responsible for the TTA are removed in conditions where arms are switched at the first target.

An additional aim of this thesis chapter was to explore the effects of practice on both the OTA and TTA phenomenon's in persons with DS. Whilst previous non disability specific research has revealed that the OTA is resistant to practice (Lavrysen et al., 2003), research within the DS population has indicated that motor skills can be modified over a period of days or weeks through task-specific practice sessions and that individuals with DS have the potential to reach the same levels of motor skill proficiency as their TD peers with adequate practice (Latash, 2007; Smith, Kubo, Black, Holt & Ulrich, 2007). Thus, in order to further investigate the possibility that the reaction times and movements times of individuals with DS can improve across practice to be in line with those of their TD peers we included the independent variable of practice into this experimental chapter of the thesis.

4.2 Method

Participants

Participants were 24 adult volunteers; 8 DS (4 males and 4 females; mean age = 25 yrs, *SD* = 8.55, range= 18-44), 8 individuals with an undifferentiated intellectual disability (UID)[5] (5 males and 3 females; mean age = 26 yrs, SD = 6.5, range = 19-40) and 8 TD (4 males and 4 females; mean age = 20 yrs, SD = 1.5 yrs, range = 18-23). The DS and UID groups were recruited from Pengwern Mencap College, Special Olympics Bangor and Mencap support groups across North Wales and the TD group were recruited from Bangor University. Of the 16 participants with an ID all lived in either a group home or with a parent/caregiver and were involved in some form of physical activity (e.g. athletics, basketball, football etc) at least once a week. In addition, 5 (DS) and 2 (UID) were in full time education and 3 (DS) and 6 (UID) were involved in part time or full time employment. All participants volunteered for the study, were naive to the experimental hypothesis, were right-hand dominant and reported normal or corrected to normal vision. Accessible easy read information sheets about this experiment were given to all participants (see appendix 5). More in-depth information sheets about the study were also supplied for support workers and parents/guardians (see appendix 6). All participants were assessed for Mental Capacity (under the guidelines for the Mental Capacity Act 2005) prior to consent (see appendix 3).

[5] All participants completed the British Vocabulary Peabody scale as a measure of mental age and intellectual functioning (Dunn & Dunn, 1997). Whilst the individuals with an UID were classified as having a high functioning intellectual disability from local service departments and parent(s)/guardian(s), this disability was not syndrome specific (i.e., Down syndrome, William's syndrome, Prader Willis syndrome). Although the participants in the two intellectually disabled groups exhibited similar patterns of day to day adaptive functioning, participants in the UID group scored slightly higher on the Peabody scale than participants in the DS group.

Specifically, participants were provided with accessible information (both verbally and visually) about the experiment and then asked a series of questions related to this information. Responses were graded for understanding by an individual trained in Mental Capacity assessment through Mencap Cymru and in line with the procedures for consent to psychological research by people with an intellectual disability (see Arscott, Dagnan, & Kroese, 1998). Accessible consent forms (see appendix 4) were signed before the start of the experiment[6]. The study was carried out according to the ethical guidelines laid down by the institutions Ethics Committee for research involving human participants.

Apparatus

Similar to Khan et al. (2010) and the methods detailed in the previous chapter of this thesis, participants were seated in front of a horizontal table top upon which was situated a wooden frame with six microswitches mounted under square keys (25mm x 25mm). The keys were positioned in 3 sets of pairs along the participants' midline (see Figure 4). The buttons on the left hand side were yellow whilst the buttons on the right side were green. The lateral distance between each key in a pair was 35mm (centre to centre) whilst the horizontal distance between each key pair was 150mm (centre to centre) resulting in an Index of Difficulty of 3.6 bits (Fitts, 1954). Participants were positioned so that each key could be easily reached and pressed with their index fingers. The start positions were the most distal keys, the middle keys were designated as Target 1 and the most proximal keys as Target 2 (see figure 4).

[6] All participants with an ID were deemed to have the sufficient mental capacity to consent themselves.

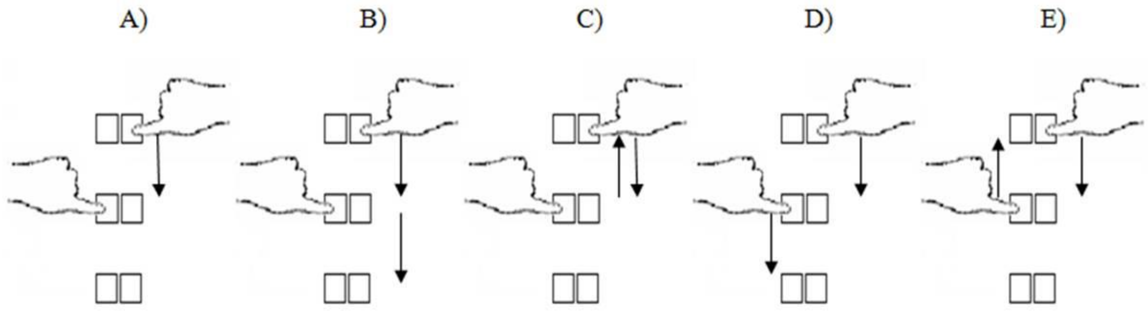

Figure 4. Starting position of fingers, and the 5 conditions used in the study. a) one target extension (1T); b) two-target single limb extension (2T1L); c) two-target dual limb extension (2T2L); d) two-target singe limb reversal (2T1Lr) and e) two-target dual limb reversal (2T2Lr).

Task

Participants were required to perform five separate extension and reversal aiming movements; one target extension (1T), two-target single limb extension (2T1L), two-target dual limb extension (2T2L), two-target singe limb reversal (2T1Lr) and two-target dual limb reversal (2T2Lr). In the 1T condition, participants were only required to move their right hand from the start position to Target 1, whilst the left hand remained stationary (see Figure 4A). In the 2T1L condition, participants moved their right hand from the start position to Target 1 and then again to Target 2, pressing both targets with the same index finger (see Figure 4B). As in the 1T condition, the left hand remained stationary. In the 2T2L condition, participants moved their right hand from the start position on Target 1 and then moved their left hand from its position on Target 1 to Target 2 (see Figure 4C). In the two-target, single limb reversal condition, participants moved their hand from the start position to Target 1 and then back to the start position, pressing both targets with the same index finger (see Figure 4D). The left hand remained stationary on Target 1. In the two-target, two-limb reversal condition, participants moved their right hand from the start position to Target 1 and then move their left hand from its position on Target 1 to the start position on the left side of the board (see Figure 4E). In the conditions involving 2 movements, participants were informed not to start the second movement until the first had been completed (complete depression of the target 1 key), but to make this changeover as quickly as possible.

Procedure

At the start of each condition, instructions were given about the task and the movement sequence for that condition was demonstrated 3 times. Each participant was then given five practice trials. Participants always started the trial by simultaneously depressing the middle left button with their left index finger and the upper right button with their right index finger (see Figure 4). At the beginning of each trial, the computer emitted two audible tones. The first tone was provided as a warning to alert the participant that the trial was about to begin whilst the second tone acted as the stimulus (the time between tones randomly varied from 1500-2500ms so that participants could not anticipate the start of the trial). Following detection of the stimulus, participants were instructed to start the sequence of button pushes as quickly as possible. Each participant completed a total of 400 trials; 4 practice blocks each consisting of 20 trials in each of the five aiming tasks. Participants completed the 4 blocks over a period of 4 consecutive days, one block per day. A 5 minute rest period was provided between each condition and the order in which the tasks were presented within each block was counterbalanced across participants.

Statistical Methods

Similar to chapter 3 of this thesis, dependent measures consisted of reaction time (RT), movement time to the first target (MT1), pause time at target 1 (PT) and movement time from the first target to the second target (MT2).

RT was the interval from the presentation of the stimulus (auditory tone) to the release of the key press at the starting position. MT1 was measured from the release of the key press at the starting position to the pressing of the target 1 key. PT was the time between the pressing of target 1 and the release of the key press to perform the second movement.

Finally, MT2 was the time from the release of the key press at target 1 to the pressing of target 2.

RT and MT1 were submitted to separate 3 Group (DS, UID, TD) x 5 condition (1T, 2T1L, 2T2L, 2T1Lr, 2T2Lr) x 4 block (trials, 1-100; 101- 200; 201-300; 301-400) ANOVAs with repeated measures on the last two factors. Whereas separate 3 Group (DS, UID, TD) x 4 condition (2T1L, 2T2L, 2T1lr, 2T2Lr) x 4 block (trials, 1-100; 101- 200; 201-300; 3001-400) ANOVAs with repeated measures on the last two factors were performed on PT and MT2 data. Significant interactions were further investigated using Tukeys (HSD) procedures ($p < .05$).

4.3 Results

Trials in which RT was less than 100ms or greater than 800ms and in which participants missed any of the required targets or initiated the second response element prior to completing the first were omitted from the analysis. This accounted for less than 5% of trials in any one participant.

Analysis of RT data revealed only a significant main effect for condition; ($F_{(2.44, 51.20)} = 6.20$, $p < .05$, $\eta^2 = .92$) with RTs in the 1T condition being significantly shorter to the 2T1L, 2T1Lr and 2T2Lr conditions (see Figure 5). There was no significant main effect for group and no significant group × condition interaction ($p > .05$). There was no block main effect or block x condition or block x group interaction.

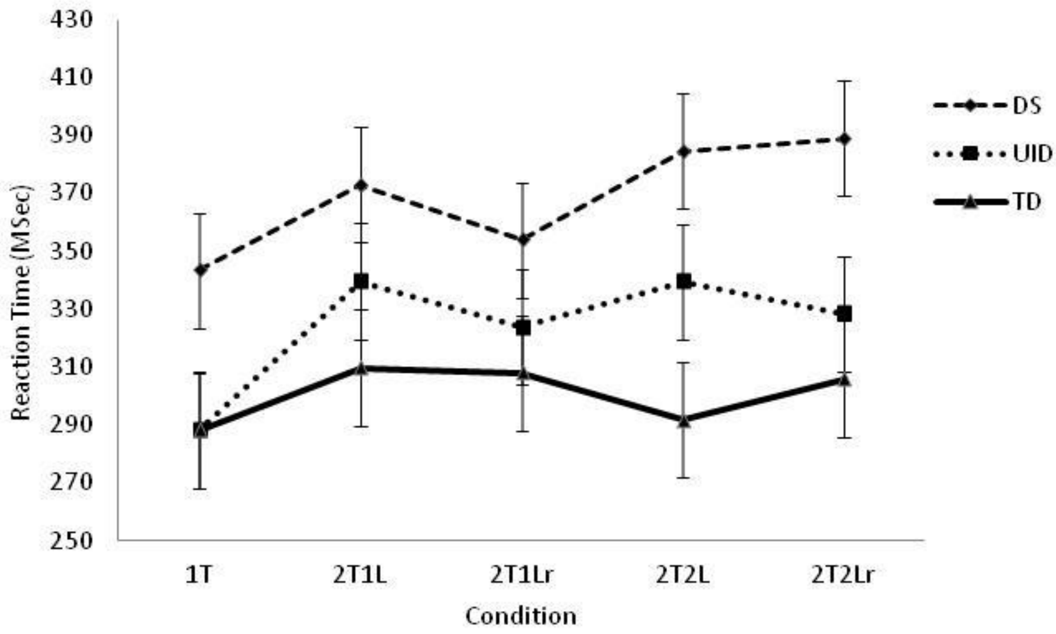

Figure 5: Reaction time as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and condition (1T = one-target extension; 2T1L = two-target, one limb extension; 2T1Lr = two-target, one limb reversal; 2T2L = two-target, two limb extension and 2T2Lr = two-target, two limb reversal.

MT1 data are shown in Figure 6. Analysis revealed a significant main effect for block ($F_{(2.19, 45.94)} = 6.42, p < .05, \eta^2 = .90$). Specifically, MT1 was significantly faster in Block 1 (329.55ms) compared to the remaining Blocks (Block 2 = 386.17ms; Block 3 = 369.58ms; Block 4 = 369.52ms). A significant main effect for condition ($F_{(2.51, 52.61)} = 5.37, p < .05, \eta^2 = .88$) revealed that movements in the 1T condition were significantly faster than those in the 2T1L, 2T2L and 2T2Lr conditions. Additionally, movements in the 2T2L condition were significantly slower than those the 2T2Lr condition. A significant group × condition interaction ($F_{(5.01, 52.61)} = 3.10, p < .05, \eta^2 = .84$) was observed and Tukeys posthoc analysis revealed that in all conditions the TD and UID groups were significantly faster than the DS group. A significant block × group interaction ($F_{(4.38, 45.94)} = 5.97, p < .05, \eta^2 = .98$), revealed that at block 1 the TD group were significantly faster than the DS and the UID groups. Additionally, the UID group were significantly faster than the DS group in Block 1. At Block 2, Block 3 and Block 4, the TD and the UID groups were significantly faster than the DS group. There was also a significant between subject main effect for group; ($F_{(2, 21)} = 7.61, p < .05, \eta^2 = .91$) with movements times being significantly longer for the DS group compared to the UID and TD groups.

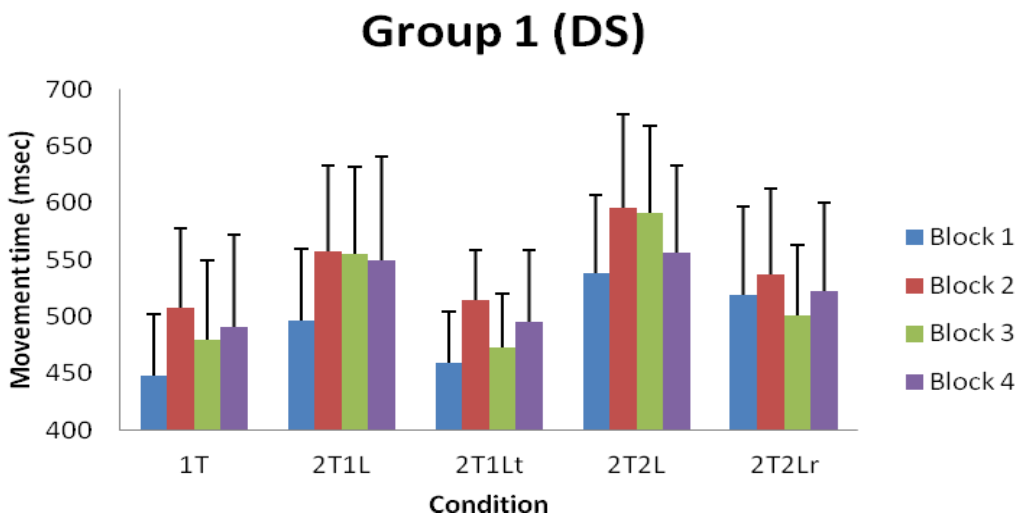

Figure 6a

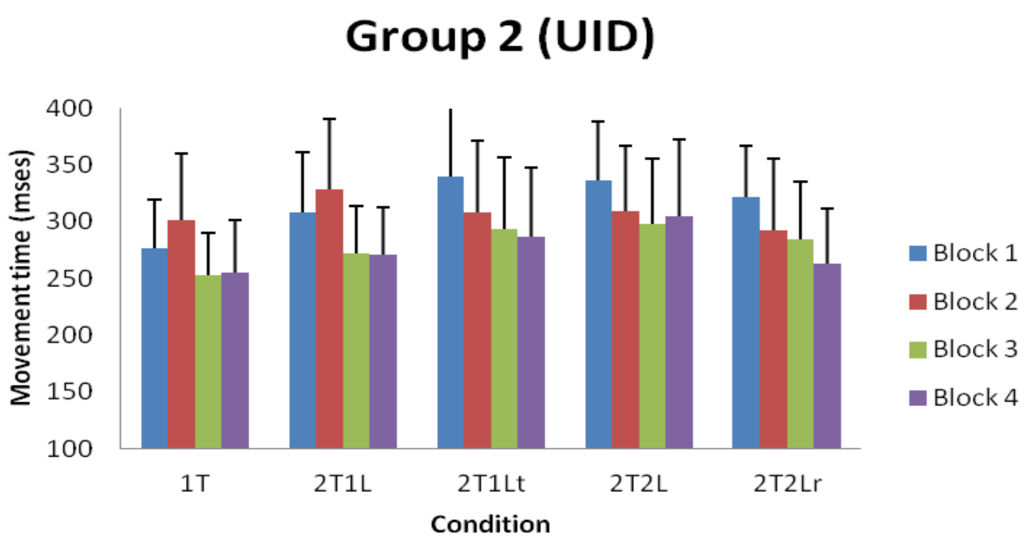

Figure 6b

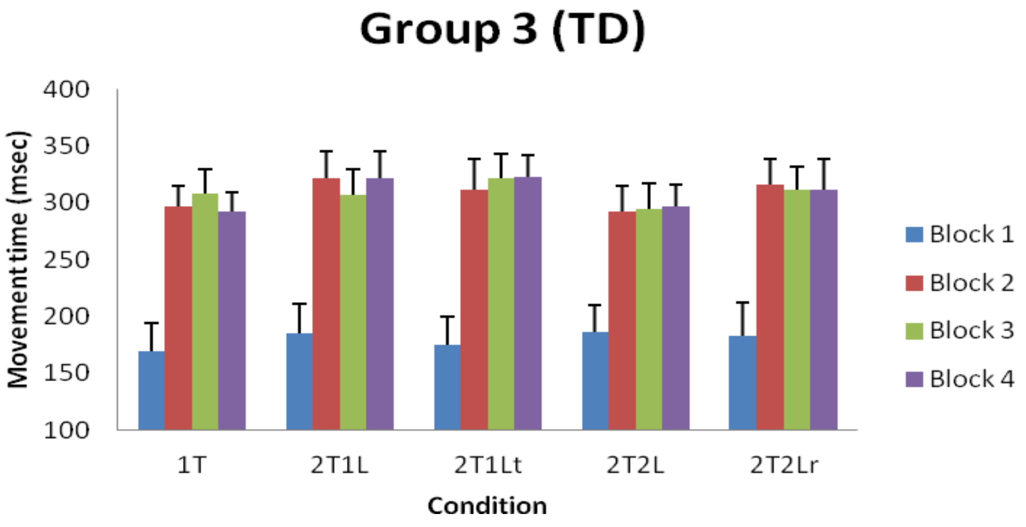

Figure 6c

Figure 6: Movement times (MSec) and standard errors of each practice block within each condition for DS group (a), UID group (b) and TD group (c)

The analysis of PT data revealed a significant main effect for condition ($F_{(1.68, 35.27)}$ = 7.42, $p < 0.05$, $\eta^2 = .89$) with 2T1L condition being significantly longer than the 2T2L and 2T2Lr conditions. Furthermore, the 2T1Lr condition was significantly longer than 2T2Lr. There was also a between subject main effect for group ($F_{(2, 21)}$ = 5.83, $p < 0.05$, $\eta^2 = .82$) with the DS group pausing for significantly longer periods between movements than the TD group and a trend for this effect between the DS and UID groups (see Figure 7). No other significant main effects or significant interactions were observed.

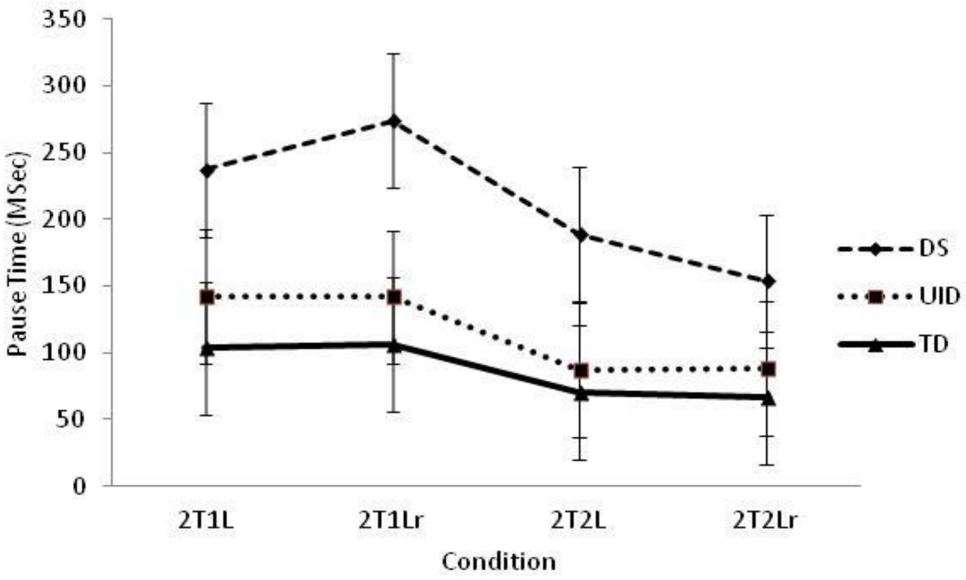

Figure 7: Pause time (MSec) as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and condition (1T = one-target extension; 2T1L = two-target, one limb extension; 2T1Lr = two-target, one limb reversal; 2T2L = two-target, two limb extension and 2T2Lr = two-target, two limb reversal.

Analysis of the MT2 data revealed a significant main effect for condition ($F_{(2.15, 45.25)} = 6.36$, $p < 0.05$, $\eta^2 = .90$). Specifically, MTs in the 2T1L condition were significantly faster than those in either the 2T2L or 2T2Lr condition. There was also a significant between subjects main effect for group ($F_{(2, 21)} = 14.61$, $p < 0.05$, $\eta^2 = .99$) with the DS group recording significantly slower movement times than the UID and TD groups. There was no significant main effect of block and no significant group × condition, group × block or block × condition interactions ($p > .05$).

4.4 Discussion

Increasing the number of targets in a sequence has been shown to increase the time taken to initiate and execute the first segment in the sequence (Glencross, 1980; Adam et al., 2000; Klapp, 2003; Khan et al., 2007; 2010) which implies that the two movements are not functionally independent of each other. The previous chapter highlighted that individuals with DS may process multiple target sequential aiming movements (extension direction) in a similar fashion to their UID and TD peers and that these strategies occur at the central origin. The OTA has been revealed in both single limb responses and manual aiming tasks in which two limbs are used (Khan et al, 2010), however when the second movement in a one-limb movement condition involves a change in direction (reversal movement), the OTA does not emerge. This is because the antagonist activity of the first movement in a reversal sequence acts as a brake to the first movement and initiates the second movement which not only saves time and energy but also simplifies the muscle pattern control process (Guiard, 1993; Helsen, Adam, Elliot & Buekers, 2001). This thesis chapter investigated the planning and execution of both multiple target extension and reversal sequential aiming movements to determine whether participants with DS use similar central and peripheral control strategies to that of the TD population. Specifically, we compared two target movements performed with a single arm to those in which there was a switch between arms at the first target in conditions when the second movement was in the same direction as the first and when it was in the opposite direction to the first.

For all populations, RTs were faster in the single-target condition compared to the two target conditions. This increase in RT as a function of the number of movements within a response is consistent with previous research (Khan et al., 2006, 2007, 2010; Klapp, 1995, 2003) and indicates that all participants were adopting a strategy of programming both response movements prior to movement initiation and that this strategy is not limited to responses within a limb. Interestingly the findings of both the previous chapter of this thesis and other DS research (Anson and Mawston, 2000; Davis et al., 1991; Henderson et al., 1991) have revealed that individuals with DS are significantly slower in initiating target directed movements compared to their TD counterparts. However, whilst the results of this thesis chapter indicated that participants with DS produced slower RTs compared to the UID and TD participants, this difference was not statistically significant. It is likely that these unexpected findings are a result of the relatively large variability within the DS data rather than any specific movement characteristics unique to this study's DS sample.

Whilst movement times to the first target were significantly greater in the DS population compared to the UID and TD populations, importantly the influence of the number of responses movements was not limited to RT data. That is, similar to the results of the previous experimental chapter and earlier research on TD individuals (Adam et al., 2000; Chamberlin & Magill, 1989; Helsen et al., 2001; Lavrysen et al., 2002; Khan et al., 2010), MT1s were quicker when a single target response was required compared to when this first movement was followed by a second movement in the same direction. This OTA was revealed within all groups for the single arm extension movements highlighting similar movement control strategies between these populations. Furthermore, the OTA was not limited to the control of movements performed with a single arm as results revealed that MTs were longer in two-target extension conditions regardless of whether a two target single arm or two target dual arm response was required. Additionally, similar to the previous chapter, the magnitude of the OTA was comparable for both the single-arm and dual-arm conditions. The combination of these findings suggests that the OTA occurs as a result of the movement integration (MIH), rather than MCH, and that the loci of interference responsible for the OTA reside at the central level. That is, whilst the MIH proposes that the OTA could materialise both within and across arms due to an overlap in the processes involved in control of the first movement and the implementation of the pre-programmed movement parameters of the second movement, the MCH proposes that the OTA occurs because movements to the first target in two element responses must be performed in a more constrained manner in order to ensure the accuracy requirements of the already planned subsequent movement are met. However, because the starting point of the second movement is fixed in the dual arm conditions, the endpoint variability of the first movement is not relevant to the production of the second movement when there is a switch in arms between the two movements. Hence there is no requirement to constrain the variability of the first movement in the two-target dual arm condition. The occurrence of the OTA in movements where there is switch in arms at the first target suggests that the mechanisms proposed in the MIH occur at a central rather than peripheral level in the DS, UID and TD populations.

The results of the MT1 data in conditions when the second movement was a reversal of the first (i.e., the 2T1Lr and 2T2Lr conditions) revealed that the OTA was eliminated in all groups. This is consistent with previous findings within the TD population (e.g., Adam et al., 2001; Khan et al., 2006, 2010) and highlights that the control strategies for integrating two target reversal movements both within and across arms do not differ between the DS, UID and TD populations. This reduction in OTA has been explained by the different underlying muscle activation patterns of the single movement and the two movement reversal actions. In a single target movement, the muscle activation follows a tri-phasic pattern whereby the agonist muscle group accelerates the limb towards the target, an antagonist muscle burst decelerates the limb upon nearing the target and a final second firing of the agonist muscle is used to dampen the mechanical fluctuations at the end of the first movement (Adam et al., 2000; Almeida, Freitas, & Marconi, 2006; Enoka, 1988; Khan et al, 2006; Wierzbicka, Wieger & Shahani, 1986). However, in a two-target reversal movement the elastic properties of the antagonist muscle group used to decelerate the first movement are also utilised to accelerate the limb in the second reversal movement and therefore there is no need to dampen the mechanical fluctuations at the end of the first movement. This bi-phasic pattern of muscle activation allows for optimal integration between movements by reducing the muscle activation processes involved (compared to single target movements) and results in the elimination of the OTA (Adam et al., 2000; Khan et al., 2006; 2010). If this elimination of the OTA is a result of the simpler peripheral processes (i.e., the bi-phasic pattern of muscular activity) involved in the control of motor responses involving a reversal movement then we would have only observed this effect in the single arm reversal condition but not the dual arm reversal condition. The rationale being that there is a change in effectors (arms) in the two arm condition and thus the removal of the peripheral elastic muscle properties associated with the single arm reversal movements. However, because the OTA was eliminated in both the single arm and dual arm two target reversal movements one can infer that these control strategies and benefits occurred due to a reduction in the central processes required to control the two target reversal compared to extension movements.

Research has revealed that movements utilising a reversal aiming movement sometimes demonstrate a TTA whereby movement times to the first target are significantly faster in two target reversal compared to single target movements. However, whilst the present investigation demonstrated a significant and important elimination of the OTA in both the single arm and dual arm reversal conditions, this TTA did not materialise. The lack of the TTA in the current data could be due to the more complex use of a three-dimensional tapping task compared to the simpler one-dimensional sliding tasks utilised in previous research where the TTA was observed (Almeida et al., 2000, 2006; Khan et al., 2006). That is, the horizontal sliding tasks of that used in the work of both Almeida and colleagues and Khan and colleagues constrained movements into a single plane of movement (y). Thus, the central processes involved in the control and integration of movements is likely to be significantly simpler in these tasks compared to those involved in tasks where the control and integration of x, y and z components of movement need to be considered and thus allow a true bi-phasic pattern of muscle activity proposed to be responsible to the TTA to occur.

As previously highlighted, the MT1 data indicated both the OTA phenomenon in the two target extension movements and the elimination of this phenomenon in the two target reversal movements. The author has proposed a central rather than peripheral process to account for these findings and the differences in the movement times to the first target between the 2T2Lr and 2T2L conditions lend further support for this proposal. Specifically, the 2T2Lr conditions produced faster MT1's compared to those of the 2T2L conditions. The simpler motor programs and parameters involved in the muscle patterns of reversal compared to extension movements (Adam et al., 2000; Guiard, 1993; Helsen et al., 2001), cannot easily result in movement time advantages because of peripheral processes when there is a switch between limbs. Thus, the benefits observed in the movement time 1 data of the 2T2Lr condition compared to the 2T2L extension condition is likely due to the requirement of less central processes for accurate retrieval and implementation the of the simpler muscle patterns involved in the reversal compared to the extension movement. These simpler movement parameters within reversal conditions may not solely be due to muscle patterns as described above. It is suggested that when the location of target two in a two target reversal movement in located proximal to the start position (as in this thesis chapter) a reduction in task complexity may occur due to grouping of the targets within a subjectively produced 'Object' with the start location target (Chen, 1998). Regardless of whether the reduction in task complexity in the reversal compared to extension movement is due to movement direction, target location or a combination of the two, the elimination of the OTA in the two target reversal movement when a switch in limbs at the first target occurred points to central origins being responsible for movement integration.

The effect of practice on the movement times to the first target revealed that all groups improved performance as practice progressed. However, this improvement was slower in participants with DS compared to individuals with an undifferentiated intellectual disability and did not result in MT similarities with either the UID or TD groups. MTs of the UID population on the other hand, where comparable to those in the TD population by the end of practice. Following a 4 day practice schedule that included 1,100 trials, Almeida et al (1994) reported dramatic improvements in the kinematics of a simple target aiming movement performed by persons with DS to the extent that performance was comparable to that of TD participants. Although the current experimental design of this thesis chapter utilised a 4 day practice schedule, the number of trials within this schedule was significantly less than that employed by Almedia and colleagues. Thus, it appears that this was not a sufficient amount of practice to allow performance of the DS population reach a comparable level to that of the TD population.

The analysis of PTs revealed that all groups increased performance over practice but performance of the intellectually challenged groups (DS and UID) did not reach levels comparable to that of the TD group. Interestingly, and similar to the findings of the previous chapter, movements requiring only a single arm paused at the first target for significantly longer periods of time than movements that required a switch in arms at the first target. Single limb movements are proposed to be controlled at a central and peripheral level, whereas dual limb movements as proposed to experience reduced amounts of interference at the peripheral level as the two movements are implemented by two largely distinct and separate neuroanatomical effectors i.e., different arms (Khan et al, 2010). Given these proposals, it can be assumed that PTs were longer in the single limb movements because of the interactive effects involved in the central processes (i.e., the accurate retrieval and implementation of the motor program) together with the peripheral processes (i.e., those involved in the concurrent muscular organisation of movement one and two) required to ensure optimal integration and transition between the movements of the performing arm. In contrast, in the two arm conditions a central loci for performance is dominant as there is a switch between hands at the first target and therefore peripheral factors are largely redundant. Again, similar to the MT data, these effects were revealed in all participants providing important evidence that the control strategies of multiple target movements did not differ between the TD and intellectually challenged (DS and UID) individuals and that the multiple target multiple arm movements of all groups were subject to interference predominantly at the central level.

Movement times to the second target were faster across groups in the single arm two-target condition compared to the dual arm two-target conditions. This may be accounted for via an activation and momentum viewpoint; whereby the limb is already active prior to the start of the second movement in the single arm conditions, whereas movement is initiated from a static position in the dual arm conditions. In addition, performing the second movement with the non-dominant hand (left hand) in the two target two-arm task could produce slower movement times. A right hand advantage is well documented in manual aiming studies (Elliot & Chua, 1996) and the potential issues for the switching and co-ordination of arms in individuals with DS that were discussed in the previous chapter (i.e., developmental issues associated with the corpus collosum) may also be relevant for the movement time to the second target findings in this thesis chapter.

In conclusion, for DS, UID and TD individuals, movement time to the first target was longer in two-target extension movements compared to single-target movements (OTA) but not the two target reversal movements (OTA was eliminated). The presence of the OTA for the extension movements implies that similar to the TD population, individuals with DS prepare and control segments of multiple target aiming sequences dependently of each other. Furthermore, the OTA emerged regardless of whether the entire movement sequence was performed with a single arm or when the arm was switched at the first target. This implies that the processes underlying the OTA are not arm specific and appear at the central origin. In addition, the elimination of the OTA in the single and dual arm two target reversal movements lends further support for central processes being responsible for the integration of movements within a sequence. The rationale being that the proposed simpler motor programs and parameters involved in the muscle patterns of reversal compared to extension movements (Adam et al., 2000; Guiard, 1993; Helsen et al., 2001), cannot easily result in movement time advantages because of peripheral processes when there is a switch between limbs (Khan et al., 2010). Therefore, the results suggest that any central deficits associated with DS do not prevent the adoption of movement strategies designed to increase the integration of elements within single and dual arm two target responses where the second movement requires either an extension or reversal in movement direction from that of the first movement. Since this pattern of results was revealed in both the TD and intellectually challenged (DS and UID) populations, it is concluded that persons with DS apply similar movement planning and control strategies as the TD population when controlling actions requiring with multiple arm, multiple movement and multiple directions. Finally, although improvements in the DS group following 400 trials of practice were not comparable to those of either the TD or UID populations, improvements were evident. This indicates the importance of considering the amount of practice within DS training interventions and it is recommended based on the findings of the present experiment that practice schedules include greater than 400 trials for significant improvements to occur.

Chapter 5

Can learning under anxiety counteract the negative effects of anxiety later in the skill acquisition of individuals with Down syndrome?

This experimental chapter was presented at the Conference for People with a Learning Disability in Bangor, Wales on 21/06/12.

5.1 Introduction

The previous two experimental chapters investigated the underlying mechanisms responsible for the planning, control and integration of multiple target aiming movements. Results suggested that whilst individuals with DS initiate and execute movements slower than TD individuals, they actually utilise similar movement planning and control strategies. That is, the movements involved in multiple target aiming were controlled in a dependent fashion. Consequently, the performance characteristics (e.g., reaction time, movement time, and pause time) of the first movement in the sequence were changed when a second movement was introduced into the required action. Specifically, reaction times and movement times to the first target were lengthened in the two-target compared to single target extension movements and remained constant when the second movement was in the opposite direction to that of the first (i.e., a reversal movement). This functional dependency between movements is the motor system's attempt to ensure movement sequences are performed in an integrated, coherent, and efficient manner. Furthermore, the occurrence of this dependency in the dual arm movements (i.e., when there was a switch between limbs at the first target) revealed that the control strategies responsible for movement integration are likely to be those proposed by the movement integration hypothesis (Adam et al., 2000) and occur at the central (i.e., the retrieval or initiation of motor programs) rather than peripheral (i.e., interference/alterations in muscle recruitment patterns associated with the first movement when a second movement is required) level. The purpose of the present research was to investigate the effects of environmental characteristics outside of those associated with the number of targets within a sequence. Specifically, the effects of performance pressure on the speed and accuracy of the movements of persons with DS.

The influence of anxiety on performance continues to be an area of major interest within sport psychology research (Baumeister, 1984; Janelle, 2002; Eysenck et al., 2007; Hardy et al., 2001; Mullen & Hardy, 2000; Williams et al., 2002; Wilson et al., 2006; Woodman & Hardy, 2001, 2003) with this research revealing that individuals often 'choke'; fail to perform to their normal ability as a result of the state anxiety the pressure to perform evokes (Beaumeister, 1984; Lawrence et al., *in press*; Lawrence et al., 2012, Mullen & Hardy, 2000; Oudejans & Pijpers, 2010)

In attempts to explain the 'choking' phenomenon, two somewhat competing theoretical positions have been adopted: self focus (Baumeister, 1984; Masters, 1992) and distraction (Eysenck et al., 2007; Wine, 1971). Self focus theorists propose that anxiety causes performers to focus their conscious attention on the process of performance resulting in a disruption in the normal automatic processes of skilled action (Jackson & Wilson, 1998; Langer & Imber, 1979; Mullen & Hardy, 2000). Distraction theorists on the other hand, propose that the pressure an individual is subjected to causes attention to be directed towards dealing with task irrelevant stimuli (e.g., anxiety/worry) which reduces the performance of the primary task (Eysenck et al., 2007).

The notion of self focus is a central tenet of the Conscious Processing Hypothesis (Masters, 1992). Masters proposes that an individual experiences elevated levels of anxiety when in a stressful or pressured situation which causes the individual to become self-conscious about performing successfully (also see, Wilson, Smith & Holmes, 2007). This increased self focus causes a previously proficient skill to be executed with more step-by-step conscious control and results in interference with normally automatic processes causing performance decrements. In support of the CPH, researchers have shown that tasks are more likely to break down under anxiety if performers have accumulated accessible and conscious task-relevant knowledge used to control movement (Masters & Maxwell, 2008). Specifically, Masters (1992) proposed that if explicit learning can be minimized (i.e. knowledge of learning is reduced) then a breakdown of automatic processes under pressure is less likely to occur in future pressure situations, as the performer has no access to explicit knowledge. Lawrence et al. (2012) have recently offered further support for these proposals by demonstrating that anxiety prevents the automatic reflexive processes involved in visual regulation (i.e., the adjustment of trajectories via the 'continuous and attention-free monitoring of visual feedback', Briere & Proteau, 2011, pp. 48) rather than the conscious, effortful and non automatic processes involved in the parameterisation of movement (i.e., movement preparation).

An alternative explanation of the anxiety-performance relationship resides in Eysenck et al's. (2007) distraction based Attentional Control Theory (ACT). Eysenck and colleagues propose that anxiety is resource intensive and results in attention being allocated to task irrelevant cues such as detecting the cause of the threat/anxiety and deciding how to cope with it. This creates an increase in the influence of the stimulus-driven system and a reduction in that of the goal-directed system i.e., that responsible for the control of the primary task performance. Consequently, the presence of anxiety results in a reduction of the resources available within the central executive component of working memory for control of the primary task. Specifically, anxiety affects the inhibition (i.e., the use of attentional control to prevent interference from task-irrelevant cues) and shifting (i.e., the use of attentional control to maintain focus on the task-relevant cues) functions of the central executive component of working memory in a harmful way (Lawrence et al., 2012). This disruption leads to greater attentional control being allocated to the stimulus-driven system and less to the goal-driven system resulting in a reduction in processing efficiency. Recent research (Wilson et al.,

2009) testing the predictions of ACT indicated that anxiety caused impaired goal-directed attentional control by increasing visual saccades just prior to movement production (i.e., reducing quiet eye). It was proposed that the increased engagement of the inhibition and shifting functions of central executive component of working memory resulted in a reduction in resources available for movement control of the primary task leading to a decrement in performance.

Since the principles of ACT stem from and extend the earlier processing efficiency theory (Eysenck and Calvo, 1992) (PET), the reduction in processing efficiency will only result in task performance decrements if applying additional attentional resources (e.g., effort) cannot compensate for the imbalance between the stimulus and goal driven systems. As such, the adverse effects of anxiety on task performance are predicted to become stronger for tasks that require greater working memory capacity (i.e., conscious, effortful and non automated tasks) (for a review see Wilson, 2008).

Both the CPH (Masters, 1992) and the ACT (Esyenck et al., 2007) provide differing, but viable explanations for why performance is affected by anxiety and have received considerable research attention. Nevertheless, few studies have sought to investigate the skill acquisition conditions under which anxiety may subsequently have less of an adverse affect on performance. Those that have sought to investigate this, have primarily chosen to manipulate the learning environment such that the learners' knowledge associated with movement production of the skill is either developed implicitly (i.e., unconsciously) or explicitly (i.e., consciously) (Hardy et al., 2001; Masters 1992). More recently researchers have investigated whether anxiety induced performance decrements can be reduced through the effective manipulation of anxiety during learning (Lawrence et al., *in press*; Oudejans and Pijpers, 2009, 2010). Over a series of studies utilising a variety of sports skills; handgun shooting (Oudejans, 2008); basketball free throwing (Oudejans & Pijpers, 2009); dart throwing (Oudejans & Pijpers, 2010), Oudejans and colleagues have shown that performance does not deteriorate in future anxious conditions when participants learn with mild anxiety and are later tested in a higher anxiety condition. Their findings imply that training with anxiety can reduce choking effects and they apply a desensitisation hypothesis to explain the effect (Hardy et al., 1996; Masters, 1992). Specifically, that adopting anxiety during learning may lead the performer to become somewhat desensitised to its effects and thus less likely to suffer from performance decrements under future anxiety situations.

In an extension of Oudejans work, Lawrence et al. (*in press*) utilised the principles of the specificity of learning hypothesis (Proteau, 1992) to investigate the possible mechanisms for the benefits of practicing with anxiety. The specificity principle proposes that the best learning experiences are those that most closely approximate the movements of the target skill and the environmental conditions of the target context. As such, Lawrence et al., hypothesised that the benefits of practicing with anxiety on subsequent performance would be dependent on anxiety being present in future tasks. In two separate experiments participants were asked to learn a golf putting task (experiment 1) and a climbing task (experiment 2) under anxious conditions before being transferred to separate anxious and non anxious transfer tasks. Results supported the specificity principle since performance was enhanced in the anxiety transfer compared to the non anxiety transfer (i.e., performance was best when the conditions of practice matched those of transfer).

Despite considerable support for both the ‘choking’ phenomenon and the benefits of training with anxiety, this research has only been explored in the TD population. It is believed that individuals with an ID and especially DS are very susceptible to neuropsychological conditions such as anxiety as a response of pressure/stressful situations (Lufi et al., 2004; Frazer & Nolan, 1994; Kerins et al., 2008). Previous research has noted that children with an ID display higher rates of anxiety related disorders than those reported in studies of children without an ID (Fisher, Allen & Kose, 1996; Whitaker & Read, 2006). In addition, it has been reported that students with an ID have higher levels of test anxiety compared to their non-ID peers and that these differences manifest themselves in test-irrelevant thinking (Lufi et al., 2004; Stevens, 2001). Furthermore, it has been noted that individuals with DS exhibit limitations in their attentional capacity and information processing speed (Guazzo, 2006; Norman & Shallice, 1986; Silverman, 2007) with studies observing discrepancies associated with memory impairments (Baddeley & Jarrold, 2007), verbal short term memory (Marcell & Amstrong, 1982; Vicari et al., 2007) and explicit long term memory (Carlesimo et al., 1997; Jarrold et al., 2007). Working memory and attentional capacity are essential features for effective learning and the production of relevant movement patterns as working memory is required to maintain and utilise the relevant information required to complete the skill and attention is required to ensure focus is optimal whilst performing the skill (Fougnie, 2008; Rapee, 1993). Chiviacowsky et al (2012) state that 'individuals with DS have fewer attentional resources available to process additional information, as more attentional capacity is needed to monitor basic aspects of motor performance as a result of less optimal movement control'(Chiviacowsky et al, 2012 pg 192). This deficit in attention can lead to focus being directed to irrelevant stimuli and cues. In addition, Guazzo (2007) states that discrepancies in motor learning and the quality of learning in individuals with DS are due to deficits at an attentional focus and attentional stability level with attention being directed to irrelevant stimuli and attention being diverted from one aspect of the task to another during learning. It has also been reported that individuals with DS are characterised by abnormities in learning and memory that leads to impairments in intellectual function (Nelson et al., 2005). These impairments have been reported to result in deficits in explicit memory ability and short term memory functioning compared to the TD population (Vicari, 2001). The reported reduction in attention and working memory in the DS compared to TD population may suggest a reduced processing efficiency for individuals with DS; a process deemed essential for coping with anxiety (Eysenck et al., 2007).

Despite the prevalence of research on anxiety and the general consideration given to the study of ID, surprisingly the authors can find no published research which investigates the affects of anxiety on the skill performance of individuals with an ID or more specifically DS. Thus, the purpose of the present study was to examine whether individuals in DS and UID populations are affected by anxiety in a similar fashion to their TD peers and to investigate whether practicing with anxiety prevents the likelihood of 'choking' in individuals with DS and a UID. To achieve this, participants from the TD, DS and UID populations practiced a football slalom dribbling task under anxiety conditions throughout practice before being transferred to both high anxiety and low anxiety transfer tests. We hypothesised that performance decrements associated with the presence of anxiety would be greater in the DS and UID groups compared to the TD population. Furthermore, it was expected that practicing under conditions of anxiety would result in slower learning in DS and UID populations compared to TD group due to an overloading of attentional resources and thus a reduction in processing efficiency. However, we expected, like their TD peers, individuals with DS to have less performance decrements associated with choking under pressure in high anxiety transfer compared to low anxiety transfer following training with anxiety in the acquisition trials.

5.2 Method

Participants

24 adult volunteer participants were recruited; 8 DS (4 males and 4 females; mean age = 27.75 yrs, *SD* = 7.36, range= 21-40), 8 UID[7], (4 males and 4 females; mean age = 26.5 yrs, SD = 5.68, range = 22-39) and 8 TD (4 males and 4 females; mean age = 23.5 yrs, SD = 2.14 yrs, range = 20-26). The DS and UID groups were recruited from Special Olympics Bangor and Mencap support groups across North Wales and the TD group were recruited from Bangor University. Of the 16 participants with an ID all lived in either a group home or with a parent/caregiver and were involved in some form of physical activity (e.g. athletics, basketball, football etc.) at least once a week. In addition, 4 (DS) and 4 (UID) were in full time education and 4 (DS) and 4 (UID) were involved in part time or full time employment. All participants volunteered for the study, were right-foot dominant, reported normal or corrected to normal vision and were self reported novice footballers. Accessible and easy read information sheets about this experiment were given to all participants (see appendix 7). More in-depth information sheets about the study were also supplied for support workers and parents/guardians (see appendix 8). All participants were assessed for Mental Capacity (under the guidelines for the Mental Capacity Act 2005) prior to consent (see appendix 3). Specifically, participants were provided with accessible information (both verbally and visually) about the experiment and then asked a series of questions related to this information. Responses were graded for understanding by an individual trained in Mental Capacity assessment through Mencap Cymru and in line with the procedures for consent to

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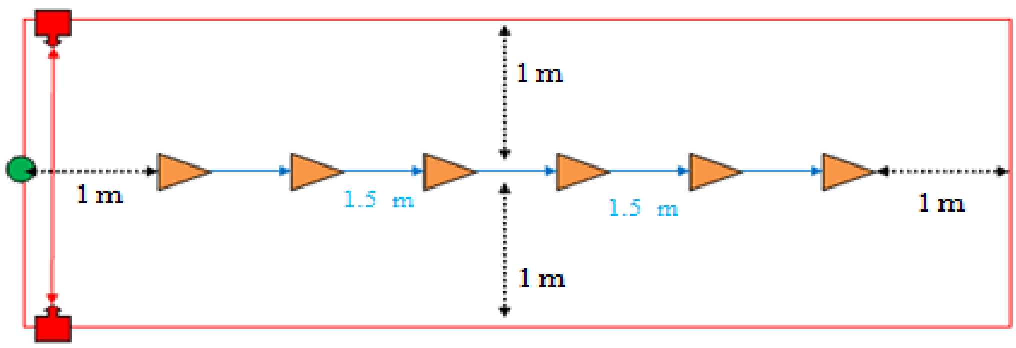
[7] All participants completed the British Vocabulary Peabody scale as a measure of mental age and intellectual functioning (Dunn & Dunn, 1997). Whilst the individuals with an UID were classified as having a high functioning intellectual disability from local service departments and parent(s)/guardian(s), this disability was not syndrome specific (i.e., Down syndrome, William's syndrome, Prader Willis syndrome). Although the participants in the two ID groups exhibited similar patterns of day to day adaptive functioning, participants in the UID group scored slightly higher on the Peabody scale than participants in the DS group.

psychological research by people with an intellectual disability (see Arscott, Dagnan, & Kroese, 1998). Accessible consent forms (see appendix 4) were signed before the start of the experiment[8]. The study was carried out according to the ethical guidelines laid down by the institutions Ethics Committee for research involving human participants.

Apparatus

The procedure for this experiment was adapted based on the protocol used by Ford, Hodges and Williams (2005), the task required the participants to dribble a size 5 regulation football (soccer) ball as quickly and as accurately as possible through a slalom course of six cones twice (i.e., up and back down) with the total distance covered being 19m per trial (see figure 8). The first cone was located at a distance of 1 metre from the start line, the remaining 5 cones were located in a straight line from the first and at 1.5 metre intervals. A 10 meter x 2 meter area was marked out using a thin rope within a slalom course and this red zone represented the area in which the dribbling should be carried out (see figure 8). The task was conducted indoors, on a carpeted surface. The time taken to complete the task was recorded using Brower laser timing gates located at the start line. A Samsung PL122 camera mounted on a tripod was used to video participant trials. Heart rate was recorded using a Biosync Fingertip Pulse Oximeter.



[8] All participants with an ID were deemed to have the sufficient mental capacity to consent themselves.

Figure 8: A birds-eye view of the task design. The red rope rounds 1 metre to the sides of the cones and 1 metre further than the first and last cone (10 metre x 2 metre). The ball (green circle) represents the start and finish point where the timing gates are stationed (red blocks). All six pylons are positioned 1.5 metres apart.

Anxiety and Task Effort Measures

Cognitive anxiety was assessed via a modified version of the Mental Readiness Form-3 (MRF-3; Krane, 1994). Schwarz (1999) stated that self reports of behaviours and attitudes are strongly influenced by features of the research instrument, including question wording, format and context. Thus, the MRF-3 was made accessible so that it could be used and understood by both the TD and ID participants (see appendix 9). Similar to the original MRF-3, the modified version comprised three single-item factors that were each scored on an 11-point Likert scale: cognitive anxiety from 1 (*not worried*) to 11 (*worried*); somatic anxiety from 1 (*not tense*) to 11 (*tense*); and self-confidence from 1 (*confident*) to 11 (*not confident*). The modification was that relevant images were placed beneath each item to show what emotion/feeling the item was referring to. This measure is a short and expedient inventory alleviating extensive testing periods that may lead to boredom for some participants (Wilson et al., 2009). For the purpose of this study only the cognitive anxiety factor was used.

The MRF-3 is a self report measure that relies on the subjective interpretation of participant's emotions and feelings. In addition to including pictures to aid understanding of items, it was explained to each participant that all reported answers would be given full anonymity in an attempt to further ensure accurate completion. However, since Thayer & Friedman (1997) reported that state anxiety results in increases in sympathetic nerve anxiety resulting in an increased heart rate (HR), HR was also recorded whilst participants completed each MRF-3 questionnaire (see appendix 9). Task effort (TEff) was measured utilising an accessible retrospective 1 (no effort) to 11 (maximum effort) Likert scale (see Mullen et al, 2005).

Task and Procedure

The experiment consisted of a pre-test, an acquisition stage and two counter balanced post-test transfer phases. Participants were given accessible information sheets prior to the study allowing for any questions and/or queries (see appendix 7). The experimenter explained that the purpose of the investigation was to examine the speed and accuracy of dribbling a football around 6 cones over a period of practice trials. It was explained that the goal of the task was to dribble the football as quickly and as accurately as possible without losing control of the ball, deviating outside of the 'red zone' or touching any of the cones. Participants were then asked if they would like to participate, once consent had been given (see appendix 4) participants were given both a verbal explanation of the task and shown a video clip of an experienced footballer demonstrating the football dribbling task with no errors. Participants were allowed to have a maximum of ten practice trials before the experiment began[9].

Following familiarisation of the task, participants were asked to place the HR monitor onto the index finger of their right hand and then asked to perform a pre test consisting of 5 trials of the football dribbling task. Participants were then given a short 5 minute break before entering the acquisition phase of the experiment. The acquisition phase consisted of 20 trials, broken down into 4 blocks of 5 trials (a 3 minute break was given in between each to minimise any potential effects of fatigue). In order to induce anxiety, participants were told at the start of acquisition that their performance would be video recorded and sent off to be evaluated by a qualified football coach (see appendix 10 for coach feedback form)[10].

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[9] During the experiment no participant completed more than 3 practice trials

[10] Smith, Smoll & Wiechman (1998) stated that the most salient source of sport specific worry is due to the fear of performance failures and the negative social evaluation that comes with it. Borkovec (1994) suggested that social evaluation issues cause worry and anxiety in non-sporting situations also. Therefore as the participants are likely to feel pressure to perform well, this social evaluation is likely to induce anxiety.

Immediately following acquisition, all participants were given a 10 minute break after which they completed two separate transfer tests that consisted of 5 trials each. Transfer 1 was performed under high anxiety conditions (social evaluation anxiety and competition anxiety) whereas transfer 2 was under normal conditions (no anxiety), both transfer blocks were counterbalanced to control for any learning effects. To manipulate anxiety in transfer 1, participants were told that their performance would appear on a leader board if they were in the top five competitors. They were also informed that the best overall performer in the 5 anxiety transfer trials would also receive a trophy[11]. An additional 5 minute break was given between transfer blocks to prevent fatigue and cross-over anxiety effects. In order to ensure that anxiety had been successfully manipulated all participants completed the MRF-3, whilst HR was simultaneously recorded by the experimenter on four separate occasions: immediately prior to the start of the pre-test; before the start of acquisition; and at the start of both transfer tests. To measure effort, participants completed the self report effort scale following the pre-test, the last block of acquisition and at the end of both transfer 1 and transfer 2.

At the end of the experiment participants were debriefed and reassured that feeling worried during the experiment was normal. It was explained that if they still felt worried they were to tell the researcher, their parent/career. Participants were also told when to expect to receive the feedback from the experienced coach and were given a letter to thank them for their participation within the study.

Dependent measures and analyses

[11] Church (1962) found that this explicit competition increases anxiety and increases errors in a reaction time discrimination task. The possibility of receiving a trophy prize is seen to work as a contingent reward if performance is satisfactory. Using contingent rewards has been found to result in pressure to perform competently, in addition to possibly inducing worry and anxiety (Baumeister & Showers, 1986). By making the performances public, research by Seijts, Meertens & Kok (1997) found that the task importance, effort and persistence increased for participants, in addition to manipulating anxiety.

Dependent measures consisted of the modified MRF-3 (anxiety), HR, effort (TEff) and the performance measures of error (ERR) and movement time (MT), An error was defined using the following criteria: The ball crossed out of the permitted Red Zone; the ball hit any of the six cones in the slalom; the ball hit the wall of the testing lab; the ball did not pass through the timing gates at either the start or finish of the trial. For each error a score of 1 was recorded and the error for any given trial was calculated as the sum of the total errors recorded during that trial.

MT (sec) was defined as the interval from when the participants crossed the Brower timing laser at the start line of the slalom course to when they returned and crossed the timing laser for the second time.

Anxiety (modified MRF-3), HR and Effort (TEff) data were analysed using separate 3 Group (DS, UID, TD) × 4 time (pre-test; acquisition; transfer 1; and transfer 2), ANOVAs with repeated measures on the second factor. Performance data (ERR and MT) were analysed during the acquisition phase using separate 3 group (DS; HFLD; TD) × 5 time (pre-test; acquisition block 1 [trials 1-5]; block 2 [trials 6-10]; block 3 [trials 11-15]; block 4 [trials 16-20]), ANOVAs with repeated measures on the second factor. The mean of each block of five trials was calculated to obtain an overall block score. In order to assess the effect of the transfer tests (high anxiety and normal conditions) on performance, ERR and MT were further submitted to a separate 3 group (DS; UID; TD) × 4 experimental phase (pre-test; acquisition; transfer 1; transfer 2), ANOVAs with repeated measures on the second factor. The mean of the pre-test, the last block of trials in the acquisition phase, and the mean of both transfer tests were utilised in this analysis. Significant interactions were investigated using Tukeys (HSD) procedures ($p < .05$).

5.3 Results

Anxiety

Modified MRF-3

Analysis of the modified MRF-3 data revealed a significant main effect for time; ($F_{(3, 63)} = 7.62$, $p < .05$, $\eta^2 = .98$) with worry scores in acquisition (4.25) and high anxiety transfer (4.12) being significantly greater than the scores in the low anxiety transfer (1.87) (see Figure 9). There was no significant main effect for group and no significant group × time interaction ($p > .05$).

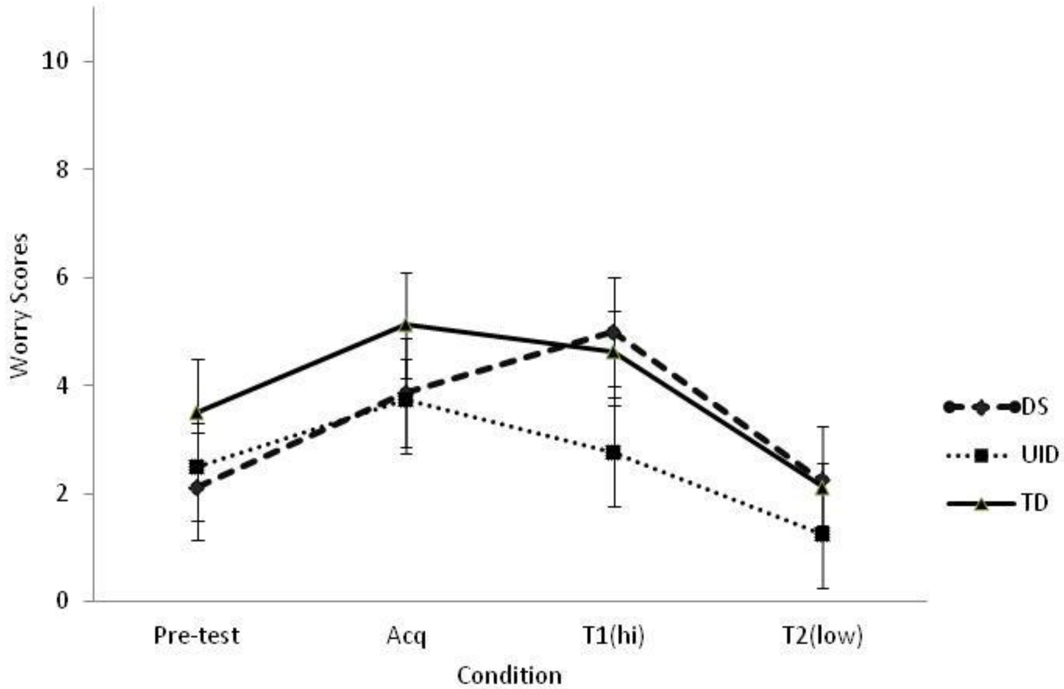

Figure 9. MRF-3 Worry Scores as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and experimental block/condition (Pre-Test, Acquisition, Transfer 1 (high anxiety) and Transfer 2 (low anxiety).

Heart Rate

Analysis of HR data revealed a significant main effect for time; ($F_{(3, 57)} = 11.43$, $p < .05$, $\eta^2 = .37$). Specifically, HR in the both the high (87.13) and low (86.18) transfer phases were significantly greater than that of both the pre test (72.42) and acquisition phases (78.13) No other significant findings were observed ($p < .05$) (see Figure 10).

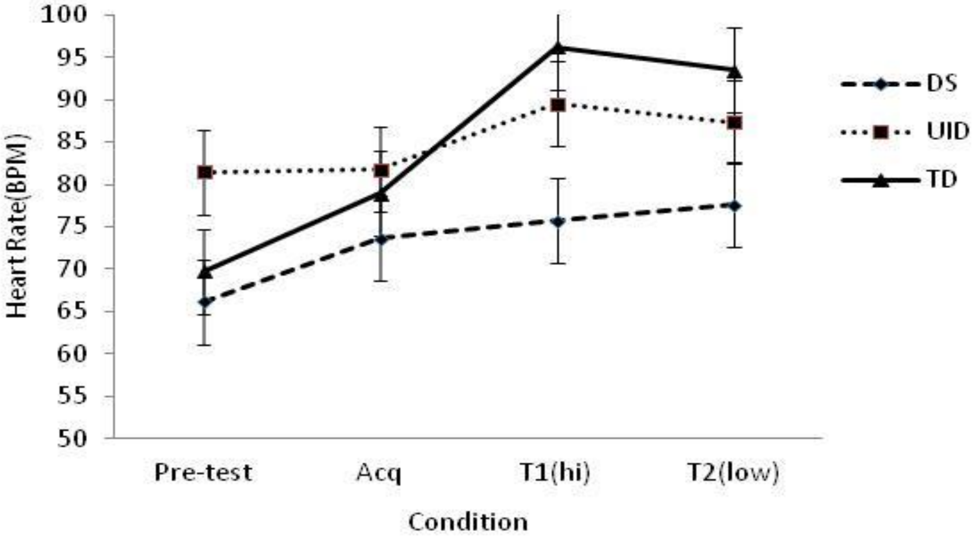

Figure 10. HR Scores as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and experimental block/condition (Pre-Test, Acquisition, Transfer 1 (high anxiety) and Transfer 2 (low anxiety).

Task Effort

The ANOVA revealed a significant main effect for time; ($F_{(2.32, 44.24)} = 4.09$, $p < .05$, $\eta^2 = .177$) with effort scores in the pre-test (8.47) being significantly less than those of acquisition (9.45), the high anxiety (9.16) and the no anxiety transfer (9.80) tests. There was no significant main effect for group ($F_{(2, 19)} = .14$, $p = .86$, $\eta^2 = .15$) and no significant group × time interaction ($F_{(4.65, 44.24)} = 1.24$, $p = .30$, $\eta^2 = .11$).

Acquisition.

Err: The analysis revealed no significant main effects (group: $F_{(2, 21)} = 1.34$, $p = .28$, $\eta^2 = .25$; time: $F_{(4, 84)} = 1.60$, $p = .18$, $\eta^2 = .48$; or interactions ($F_{(4, 84)} = .91$, $p = .51$, $\eta^2 = .39$), thus any differences in the MT dependent variable cannot be due to any speed-accuracy trade-offs.

MT: The ANOVA conducted on the MT data revealed a significant main effect for both group ($F_{(2, 21)} = 5.08$, $p < .05$, $\eta^2 = .76$) and time ($F_{(1.55, 32.63)} = 4.55$, $p = .02$, $\eta^2 = .66$). Specifically, MTs were significantly slower in the DS (44.83secs) compared to TD (20.68secs) group and MTs in pre test (35.73secs) and block 1 of acquisition (33.55secs) were significantly slower than the remaining 3 blocks of acquisition (block 2 = 31.91; block 3 = 31.98; block 4 = 31.36) indicating that all groups improved their MT as a result of practice (see Figure 11). The group × time interaction was non-significant ($F_{(3.1, 32.63)} = .81$, $p = .08$, $\eta^2 = .56$).

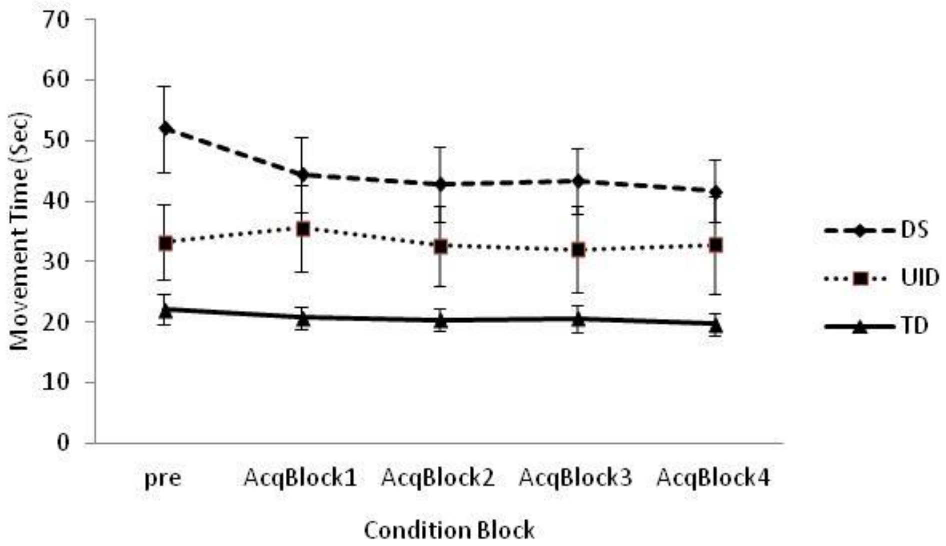

Figure 11. MT as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and experimental block/condition (pre-test and the 4 blocks of acquisition).

Pre Test versus Acquisition versus Transfer.

Err: Analysis of error revealed a significant main effect for experimental phase ($F_{(3, 63)} = 4.12$, $p = .01$, $\eta^2 = .82$) with significantly more errors being recorded in the pre test (3.30) compared to the high anxiety transfer (2.39). There were no further significant main effects or interactions (group, $F_{(2, 42)} = 1.89$, $p = .82$, $\eta^2 = 0.009$; group × time, $F_{(4, 42)} = 1.12$, $p = .35$, $\eta^2 = .097$).

MT: Analysis revealed a significant main effect of group ($F_{(2, 21)} = 4.89$, $p < .018$, $\eta^2 = .74$) with MTs of the DS group (43.78secs) being significantly slower than those of the TD group (19.91). Although the UID group (32.03secs) were faster than the DS group this difference was not significant. Importantly, the analysis also revealed a main effect for experimental phase ($F_{(1.5, 31.90)} = 6.59$, $p = .007$, $\eta^2 = .81$). Breakdown of which indicated that the pre test MTs (35.75secs) were significantly slower than those of the high anxiety transfer tests (29.17) (see Figure 12).

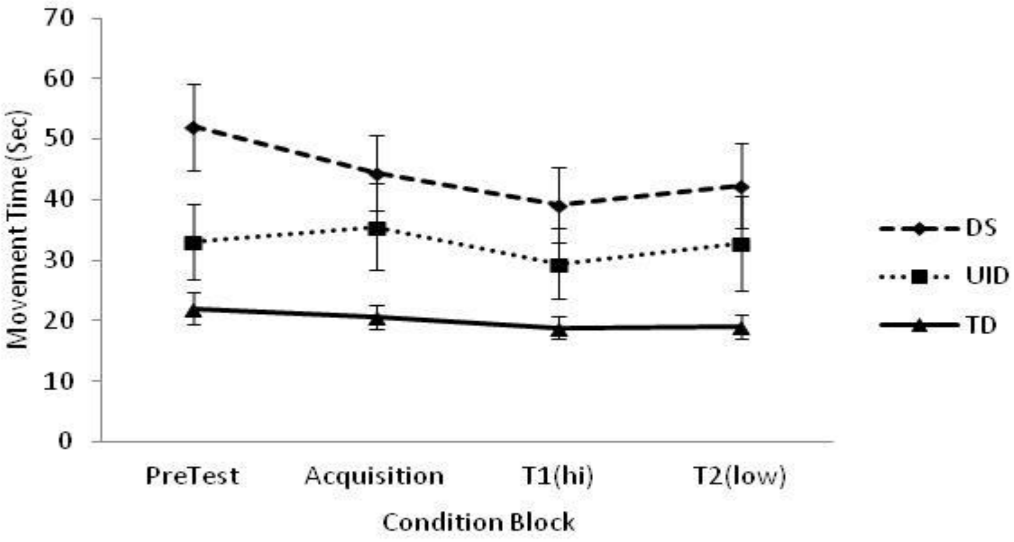

Figure 12. MT as a function of group (DS = Down syndrome; UID = higher functioning undifferentiated intellectual disability; and TD = typically developing) and experimental block/condition Pre-Test, Acquisition, Transfer 1 (high anxiety) and Transfer 2 (low anxiety).

5.4 Discussion

The main purpose of this experimental chapter was to investigate if the positive effects of practicing with anxiety that are observed in the TD population (Lawrence et al, *in press*; Oudejans, 2008; Oudejans and Pijpers, 2009, 2010) extend to individuals with DS. Specifically, we wanted to examine if learning a gross motor skill under conditions of anxiety would prevent the choking effect typically seen during performance when anxiety in present. Results revealed that the acquisition protocol increased performance and learning since the speed that both the TD and ID participants completed the slalom course improved over acquisition and from pre test to transfer. This latter finding indicates that training with anxiety prevents the typically observed decrement in performance in high anxiety transfer tests (Masters, 1992; Wilson 2008) (i.e. alleviates the choking phenomenon).

Cognitive anxiety data from the modified MRF-3 indicated that the manipulation of anxiety was successful where targeted since worry scores in the acquisition (4.25) and high anxiety transfer (4.12) phases were significantly higher than those reported in the low anxiety transfer (1.87) for all groups. During acquisition the use of a video camera appeared to have increased the anxiety levels of participants since the levels of worry were reported were highest in the acquisition phase. Interestingly, whilst non significant, worry scores had a trend to be higher in this experimental phase compared to the high anxiety transfer phase. This may lend support to the theory that participants develop motor plans during acquisition that are specific to the conditions available at the time of learning (Elliot et al, 1995; Mackrous & Proteau, 2007) That is, participants may have became accustomed or desensitised to performing under conditions of pressure during the acquisition phase, thus leading to lower feelings of worry during the higher anxiety transfer.

HR data revealed that participants had greater beats per minute (bpm) in the transfer compared to the pre test and acquisition experimental phases. These findings are partially supportive of those associated with the modified MRF-3 data in that increased cognitive anxiety (worry) was accompanied by an increase in somatic anxiety as measured by HR. However, whilst HR in the high anxiety transfer (87.13) tended to be higher than that in the low anxiety transfer (86.18) this difference was not significant. This unexpected pattern of results can be explained via two separate possibilities. Firstly, it is possible that whilst the level of cognitive anxiety experienced in the high anxiety transfer test was significantly greater than that reported in the low anxiety transfer, it was not sufficient enough to produce greater increases in somatic anxiety. However, if this was true then one cannot easily explain the significantly greater HR levels in the high anxiety transfer test compared to low anxiety pre-test. Thus, we propose a second possibility related to the increased duration of exercise exposure participants had experienced by the transfer experimental phases compared to the pre-test and acquisition phases. Specifically, when HR was measured at transfer participants in all groups had been exercising (dribbling through the slalom course) for a greater period of time compared to when the same measure was recorded at the earlier pre-test and acquisition phases. Thus it is possible that HR simply increased as a result of greater exposure to exercise. This potential confound could be further investigated in future research via the use of a less physically demanding task (i.e., a golf putt) and/or through the use of different psychophysiology measures reported to indicate somatic anxiety and cognitive effort such as HR variability, ECG and skin conductance (Miu, Heilman & Houser, 2008).

Effort scores in the pre-test were significantly less than those of acquisition in the high anxiety transfer and the low anxiety transfer tests. Similar to Lawrence et al. (*in press*), the task effort level was similar across all groups and the presence of anxiety did not result in any significant changes in self reported effort. Although the PET prediction that participants may exert more effort in a more threatening situation cannot be applied to the current study (Eysenck, 1992; Wilson, 2008), participants investment of effort in the task did not decrease thus it can be assumed that they did not disengage throughout the experiment as a result of either anxiety manipulations or levels of fatigue. Task effort scores were consistently above 8 even in the low anxiety conditions, therefore another suggestion could be that the use of a 1 to 11 Likert scale may not be sensitive enough to measure the differences in exerted effort between the low anxiety and high anxiety conditions in the current study. It has been reported that people tend to respond to questions so as to be viewed in a favourable light and this may have led to the high effort scores across conditions as participants did not want to report effort scores that may not be perceived as socially desirable (Cohen & Swerdlik, 1999). It has also been noted that simple behavioural questions can pose complex cognitive tasks in relation to self reporting (Schwarz & Oyserman, 2001). As individuals with DS have been reported to experience cognitive limitations, to ensure this confound is controlled for, a more sensitive measure of effort should be utilised in future research. Going forward, future research should look to produce and validate a series of self report questions for individuals with IDs whilst also measuring psychophysiology measures of effort and anxiety. If there is a significant positive correlation between the two measures then it could give support that the adapted anxiety measurement measures what it intends to. This could diminish potentially avoidable discrepancies that may arise from unnecessary cognitive task complexity for people with an ID. The introduction of focus groups to include people with IDs to aid the validation of a new adapted anxiety measurement for individuals with an ID are imperative to ensure that the measure is understood and made accessible for individuals with an ID.

A further note of interest can be seen in the results of the error in performance data between pre-test and acquisition as this revealed no significant main effects or interactions, showing that individuals with IDs performed with similar accuracy to their TD peers. Any differences in the MT dependent variable cannot therefore be due to speed-accuracy trade-offs. There were significantly more errors recorded in the pre test compared to the high anxiety transfer test indicating that all groups learnt to control and dribble the football around the cones with more accuracy and did not show the choking behaviours typically reported in the stress and performance literature (Baumeister, 1984; Beilock and Carr, 2001; Gucciardi & Dimmock, 2008; Jordet & Hartman, 2008). The alleviation of the choking phenomenon in all groups lends further support to the view that training under conditions of anxiety leaves one insensitive to its effects in future situations (Lawrence et al., *in press*; Oudejans, 2008; Oudejans & Pijpers, 2009; 2010) whilst also extending this notion to the DS and UID populations.

Whilst the error scores did not differ between the TD and ID populations, as expected participants from the TD population did have superior MT performance compared to both the DS and UID individuals. Thus it appears that in order to obtain a similar performance in regards to error rates, the ID individuals (DS and UID) need to execute movements at a significantly slower speed than their TD counterparts. Whilst it has been reported that individuals with DS often trade accuracy for movement time (Lam et al., 2009; Seyforth & Spreen; 1979) it appears that both the DS and UID participants in the present study adopted a strategy of reducing movement speed in order to achieve a better accuracy score. This is likely due to the extensively reported deficits in their feed-forward control and reliance on online afferent feedback to control actions (Elliott et al., 2004; Hodges et al., 1995). Since the use of afferent information online to correct for errors in movement planning increases movement times compared to situations where actions are planned accurately (see Khan et al., 2006 for a review), it is not surprising that individuals with DS took significantly longer than the TD population to perform actions of the same resultant accuracy.

In addition to the possibility that the MTs of the DS group were increased due to greater use of visual feedback, the DS literature has reported differences between the TD and DS populations in tone, ligament laxity, the development of myelination, balance, the development of postural reactions, and muscle torque and function in ankle movements (valgus position) (Latash, Wood &Ulrich, 2008; Newton, 2004; Sacks & Buckley, 2003; Parker, Bronks & Snyder, 1986; Virji- Babul & Brown, 2004). Since individuals with DS have reduced function compared to TD individuals in these physiological entities, it is possible that these differences are contributors to the delay in motor skill acquisition and reduced performance of the DS compared to TD individuals in this thesis chapter. However, whilst hypotonia is referenced frequently in the DS literature as being one of the main causes of perceived motor deficits, it has been noted that this association needs greater exploration due to a lack of operational definition of hypotonia within the DS population (Almeida et al., 2000; Martin et al., 2005). Furthermore, Almeida et al. (2000) stated that individuals with DS may have greater difficulty performing movements that require the coordination of multiple joints, because of issues surrounding ligament elasticity, muscle strength, and ankle joint dysfunction but did not specifically measure all of these variables. In addition, whilst it is plausible that hypotonia, ligamentous laxity, delayed development of myelination, balance, postural reactions, and issues in muscle torque and dysfunction of the ankle movement (valgus position) are causes of the significantly slower movement times of the DS compared to TD individuals, the current study did not explicitly measure these variables and thus can only speculate as to their role in our findings.

In addition to the aforementioned biomechanical and physiological issues associated with DS, medical research has proposed that neuropathological and neurophysiological abnormalities (e.g., reduced frontal lobe, disproportionately smaller cerebellum, shorter brain stem in individuals with DS) could be related to impaired cognition and motor coordination in the DS population (Penrose & Smith, 1966; Pinter, Eliez, Schmitt, Capone & Reiss, 2001). In addition, attentional focus during practice is perceived as being more difficult for individuals with ID due to cognitive limitations (Chiviacowsky et al., 2012) and it is reported that individuals with DS are easily distracted and less able to recognise the importance of adherence to goals imposed during learning, which leads to less competent use of the conscious mechanisms involved in skill acquisition (Smith et al., 2007). In line with these findings, it is possible that the task of simultaneously dribbling a football, navigating it around 6 cones, staying in a designated area and being subjected to cognitive worry may have overloaded the already reduced working memory capacity of the DS participants in the present study leading to a decreased processing efficiency and slower MTs in comparison to their TD counterparts.

Despite the significantly greater MTs of the DS and UID groups in comparison to that of the TD, the significant main effect of experimental phase and lack of significant group × experimental phase interaction indicates that all groups significantly improved performance as a function of practice. This is an interesting finding since it has been well documented that individuals with DS display differences in physiology, cognitive functioning and motor skill performance compared to the TD population (Brunamonti et al., 2011; Cheviacowky et al, 2012; Hodges et al, 2005; Sacks & Buckley, 2003; Virji-Babul et al, 2011). However, whilst individuals with DS clearly experience movement deficits, both Almeida et al. (1994) and Latash (2007) have reported that after significant periods of practice these individuals can reach performance levels comparable to that of the TD population. Thus, it is possible that the movement strategies applied to learning the football dribbling task were similar across groups which resulted in a comparable increase in performance from pre-test to transfer.

The increase in MT performance from pre-test to the high anxiety transfer test indicates that learning with anxiety can prevent choking in subsequent high pressured situations. Thus, similar to the findings of Oudejans & Pijpers (2010), the current study indicates that training with anxiety can reduce choking effects. Whilst this positive effect of practicing with anxiety has been previously shown in the TD population (Lawrence et al., *in press*; Oudejans, 2008; Oudejans & Pijpers 2009, 2010) this is the first time the effect has been investigated and reported in the DS and wider ID population. One possible explanation for this finding could be because participants became desensitised to the effects of anxiety through experiencing these conditions during acquisition (Mullen et al., 1996). Alternatively, it is possible that the movement plans developed during acquisition were specific to the conditions experienced during that experimental phase. That is, similar to the research within the specificity of practice domain (Elliott et al., 1995; Khan & Franks, 2000; Khan, Franks, & Goodman, 1998; Mackrous & Proteau, 2007; Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau, Marteniuk, Girouard, & Dugas, 1987; Tremblay & Proteau, 1998, 2001) individuals in all groups developed movement plans that were specific to the conditions of learning i.e., the presence of anxiety.

In order to investigate the possible specificity effect of practicing with anxiety thos experimental chapter of the thesis adopted a second low anxiety transfer test. The rationale here being that if individuals successful performance is based on motor programs that are developed under conditions of anxiety and thus specific to that mood state then performance should suffer when there is change in that mood state (i.e., a change in environmental or contextual conditions). Despite these specificity predictions, the findings of this thesis chapter did not reveal any performance decrements in the low anxiety transfer test compared to any of the other experimental phases (pre-test, acquisition, high anxiety transfer). However, data did reveal that whilst performance significantly improved from pre-test (low anxiety conditions) to high anxiety transfer, performance did not increase from pre test to the low anxiety transfer. This pattern of results does suggest that specificity may have been playing a role during learning. That is, performance benefits were only observed when the conditions of practice matched those of transfer. Since the specificity literature reveals that the effect is amplified following periods of practice (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau, et al, 1987; Tremblay & Proteau, 1998, 2001), it is possible that increasing the number of acquisition trails within the present study may have resulted in a significant decrement in performance between the end of acquisition and the low anxiety transfer test. That is, participants may have developed movement plans that were specific to the mood conditions experienced during learning. Hence, when the practice conditions were changed following the shift from high anxiety to low anxiety, the movement plan previously developed during the anxiety acquisition phase would no longer be appropriate for successful performance in the low anxiety transfer test.

The results of this current investigation show that similar to their TD and UID peers, individuals with DS were able to improve their performance in a football dribbling slalom task following practice. Participants with DS achieved levels of accuracy for this task similar to that of their UID and TD peers. Whilst their overall movement times did improve as a function of practice, they remained slower in comparison to their TD counterparts. Similar to previous findings in the TD population, learning with anxiety was not detrimental to performance and the choking effects were minimised in the anxiety transfer for all groups. However, results are somewhat cautionary as further explorations into these positive effects of learning with anxiety need to be investigated in experiments that also include control groups (e.g., groups that learn without anxiety) to categorically confirm that learning with anxiety can in fact benefit performance in subsequent anxiety conditions. However, to our knowledge the present investigation is the first to attempt to investigate and demonstrate that learning with anxiety is not detrimental for skill acquisition in people with intellectual disabilities. The findings reveal that individuals with an ID should be trained with anxiety to prepare them for anxiety induced life situations such as sporting competition and performing in front of peers during education or work settings. Learning with anxiety or having experience of being exposed to anxious situations through role play, competitions, mock examinations or interviews could potentially assist individuals with an ID in developing better coping strategies in relation to meeting challenges that have internal and external pressures associated with them. These findings are particularly poignant because they contrast with common practice where people with IDs are protected from controlled pressured environments during learning.

Chapter 6

General Discussion

6.1 General Discussion

Previous research has associated poor motor coordination and a perceived clumsiness in motor performance to individuals having DS (Frith & Frith, 1974; Vimercati et al., 2012; Virji-Babul et al., 2003). Additionally, it is widely thought that the physiological, anatomical and neurological abnormalities arising from the genotype mutation in individuals with DS impacts both physical and cognitive development (Simon, Elliot & Anson, 2003). The experimental chapters contained in this thesis are intended to explore the underlying mechanisms of motor control and the environmental effects of performance pressure on skill acquisition in individuals with DS. Research has indicated that individuals with DS display a noted reduction in speed of movement performance characteristics compared to TD individuals (Arisi et al., 2012; Elliott et al., 2004; Henderson et al., 1991; Hodges et al., 1995; Masumoto et al., 2012). The reasoning behind these differences is the premise that individuals with DS have a heavy reliance on afferent information to correct movements (Elliott et al., 2004; Elliott et al., 2010; Hodges et al., 1995). Additionally, it has been noted that individuals with DS exhibit limitations in their attentional capacity and information processing speed (Guazzo, 2006; Norman & Shallice, 1986; Silverman, 2007) and these issues with working memory and attentional capacity are essential features for effective learning and the production of relevant movement patterns. These issues have often been attributed to both central processes (Frith & Frith, 1974) and peripheral anatomical characteristics (Henderson et al, 1991; Morris et al., 1982) associated with DS.

Historically, the motor performance of individuals with DS has predominantly been conducted on single target directed movements, with results highlighting the differences between individuals with DS and TD individuals. Yet, the majority of everyday motor skill tasks are not performed by single upper limb aiming movements but rather by the coordinated actions of both upper limbs. Furthermore, every day skill learning and performance occurs with outside environmental characteristics affecting the acquisition and outcomes (i.e., performance pressures). Therefore, we wanted to embark on novel research designed to investigate how people with DS plan to integrate movements both within and across limbs. We also sought to investigate the basic principles behind the effects of performance pressure on the speed and accuracy of the movements of persons with DS. It was of pertinent interest to this investigational thesis to observe whether individuals with DS were concerned with movement integration and performance pressure in a similar fashion to that observed in the TD population and by individuals with an UID. By assessing potential similarities and differences between groups, we would be able to understand the basic principles behind these actions and it would not just have theoretical implications but also practical implications such as designing practice protocols for functional skill learning.

It has been generally observed in the TD population that RT is greater for two-target responses compared to the single target responses in simple RT tasks as a participant knows what the required response is prior to stimulus presentation (Khan et al., 2006; Klapp, 1995, 2003). Alike previous RT research, the findings of experimental chapters 3 and 4 revealed that individuals with DS produced longer RTs than their TD and UID peers (Arisi et al., 2012; Davis et al., 1991; Henderson et al., 1991; Masumoto et al., 2012). Interestingly, it was established that increasing the number of response segments in a manual aiming movement produced an increase in the time taken to execute the first segment in a sequence for all groups. This thesis has shown similar results to further support previous RT literature as RT was shown to increase as the number of elements in the response increased (Khan et al., 2010). Additionally, findings from chapters 3 and 4 highlight similar movement control strategies as RT was longer in two-target conditions regardless of whether participants had an intellectual disability (DS or UID) or no intellectual disability (TD).

6.2 Movement integration and DS

To explore the underlying mechanisms of movement in individuals with DS we employed the One Target Movement Advantage (OTA) paradigm for chapters 3 and 4. This thesis has shown support for the premise that the influence of the number of elements in a response is not limited to the RT interval as movement times to the first target (MT1) were greater when participants were required to continue and hit a second target compared to when they are required to stop on the first target (Glencross, 1980; Adam et al., 2000; Chamberlin & Magill, 1989). Similar to their TD and UID peers, this OTA was present for individuals with DS despite movements being performed with one or two upper limbs and this lends support to the suggestion that movements within a sequence are not prepared and executed independently. In support of the findings of Khan et al. (2010), the results of the chapters 3 and 4 of this thesis revealed that the OTA not only emerged for single arm aiming movements but also when there was a switch in arms at the first target. The presence and magnitude of the OTA was not effector dependent as similar levels were reported for single and dual arm conditions. Therefore, it can be accepted that the OTA occurs as a result of the movement integration (MIH), rather than movement constraint (MCH). The rationale for this being that there is no requirement to constrain the variability of the first movement in the two-target dual arm condition as the starting point of the second movement is fixed in the dual arm condition and therefore the endpoint variability of the first movement is not relevant to the production of the second movement when there is a limb switch between the two movements. These findings extend the results of Khan et al (2010) to individuals with DS and suggest that the loci of interference responsible for the OTA exist at the central level.

There are two potential loci of the interference effect reflected by the OTA; these are a central origin and a peripheral origin. At the central origin, interference is associated with the retrieval of a motor program from a motor buffer, whereas at a peripheral origin, interference comes from the execution of these motor instructions into muscle activity to execute movements. If MT1 data in the single and dual limb sequential aiming tasks are compared then a potential distinction can be made between the two possible loci. In the 2T1L conditions of chapters 3 and 4, both central and peripheral processes could be contributing to the OTA effect but as the 2T2L condition has two movements that are completed by two separate anatomical effectors, this would seem to decrease or even eradicate a possible peripheral interference occurring. When there is a switch between the limbs at the first target in a dual limb aiming task, peripheral factors would seem to play a very minor role also. Therefore in this thesis a central origin of interference can be assumed as it seems that the processes that lead to interference during movement execution to the first target are effector independent. MT1 results from both Chapters 3 and 4 revealed that the OTA was present in both the 2T1L and 2T2L conditions and the magnitude of this OTA was comparable for both the single-arm and dual-arm conditions. This suggests that the loci of interference responsible for the OTA resides at the central level for all groups, giving further support that individuals with DS plan and execute extension movements in a similar manner to their UID and TD peers.

Further support for a central loci of interference can be seen in chapters 3 and 4 of this thesis as similar pause time (PT) effects were revealed across groups. This not only provides important evidence that the control strategies of multiple target movements did not differ between the TD and individuals with an ID (DS and UID) but also that multiple arm sequential target aiming movements of all groups were subject to the OTA interference. When performing two target single limb movements, it was noted that participants paused at the first target for significantly longer periods of time compared with movements that required a switch in arms at the first target. Khan et al. (2010) propose that single limb movements are controlled at a central and peripheral level, whereas dual limb movements are controlled at a peripheral level as the two movements are implemented by two largely distinct and separate neuroanatomical effectors. Given this proposal it can be assumed that PTs were longer in the single limb movements due to interactions of the central processes and the peripheral processes working alongside each other to ensure optimal integration and transition between the movements of the performing arm. As previously stated, in the two limb conditions there is a switch between hands at the first target and therefore peripheral factors are largely redundant. Similar to the movement time data, the PT findings revealed important evidence that the control strategies of multiple target movements did not differ between the TD and intellectually disabled (DS and UID) individuals and that the multiple target multiple arm movements of all groups were subject to interference predominantly at the central level. Therefore, it appears that the movement planning deficits caused by integration of movement segments within the DS and UID populations mirror those that occur in their TD counterparts. The influence of the MIH on movement production appears to affect these variant populations in a similar manner. Notwithstanding the movement planning and performance decrements highlighted in previous literature in the DS population (Frith & Frith, 1974), there appears to be no additional degradation on performance involved with the introduction of a second movement in manual aiming tasks over and above that seen in the TD population. Whilst previous literature has indicated that performance may be affected at both a central and peripheral level for individuals with DS (Frith & Frith, 1974; Henderson et al, 1991; Morris et al., 1982) our findings seem to indicate that influence at a central level has greater impact than at a peripheral level if not generally then certainly for the specific paradigm used in chapters 3 and 4 of this thesis and previous research (Khan et al., 2010).

Findings additionally revealed that there was a tendency for a greater OTA in the dual limb condition compared to the single limb condition for individuals with DS and this may be accounted for by the involvement of the non-dominant left hand in the dual limb responses. Previous research has revealed that RTs are slower in the left hand compared to the right hand of individuals with DS suggesting that the motor programs required to initiate movement of the left arm require greater cognitive processes than that of the right arm (Elliott, 1985; Elliott & Chua, 1986). Therefore, we can assume that when attempting to integrate movements when there is a switch to the non-dominant hand, individuals with DS have to apply greater cognitive recourses compared to their TD and UID peers and this can lead to greater interference during the first segment and hence an increased OTA in the dual compared single arm responses. An alternative explanation for this larger interference may be due to the need for inter-hemispheric integration when both the right and left arm are involved in the aiming sequence. Further support could be given to previous research that found that communication between the left and right cerebral hemispheres is affected due to abnormal development of the corpus callosum in individuals with DS (Wang, et al., 1992; see also Heath et al., 2007). An addition of a left hand start position may be of interest for future research investigation to further explore these findings.

In single limb conditions the limb is already active prior to the start of the second movement, whereas in dual limb conditions movement is initiated from a static position. In this thesis we found that movement time to the second target (MT2) was faster in the single limb two-target condition compared to the dual arm two-target conditions for all groups. This may potentially be related to the use of non-dominant hand (left hand) in second movement of the two target two-arm condition. As previously stated a right hand advantage and developmental issues associated with the corpus collosum in individuals with DS are well documented in manual aiming studies (Elliot & Chua, 1996) and the potential issues for the switching and co-ordination of arms may be pertinent for the movement time to the second target findings in this thesis.

The OTA has been shown to be a robust phenomenon; however there is a notable exception when reversal movements are introduced after the first target. Chapter 4 of this thesis further examined the OTA phenomenon by examining the effects of a reversal movement in dual limb sequential aiming in individuals with DS. Everyday motor skill tasks are not exclusively restricted to extension movements, therefore the potential practical implications for practice protocols in the DS population would require exploration of both extension and reversal movements. Khan et al (2010) stated that although the OTA has been uncovered in both single limb responses and manual aiming tasks in which two limbs are used, when the second movement in a one-limb movement condition involves a change in direction (a reversal movement), the OTA does not emerge. Consistent with previous findings in the typical developing population (Adam et al., 2001; Khan et al., 2006, 2010), OTA was eliminated in all groups when the second movement was a reversal of the first movement (i.e., 2T1Lr and 2T2Lr conditions). This elimination of the OTA can be explained by differences in the underlying muscle activity patterns utilized in single versus multiple element responses. Muscle activity patterns are characterised by a tri-phasic pattern of activation in single movement responses, whereas in dual movement responses a bi-phasic pattern of muscle activation is present. In a single element response the agonist muscle group accelerates the limb towards the target followed by an antagonist muscle burst that decelerate the limb at the target. A second agonist muscle action then acts to serve the purpose of dampening the mechanical oscillations at the end of the movement (Adam et al., 2000; Almeida et al., 2006; Enoka, 1988; Khan et al, 2006; Wierzbicka et al., 1986). In the two-target reversal condition the antagonist used to decelerate the limb at the first target additionally acts as the agonist for the second movement allowing for optimal integration between movements. Specifically, the second agonist muscle impulse is not required because the elastic properties of the antagonist muscle can be utilised to save time and energy by moving the limb in the reverse direction (Khan et al., 2006). The similar findings between groups gives further support for similar control strategies for integrating movements between the DS, UID and TD populations.

Whilst the majority of the agonist/antagonist influence may reside at a muscular/ skeletal physiology level (i.e. peripheral), some elements of the movement production as well as the entirety of the movement control interference associated with two element movements will reside at a central processing level. With a number of areas of skilled movement production being influenced at this central level, it is unsurprising that data seems to indicate that it is at this loci where a significant amount of interference occurs. Further support for a central rather than peripheral locus of interference can be seen in chapter 4 of this thesis as the OTA was eliminated in both the single arm and dual arm two target reversal movements. Therefore, it can be assumed that these control strategies and movement benefits occurred due to a reduction in the central processes required to control the two target reversal compared to extension movements. Specifically, if we look at the results from the 2T2Lr condition, faster movement times to target 1 were produced compared to those in the 2T2L condition. Therefore, because of the peripheral implications involved in a switch between limbs at the first target, the motor processes involved in the muscle patterns of reversal compared to extension movements could not result in movement time advantages as there is no bounce back advantage when the limbs are switched (Adam et al., 2000; Guiard, 1993; Helsen et al., 2001). Specifically, there are less central processes for accurate retrieval and implementation due to the simpler muscle patterns involved in reversal movements compared to the extension movements. Again, it appears that the central processing deficits previously reported in the DS population do not have additional influence on the integration of simple aiming movements, be it extension or reversal.

Another potential central origin explanation for this movement time advantage in reversal movement integration may reside in the target locations. In chapter 4 of this thesis the start target and reversal end target are located proximal to each other. It is suggested that when the location of target two in a two target reversal movement is located proximal to the start position (as in chapter 4) a reduction in task complexity may occur due to grouping of the targets within a subjectively produced ‘object’ with the start location target (Chen, 1998), that is, it is easier to return to a location previous occupied by the limb than a novel one.

Previous research has suggested that not only can task-specific practice sessions modify and improve motor skills over a period of days or weeks but also with adequate practice individuals with DS have the potential to reach the same levels of motor skill proficiency as their TD peers (Almeida et al., 1994, Latash, 2007; Smith et al., 2007). In this thesis we included a practice variable in chapter 4 to further investigate this possibility that the RTs and MTs of individuals with DS can improve with sufficient exposure to practice. Even though the improvement was slower for individuals with DS compared to the other two groups, the effect of practice on reaction times and the movement times to the first target was revealed and all groups improved as a function of practice. Due to time constraints the chapter 4 experimental design utilised a 4 day practice schedule but the number of trials within this schedule was significantly less than the 1,100 trials employed by Almeida et al. (1994). Although improvement was seen for individuals with DS across the experiment, their RT, MT and PT were consistently slower than the TD and UID groups. Therefore, it would appear that this was not a sufficient amount of practice to allow performance of individuals with DS to reach a comparable level to that of the TD and UID populations. Further research should increase the number of trials to ensure that adequate acquisition is accomplished by all groups.

Chapters 3 and 4 investigated the underlying mechanisms responsible for the planning, control and integration of multiple target/multiple direction aiming movements. Results suggested that whilst individuals with DS initiate and execute movements slower than TD individuals, they actually utilise similar movement planning and control strategies, that is the movements involved in multiple target aiming were controlled in a dependent fashion. The general findings from these two experimental chapters were that the performance variables of the first movement in the sequence were altered when a second movement was introduced. Specifically, RTs and MTs to the first target were lengthened when two-targets were introduced compared to a single target. This remained the same even regardless of whether the second movement was an extension movement or in the opposite direction to that of the first (i.e., a reversal movement). This functional dependency between movements is the motor system's attempt to ensure movement sequences are performed in an integrated, coherent, and efficient manner. As this reliance between movements occurs in the dual arm movements also, we can assume that the control strategies responsible for movement integration are similar to those proposed by the movement integration hypothesis (Adam et al., 2000). We can also conclude that these processes occur at the central level rather than peripheral indicating that the central deficits associated with DS do not prevent the central process deemed responsible for movement integration.

6.3 Dealing with performance pressure and DS

The latter programme of research presented in the final experimental chapter (chapter 5) of the thesis was designed to investigate the effects of environmental characteristics outside of those associated with the number of targets within a sequence. Specifically, we wanted to see the effects of performance pressure on the speed and accuracy of the movements of persons with DS and if the positive effects of practicing with anxiety that are observed in the TD population (Lawrence et al., *in press*; Oudejans, 2008; Oudejans and Pijpers, 2009, 2010) extend to individuals with DS. In chapter 5 of this thesis we examined whether learning a gross motor skill such as a football dribbling slalom task under conditions of anxiety would prevent the choking effects typically seen during performance when anxiety in present.

Results revealed that cognitive anxiety was successfully manipulated within this study with reported higher worry scores in the anxiety induced conditions compared to the low anxiety transfer condition. During the higher anxiety transfer lower feelings of worry were reported compared to the anxiety induced acquisition, this figure was not significant but the trend may give support to the theory that participants develop motor plans during acquisition that are specific to the conditions available at the time of learning (Elliot et al, 1995; Mackrous & Proteau, 2007). Results for cognitive anxiety were comparable across all groups lending support to our proposal that individuals with DS are affected by pressure in a similar manner to their TD and UID peers. Consistent with previous findings (Lawrence et al., *in press*), the level of task effort was similar across all groups also and there were no changes in effort reported by participants with the addition of anxiety. The PET predicts that when placed in a threatening situation participants exert more effort (Eysenck, 1992; Wilson, 2008), as this was not observed in the current study support cannot be given for this PET theory. However, across groups the investment of effort in the task did not decrease thus it can be assumed that participants did not disengage throughout the experiment.

Regarding performance outcomes, thesis chapter 5 reported the error scores and MT for all participants across conditions. Error scores for individuals with an ID (UID and DS) suggest that both ID groups performed with similar accuracy to their TD peers between pre-test and acquisition showing that across all groups all participants learnt to control and dribble the football around the cones with more accuracy. All participants showed less choking behaviours having learnt with anxiety with less errors being recorded on the high anxiety transfer compared to the pre-test. Additionally, the movement time data revealed that participants with DS demonstrated similar learning patterns to their UID and TD peers as all groups improved their MT as a result of practice with MTs decreasing from pre test to the last block of acquisition. Consistent with the finding from the previous chapters and previous research examining movement time in the DS population, movement time was found to be significantly slower in the DS group compared to TD group across all blocks. Interestingly, contrary to previous findings comparing MT between all three groups the MTs of the UID group were not significant compared to the DS group and the MTs for this group were closer to those reported in the DS group compared to the TD group.

Similar to findings by Oudejans & Pijpers (2010) results from chapter 5 of this thesis show that learning with anxiety was seen to prevent choking effects across all groups as anxiety did not disrupt and increase the MTs of participants in the high anxiety transfer condition and performance did not deteriorate in the subsequent anxious condition when participants learnt with anxiety and were later tested in a higher anxiety condition. This gives support to the notion that similar to the TD population, individuals with DS are affected by anxiety in a similar fashion and that learning with anxiety shows similar performance benefits later on when anxiety is re-introduced to performance. One can assume that participants in all groups became accustomed to the effects of anxiety by learning with it and developed movement strategies largely dependent of the presence of anxiety. Therefore, participants did not suffer from performance decrements under future anxiety inducement (Hardy et al., 1996; Masters, 1992). Additional practice trials would be required to lend support to a specificity perspective and see a significant difference between the two transfer conditions. Specificity of practice with anxiety benefits may be seen as extra exposure to practice under conditions of anxiety may lead participants to develop motor plans during acquisition that are specific to the conditions available at the time of learning (Elliot et al, 1995).

The results of chapter 5 show that similar to previous findings in the TD population, learning with anxiety was not detrimental to performance and the choking effects were minimised in the anxiety transfer for all groups including individuals with DS. All participants were able to improve their performance in a football dribbling slalom task following practice and whilst their overall movement times did decrease as a function of practice, MT remained slower in the DS group in comparison to the other two groups. An addition of extra acquisition trials in future research may enable individuals with DS to improve their MT to a comparable level of that of the TD and UID groups. Results from this chapter are somewhat cautionary as further exploration into these positive effects of learning with anxiety need to be investigated utilising controls groups that learn without anxiety to categorically confirm that learning with anxiety can in fact benefit performance in subsequent anxiety conditions.

6.4 Limitations and future directions within DS population research

There are a number of analyses that were beyond the scope of the current thesis, while others were not investigated due to time constraints and issues relating to access to participants with IDs. Thus, experimental limitations will be discussed and several directions for future research shall be proposed. It is recommend that for future research larger group sizes and control groups should be used for greater statistical power, a better representation of the DS population and potentially showing significant findings in place of trends found in the present thesis. In chapter 5 a control group could not be utilised due to time and recruitment constraints. It is imperative to use control groups for all populations in future research as this should highlight and compare whether when put under pressure (anxiety induced transfer) those who learnt with anxiety would have less decrements in performance associated with choking than those who learnt the skill without anxiety. As stated previously, the time constraints and access to participants were particularly difficult throughout this process as no departmental connections to intellectual disability charities or groups existed before this project. Hence, the initial contact to gain access for recruitment of participants and the subsequent networking to ascertain trust for recruitment purposes were very time consuming and labour intensive throughout this project.

In relation to chapter 5 of this thesis it was also noted that a less exertive exercise task such as a golf putting task should be used opposed to the football dribbling task to ensure that the HR measure for somatic anxiety is more measurable and the error scores and variability can be assessed more stringently (e.g. Vicon Analysis). In chapter 3 and 4 only the right hand was used to start each trial. Future research should include counterbalanced left hand start positions to ascertain any right or left hand advantages in individuals with DS. This may also give support to some of the previously mentioned ‘handedness’ (Elliott, 1985; Elliott & Chua, 1986) and inter-hemisphere research (Heath et al., 2007). As previously stated although improvements in the DS group were seen for the tasks, even following 400 trials of practice in chapter 4 of this thesis, these improvements were not comparable to those of either the TD or UID populations. Similar findings were found for the MT in the football dribbling task in chapter 5 after 20 trials of acquisition. These findings indicate the importance of considering the amount of practice within DS training interventions and it is recommended that based on the findings of this thesis, acquisition should include greater than 400 trials for significant improvements to occur. This may ensure relevant attainment of skill for the DS participants. Future research looking at how this practice should be structured (blocked vs. random) would be of great benefit also for practical skill learning protocols for individuals with DS. An additional future research suggestion would be to look at how performance outcomes are processed by looking at the types of feedback and the feedback frequency that are most beneficial for people with DS during skill acquisition.

A potential limitation associated with the measurement of dependent variables, was the modified MRF-3 questionnaire. Attention was drawn to the fact that some participants with IDs verbally reported after data collection that they did not want to report feelings of worry as it was linked with a sad face and thus did not want the researcher to think that they were not enjoying the task. Additionally, there were some reports from participants with IDs that words such as ‘confidence’ and ‘tension’ were not easily understood and they required additional help to fill out the questionnaires. Therefore, potential adapted questionnaire measures should be submitted to focus groups including people with varying levels of intellectual disability to highlight how understanding can be improved and to ensure words and sentences are ‘easy read’ and accessible. It is also recommended that different pictorial representations of emotions be utilised such as beakers which are full to empty to ensure the picture does not complicate the intension of the Likert scale. A definition of ‘easy read’ documentation is highlighted by the Department for Health (2010, pg 12), they state that “making information easier to understand for people with learning difficulties is about more than making your text size bigger and putting some symbols or pictures in your document. It’s about working with people your information is for, finding out together how you can make the information useful and accessible for them. It’s about thinking about how we all make sense of information”. These suggestions appear to be of paramount importance during research protocols that utilise persons with IDs. Whilst it was out of the scope of the current thesis, it is recommended, based on the anecdotal evidence above together with the recent ‘easy read’ Departmental Health guidelines, that steps are taken to carry out the validation of modified self report measures within the ID population rather than simply utilising measures that have been previously validated within the TD population.

This thesis has shown many positive results in relation to the ability and future inclusive training programmes for individuals with DS. Findings of this thesis have revealed that when controlling actions with multiple movements whilst individuals with DS initiate and execute movements slower they do in fact apply similar movement planning and control strategies and are also affected by anxiety and learning with anxiety in a similar fashion to the TD population. Chapter 3 and 4 of this thesis reported that movement time to the first target was longer in two-target sequential extension movements compared to single-target movements for all participants. The presence of the OTA in these extension movements implies that similar to the TD population, individuals with DS do not prepare and control segments of multiple target aiming sequences independently. This indicates that the reported central deficits of the DS population do no prevent the integration between movement segments in multiple target aiming. Therefore, similar to TD individuals, it appears that for individuals with DS, central rather than peripheral processes underlie the cause of the OTA. In chapter 4 of this thesis we also looked at reversal movements and found that when the second movement was a reversal of the first (i.e., the 2T1Lr and 2T2Lr conditions) the OTA was eliminated in all groups. This is consistent with previous findings within the typical developing population (Adam et al., 2001; Khan et al., 2006, 2010) and of particular interest highlights that the control strategies for integrating two target reversal movements both within and across arms do not differ between the DS, UID and TD populations.

Results of this thesis suggest that any central deficits associated with DS do not prevent the implementation of movement plans designed to improve the integration of elements within responses and that these integration strategies likely involve anticipatory behaviour (i.e., implementing the second movement in a sequence at an appropriate time during the execution of the first) in order to maximise the smooth transition between movements. Khan et al. (2011) suggested that when participants prepare two-target movements, the first segment is monitored through visual and/or proprioceptive feedback to determine when the second segment should be implemented. Therefore as previously mentioned individuals with DS, like their TD peers, treat movements within a sequence as functionally dependent and it is perhaps the central processes associated with the timing of the implementation of the second element that are responsible for the interference that leads to the one-target advantage. It can also be noted that performance pressure and learning with anxiety have similar affects in individuals with DS compared to their TD peers. Although the DS group remained slower following acquisition in all experimental chapters and their performance times were not comparable to those of the TD population, improvements were evident and a similar pattern of results was reported in both the typically developing and intellectually disability (DS and UID) populations. Therefore it can be concluded that persons with DS apply similar movement planning and control strategies as the TD population when controlling actions requiring the use of upper limbs and the lower limbs (separately) in multiple movement sequences and multiple movement directions.

To our knowledge this investigative thesis is the first to examine the OTA phenomenon in individuals with DS and also to demonstrate that learning with anxiety is not detrimental for skill acquisition in people with IDs. Whilst more research is needed before these findings can be applied to general settings, from a practical perspective these new understandings do offer some intriguing and thought provoking reflection. For example, the majority of practical intervention knowledge is based on the research findings conducted on non-pressure inducing basic single limb pointing movements in laboratory settings and practitioners should be mindful of this when designing learning interventions for complex multiple movement actions that are used to learn more applicable real life functional skills. This is especially important given that the findings of this thesis revealed that the DS population are affected by anxiety in a similar manner and apply similar movement planning and control strategies to the TD population in regards to multiple joint/multiple direction movements.

The findings of this thesis are very important as it seems to be a universal assumption to underestimate the motor skill ability of people with IDs and in particular DS. In addition, it has been anecdotally observed during the testing of the current thesis research programme that people with DS are overprotected when it comes to physical activity and/or motor skill learning and they play a passive role (if any) in deciding what exposure may be beneficial to their own learning. Furthermore, persons with DS are frequently not included in the decision making of what research needs to be conducted in order to better enhance their functional independence. These issues, together with the combination of the external validity issues of the tasks used in previous research and the findings of this thesis, highlight the need for practitioners to reflect on and question a number of potential areas of improvement. The value and extent for the need of special or adapted learning equipment and interventions must be questioned, together with the typically adopted strategy of reducing the complexity of the to-be-learned task together with removing exposure to pressure in motor skill acquisition when teaching individuals with DS everyday multiple movement actions that require integration for successful completion (i.e., food preparation, personal hygiene, computer use, driving, machine operation, typing skills, etc.). Additionally, it should be considered that individuals with DS, like their TD peers, can have the option to be trained with anxiety to prepare for real life anxiety induced situations such as sporting competition, learning a new functional living skill in college, examinations, work experience during college, transition from college to work, interviews or starting a new job. Learning with anxiety or having experience of being exposed to anxious situations through role play, competitions, mock examinations or interviews could potentially assist individuals with DS in developing better coping strategies in relation to anxiety and therefore enable them to prepare for future situations which may induce anxiety.

In conclusion, this thesis has examined the underlying mechanisms of reversal and extension aiming movements, the interrelation between two movements and the effects of performance pressure on the motor skill learning of individuals with DS. The experimental chapters in this thesis have shown the OTA to be a robust phenomenon not only for the TD population but individuals with DS and UID. Furthermore, like their TD peers, learning with anxiety helps in the prevention of choking behaviours for individuals with DS. Therefore as previously mentioned and similar to their TD and UID peers, individuals with DS treat movements within a sequence as functionally dependent and seem to display the same underlying mechanisms for the integration of movements whether the movement is an extension movement, a reversal movement or arms are switched during the movement sequence. Additionally, performance pressure and learning with anxiety have similar affects in individuals with DS compared to their TD and UID peers. Future research must be conducted to ensure that individuals with DS are given the most appropriate functional skill acquisition protocols to ensure that adequate levels of functional independence can be achieved. The answer to this may simply lie in the need for motor skill acquisition in individuals with DS to be less under-estimated.

Chapter 7

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Chapter 7

Appendices

Appendix 1

Accessible Participant Information Sheet for Thesis Chapter 3

Information Sheet

What we want to know?

We would like to find out how you move and how you learn movements.

What we want you to do?

We would like you to press some buttons as fast as you can.

We would like you to try and only hit the buttons we ask you to hit and show you to hit.

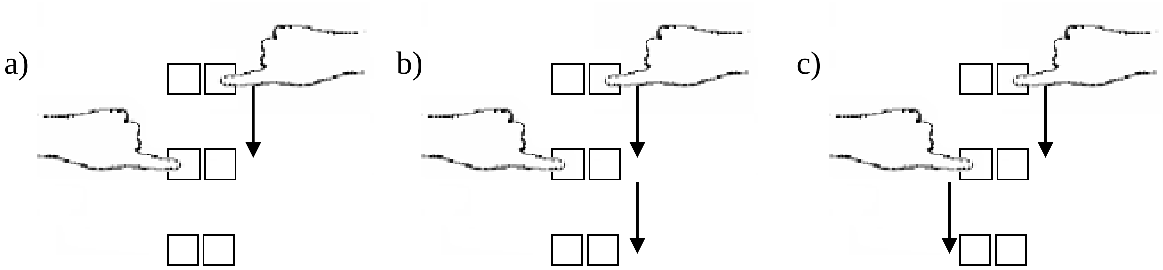
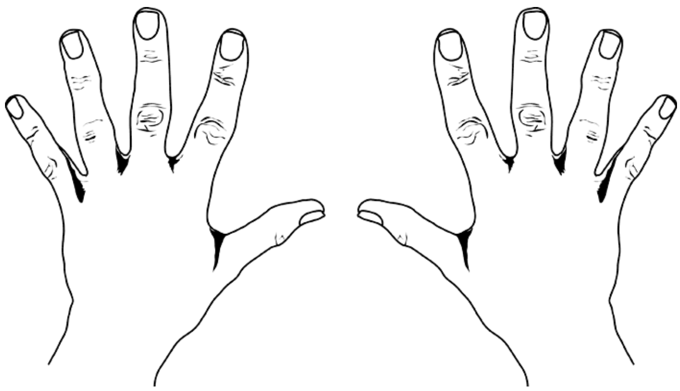


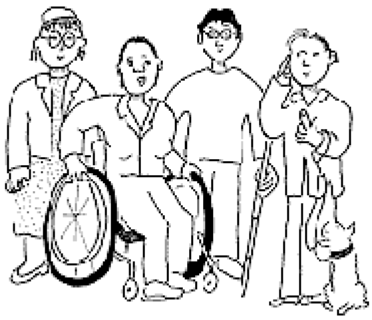
Figure 1. Starting position of fingers for right hand dominant movements, and the 3 conditions used in the study. a) Single target (1T); b) Two-target, single limb (2T1L); c) Two-target, two limbs (2T2L).

What will happen?

1. **We will ask you for your permission**
2. **We will collect information about your age, your health and which hand you prefer to draw with.**



3. **We will put the information on to a computer with a password, but we won’t use your name, age or address.**
4. **If you agree, we will look to see if you and lots of other people make movements in a similar or different way.**



5. **We will use the information to help us understand more about how you move and how you learn movements.**
6. **This will help Mencap to see what kind of help you and the people you live with might need to learn movements and skills.**

Can I say no?

- It's OK to say no if you want to.
- You can say no now, or if you change your mind later.
- You can tell us, or a member of staff at any time.

Questions?

- You can ask us anything you want now.
- Or, you can ask a member of staff to phone us.

Appendix 2

Information Sheets about Study for Support workers and Parents/Guardians for Thesis

Chapter 3

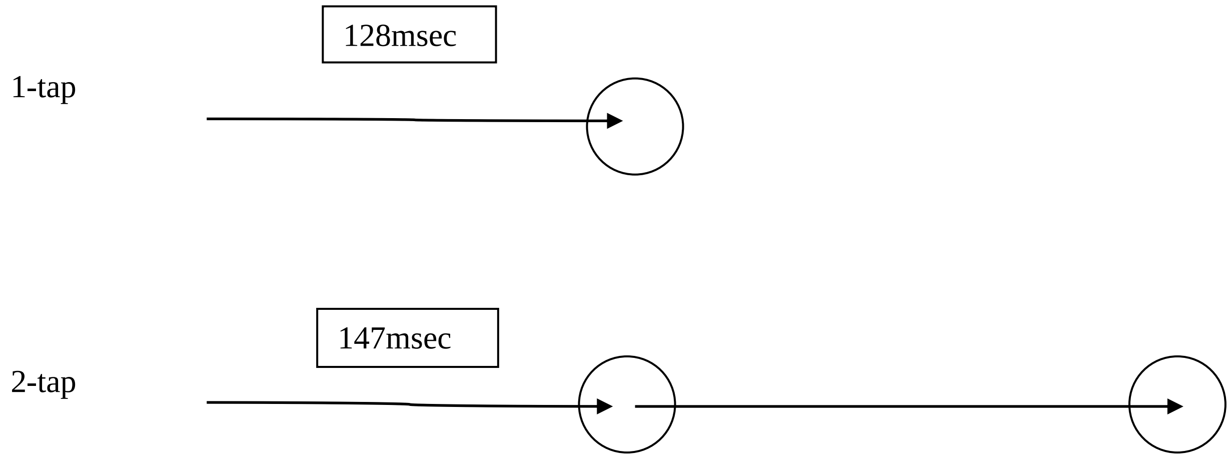
mencap cymru
Llais anabledd dysgu
The voice of learning disability

PRIFYSGOL BANGOR UNIVERSITY

Study Information Sheet

Purpose of Study

The purpose of this study is to test how individual s with Down syndrome integrate limb movements. Specifically, testing whether the one-target advantage will emerge in when there is a transfer between the limbs in sequential aiming movements. The one target advantage reflects a slower execution of the first movement in the two- tap condition compared to the corresponding movement in the one tap condition (see below).

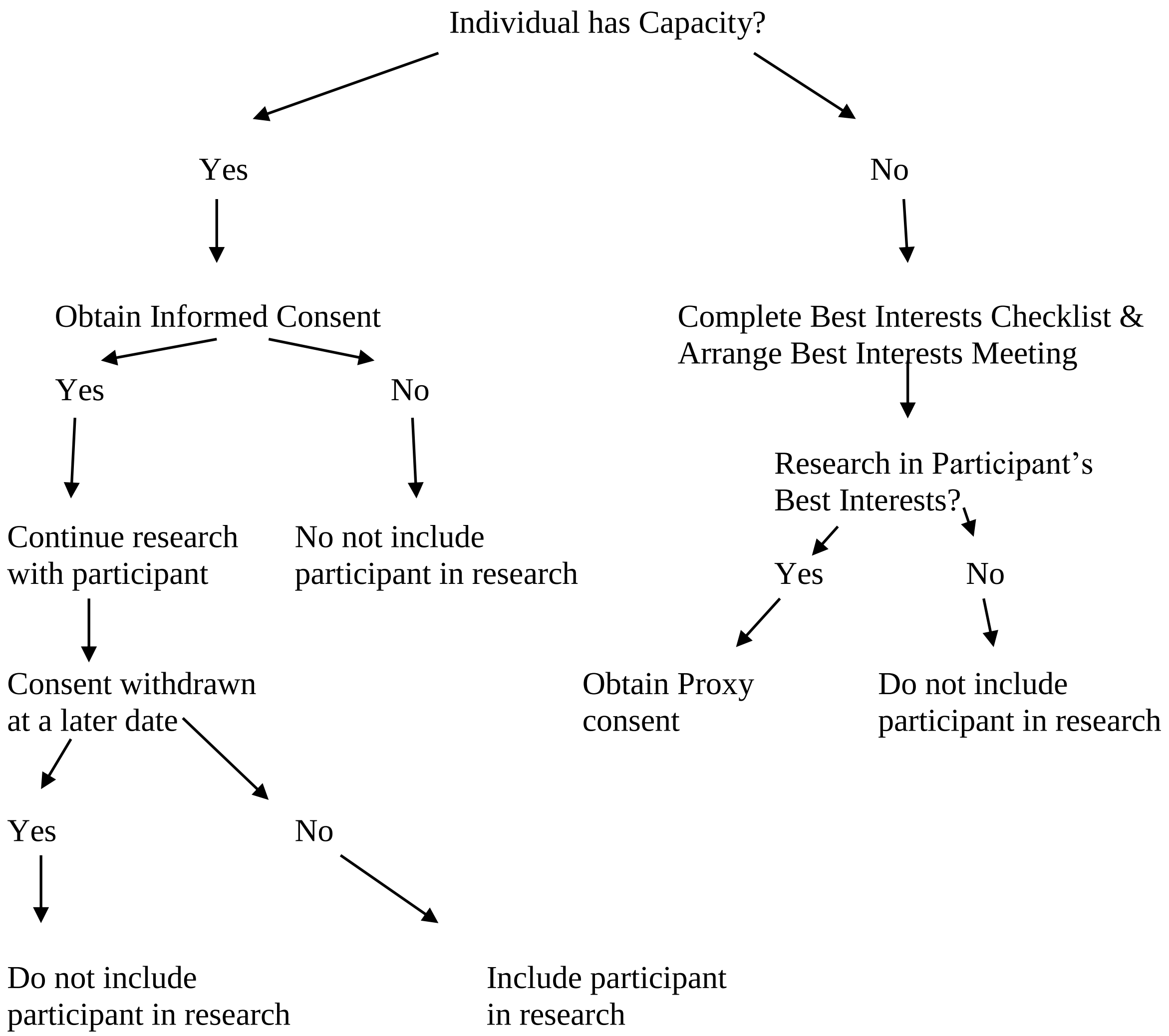


What will be involved?

For this project we will compare 3 movement actions. These movements will be a single target movement, a two-target movement with the action being performed by a single limb, and a two-target movement where the first movement will be performed with one arm and the second movement performed with the other arm. The apparatus used to obtain this data will be a non evasive six micro-switch horizontal wooden frame situated on a tabletop in front of seated participants. In order to protect anonymity, we will remove the names, dates of birth and addresses of each participant. We would like to ask each participant if they would kindly allow the anonymous movement results to be used to inform other people of the findings. These findings may then be used to help improve the movement acquisition of individuals with an intellectual disability. The process for obtaining consent from participants for us to use their information in this way is shown below.

Flow Chart of the Capacity & Consent Process

Functional Assessment of Capacity to give Consent to Participate in Research Study



Confidentiality & Data Protection

All data from participants will be anonymous. Data entered into the database will be password protected. All paperwork relating to capacity and informed consent will be locked in a filing cabinet in the School of Sport, Health and Exercise Sciences, Bangor University. Only researchers directly involved in the project will have access to the information.

At the end of the study

The overall findings of the research will be summarised and circulated to all participants. The results from the research may be published, again to inform wider understanding.

Any questions?

If you have any questions regarding this research, please contact, Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, George Building, Bangor, *Gwynedd*, LL57 2PZ. Or alternatively phone 01248 388256 during normal office hours, or email the researcher (see below).

Niamh Reilly

pepa2d@bangor.ac.uk

Supervised by:

Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, Bangor University

Mr. Wayne Crocker, Director of Mencap Cymru.

Appendix 3

Functional Assessment of Capacity: Mental Capacity Act 2005

Mental Capacity Act 2005
Functional Assessment of Capacity
CONFIDENTIAL

Name…………………………………..…………………………………………………..

DoB………………………...

Preferred Language………….…………..……………………………………………

DIAGNSTIC THRESHOLD
Does the individual have an impairment of, or a disturbance in, the functioning of the mind or brain? **YES** **NO**

If **YES** record nature of the disturbance

Neurological Disorder	Intellectual disability	Mental Disorder
Dementia	Stroke	Head Injury
Delirium	Unconsciousness	Substance Use
Other (give details)		

NATURE OF DECISIONS/ACTIONS/INTERVENTIONS PROPOSED
Record below the nature of the decision for the person being assessed

FUNCTIONAL ASSESSMENT
1. Is the individual able to understand the relevant information, for example, the purpose of the research and the consequences of using data for research purposes?
YES **NO**
Give details

2. Is the individual able to retain the relevant information (as above)?
YES **NO**
Give details

3. Is the individual able to use or weigh the relevant information as part of the decision making process (as above)?
YES **NO**
Give details

4. Is the individual able to communicate the decision(s) verbally or non-verbally (as appropriate)?

YES **NO**

Give details

Answering no to 1-3 indicates lack of capacity – complete "Best Interests Checklist" and refer decision to "Best Interests Meeting".
Answering no to 4 DOES NOT indicate incapacity – ensure practical measures are used to enable communication, for example liaising with Speech & Language Therapist.

Details of Assessor

Name………………………………………………………………………………………

Nature of professional relationship……………………..…………………………

Nature of interest (financial or other) in matter for which assessment was carried out

………………………………………………………………………………………………

………………………………………………………………………………………………

Signed……………………………………………………………………………………

Date & Time…………………..……………………………………………………….

Details of Witness

Name……………………………………………………………………...……….

Nature of professional relationship……………..……………………………………

Signed…………………………………………………………………………………..

Date & Time……………………………………………………………………………

Guidelines for the Functional Assessment of Capacity

Diagnostic Threshold

The Mental Capacity Act (2005) acknowledges that if there is an established diagnosis of mental illness, intellectual disability or some other condition, then this is sufficient to confirm "impairment or disturbance of the mind".

Nature of decision

Assessors should record the key decisions facing clients/patients

Test

1. Understanding the information

   The assessor is required to help the person understand the information relevant to the decision. Information should be presented in a clear and simple way or with the use of visual aids. Cultural and linguistic considerations should be included and family, friends, carers or support staff of the person being assessed should be used to assist the process

2. Retaining the information

   Information only needs to be held in the mind of the person long enough to make the decision.

3. Use or weigh the information

   Some people can understand the information, but an impairment stops them from using it. Whereas others may make a decision without understanding it. A person capable of using or weighing the information would also need to demonstrate that they could foresee the consequences of making, or failing to make, that decision.

4. Communicate the decision

   Communication can be whatever the assessor accepts. Assessors should consider using specialist workers to assist in communication (for sensory impairment etc).

Protocol for Assessing Capacity

1. Read Information sheet once to participant

2. Read the following part of the Information sheet: “We would like to find out how you move and how you learn movements. We would like you to press some buttons as fast as you can when they light up. We would like you to try and only hit the button which is lit up.

Ask the participant: “**Why do I want you to press the buttons?**”

Score 1 if the person gives an answer similar to “To find out about how I move” or “To see how I learn movements”.
Score 0 if the answer is irrelevant or too vague (e.g. “See me”).

3. Read the following part of the Information sheet: “We would like your permission to use some data from your file, to see how you learn movements and to see if you move similarly to how other people move”.

Ask the participant: “**What do I want to find out?**”.
Score 1 for correct answer (e.g. “to see how I learn to move…compare me to others”)
Score 0 for incorrect answer or an answer that is too vague.

4. Read the following part of the Information sheet: “We will put the information on to a computer with a password, but we won’t use your name, age or address”

Ask the participant “**Are you happy for me to come to collect this information?**”

Answers Yes or No.

Ask the participant: “**Are you happy for me to share the information to help other people with a learning disability?**

Answers Yes or No.

For consent to be given the participant needs to answer Yes to both questions.

5. Read the following part of the Information sheet: “If you say yes, but then you change your mind that’s OK. It’s OK to say no if you want to.You can say no now, or if you change your mind later. You can tell us, or a member of staff at any time”

Ask the participant: “**What will you do if you change your mind?**”.
Score 1 for any answer similar to “Tell you No”.
Score 0 if answer is irrelevant or too vague.
Overall Scoring

If the participant scores 0 to any of the questions under items 2,3 or 5, then the participant is assessed as not having the capacity to consent in this specific context. The assessment should be repeated at another time if possible. If the outcome is the same the researchers should follow the alternative route of seeking consent through the legal representatives and the “Best Interests Meeting”.

If the participant scores 1 in every question under items 2,3,4 and 6 and answers "Yes" to both questions under item 4, then the participant is assessed as having the capacity to consent and s/he is indicating their wish to participate. If the participant scores 1 in every question under items 2,3 and 6 but answers "No" in either question 4, the participant is assessed as having the capacity to consent and is indicating his refusal to participate.

This protocol is based on the procedure followed by Arscott, Dagnan & Kroese, 1998.

Arscott, K., Dagnan, D., & Kroese, B.S. (1998). Consent to psychological research by people with an intellectual disability. *Journal of Applied Research in Intellectual Disabilities, 11(1),* 77-83.

Mental Capacity Act 2005
Best Interests Checklist
CONFIDENTIAL

Name…………………………………………………………………………………..
DoB……………………...

Preferred Language…………………………………………………………………..

Decision/Intervention proposed

Checklist

1. Have you considered, so as far as is practicable, that the person may regain capacity at some time in the future and whether a delay in decision-making is possible which will allow the person to make that decision themselves at a later date?

   YES NO

   Please give details below

2. Have you considered as far as is practicable that person's involvement in actions proposed on their behalf or in any decisions affecting them?

   YES NO

   Please give details below

3. Have you considered the beliefs and values that the person's past and present wishes and preferences about the matter in question?

   YES NO

   Please give details below

4. Have you taken into account other factors that the person had when capable, that would likely influence the person's attitude to the decision in question (religion, culture, lifestyle etc.)?

   YES NO

   Please give details below

5. Have you taken into account other factors that the person would be likely, if they were capable, to consider in relation to the matter (emotional bonds, family obligations, deciding how to spend money etc.)?

   YES NO

   Please give details below

6. Have you consulted and taken into account the views of other key persons as to what would be in the person's best interests and taken into considerations their wishes, feelings, beliefs, values etc.?

   YES NO

   Please give details below

7. Any disagreements, conflicts, doubts expressed by any parties during this assessment & methods used to resolve these?
   Give details

8. Has a referral been made to the Best Interests Meeting?

   YES NO

   Give details (including date)

Details of Assessor

Name…………………………………………………………………………………

Nature of professional relationship…………………………………………………..

Nature of interest (financial or other) in matter for which assessment was carried out

………………………………………………………………………………………………

………………………………………………………………………………………………

Signed………………………………………………………………………………………

Date & Time…………………………………………………………………………………

Details of Witness
Name…………………………………………………………………………………………

Nature of professional relationship…………………………………...…………...

Signed……………………………………………………………………………………..

Date & Time…………………………………………………………………………………

Letter for Best Interests Meeting

Xx/xx/2011

Dear xxxxxxxx,

We are currently conducting research for Mencap Cymru, looking into improving the movement skills of individuals with learning disabilities. This research is being conducted using information collected from a simple button pressing task.

As part of this research we need to obtain informed consent from participants to allow us to access and use information we receive from this test.

We would therefore like to ask you to consider if taking part in this study would be in the best interests of the individual with the learning disability. If you think that taking part in this research is in best interests, could you please complete the attached “Proxy Consent form” and return it to us in the envelope provided, or alternatively contact us using the contact details below to arrange a meeting.

Please find enclosed copies of the completed capacity assessment form, the Best Interest Checklist and the participant and general information sheets.

If you have any questions please don’t hesitate to contact me,

Yours sincerely,

Niamh Reilly

pepa2d@bangor.ac.uk

Supervised by:

Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, Bangor University

Mr. Wayne Crocker, Director of Mencap Cymru

Proxy Consent Form

Please tick

O I confirm that I have read and understand the information sheet dated ……/……/…… for the above study and have had the opportunity to ask questions.

O I understand that participation is voluntary and that I am free to withdraw my relative/client at any time without giving any reason. This will not affect the care or legal rights of my relative/client.

O I therefore agree on behalf of ………………… that researchers can collect data & this data may be summarised, potentially for publication

Name of person giving consent	Date	Signature
Relationship to participant	Contact details	
Researcher Date		

Appendix 4

Adapted and Accessible Consent Forms (English & Welsh)

mencap cymru
Llais anabledd dysgu
The voice of learning disability

PRIFYSGOL BANGOR UNIVERSITY

CONSENT FORM

1. **I have been given information about the study** **YES**

   NO

2. **I have been able to ask questions if I wanted** **YES**

   NO

3. **I know that I can say no at any time**

   YES **NO**

4. **I am happy for my information to be used** **YES**

   NO

Written Consent

Signed…………………………………………………………

Date……………………………………………………………

Verbal Consent

YES **NO** **N/A**

Witnessed by ………………………………………………………………….....

Name……………………………………………………………………………

Position…………………………………………………………………………

Date & Time……………………………………………………………………

Researcher……………………………Name…………………………………………

Date & Time…………………………………………………………..…………….

Cydsyniad

1. **Rwyf wedi derbyn gwybodaeth am yr ymchwil** **YDW**

   NAC YDW

2. **Rwyf wedi cael y cyfle i ofyn cwestiynau** **YDW**

   NAC YDW

3. **Rwyf yn gwybod gallaf ddweud na ar unrhyw adeg**

   YDW **NAC YDW**

4. **Rwyf yn hapus i fy ngwybodaeth cael ei defnyddio**

   YDW **NAC YDW**

Cydsyniad Ysgrifenedig

Llofnod…………………………………………………………

Dyddiad………………………………………………………..

Cydsyniad ar lafar

IE **NA** **N/A**

Tystiwyd gan………………………………………………………………….......

Enw.……………………………………………………………………………

Swydd………………………………………………………………………….

Dyddiad &Amser……………………………………………………………….

Ymchwilydd……………………………Enw…………………………………………

Dyddiad & Amser…………………………………………………..………………

Appendix 5

Accessible Participant Information Sheet for Thesis Chapter 4

Information Sheet

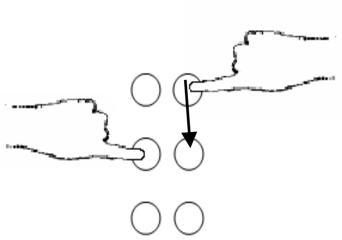
What we want to know?

We would like to find out how you move and how you learn movements.

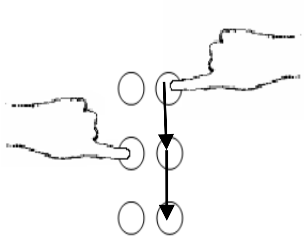
What do we want you to do?

We would like you to press some buttons as fast as you can.

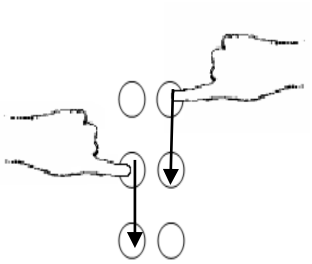
We would like you to try and only hit the buttons that we ask you to press.



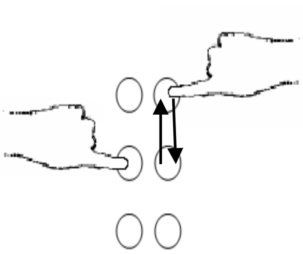
1 Target



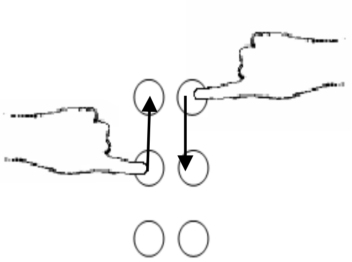
2 Target 1 Hand



2 Targets 2 Hands



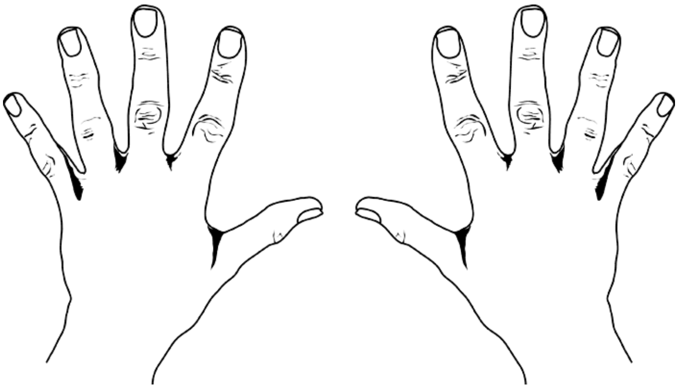
2 Targets 1 Hand Moving forwards and backwards



2 Targets 2 Hands Moving forwards and backwards

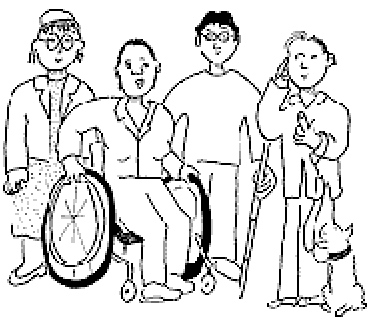
What will happen?

7. **We will ask you for your permission.**
8. **We will collect information about your age, your health and which hand you prefer to draw with.**



9. **We will put the information on to a computer with a password, but we won't use your name, age or address.**

10. **If you agree, we will look to see if you and lots of other people make movements in a similar or different way.**



11. **We will use the information to help us understand more about how you move and how you learn movements.**

12. **This will help Mencap to see what kind of help you and the people you live with might need to learn movements and skills.**

Can I say no?

- **It's OK to say no if you want to.**
- **You can say no now, or if you change your mind later.**
- **You can tell us, or a member of staff at any time.**

Questions?

- **You can ask us anything you want now.**
- **Or, you can ask a member of staff to phone us.**

Appendix 6

Accessible Participant Information Sheet for Thesis Chapter 4

Study Information Sheet

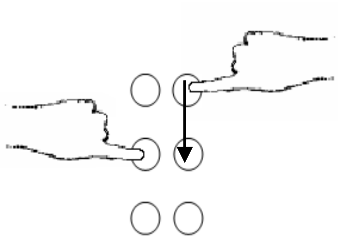
Purpose of Study

The purpose of this study will be to examine whether individuals with Down syndrome integrate two element reversal movements in the same manner as typically developing adults (TD) and adults with a high functioning learning disability (NDS). Specifically, testing whether the two-target advantage will emerge when there is a transfer between the limbs in reversal sequential aiming arm movements. The two target advantage happens when the movement time to the first target is quicker for two-element responses compared to single element responses.

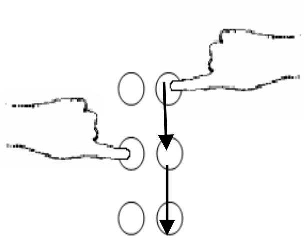
What will be involved?

For this project we will ask participants to complete 5 sets of movement actions. These movements will be a single target movement, a two-target reversal movement with the action being performed by a single limb, a two-target movement where the first movement will be performed with one arm and the second movement performed with the other arm (see figure below). The apparatus used to obtain this data will consist of a non invasive horizontal wooden frame containing with six buttons. This will be situated on a tabletop in front of seated participants. In order to protect anonymity, we will remove the names, dates of birth and addresses of each participant. We would like to ask each participant if they would kindly allow the anonymous movement results to be used to inform other people of the findings.

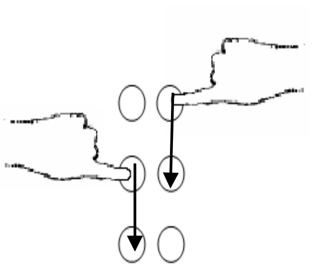
These findings may then be used to help improve the movement acquisition of individuals with an intellectual disability.



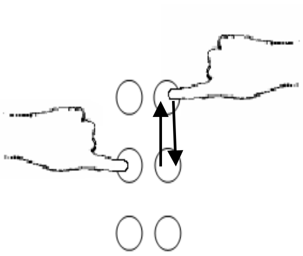
1T (one-target)



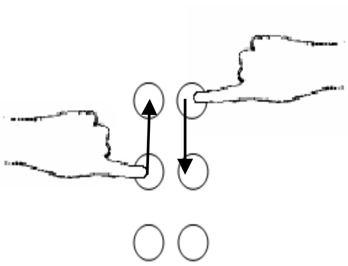
2T 1L (two-target, one limb)



2T 2L (two-target, two limb)



2TR 1L (two-target reversal, one limb)

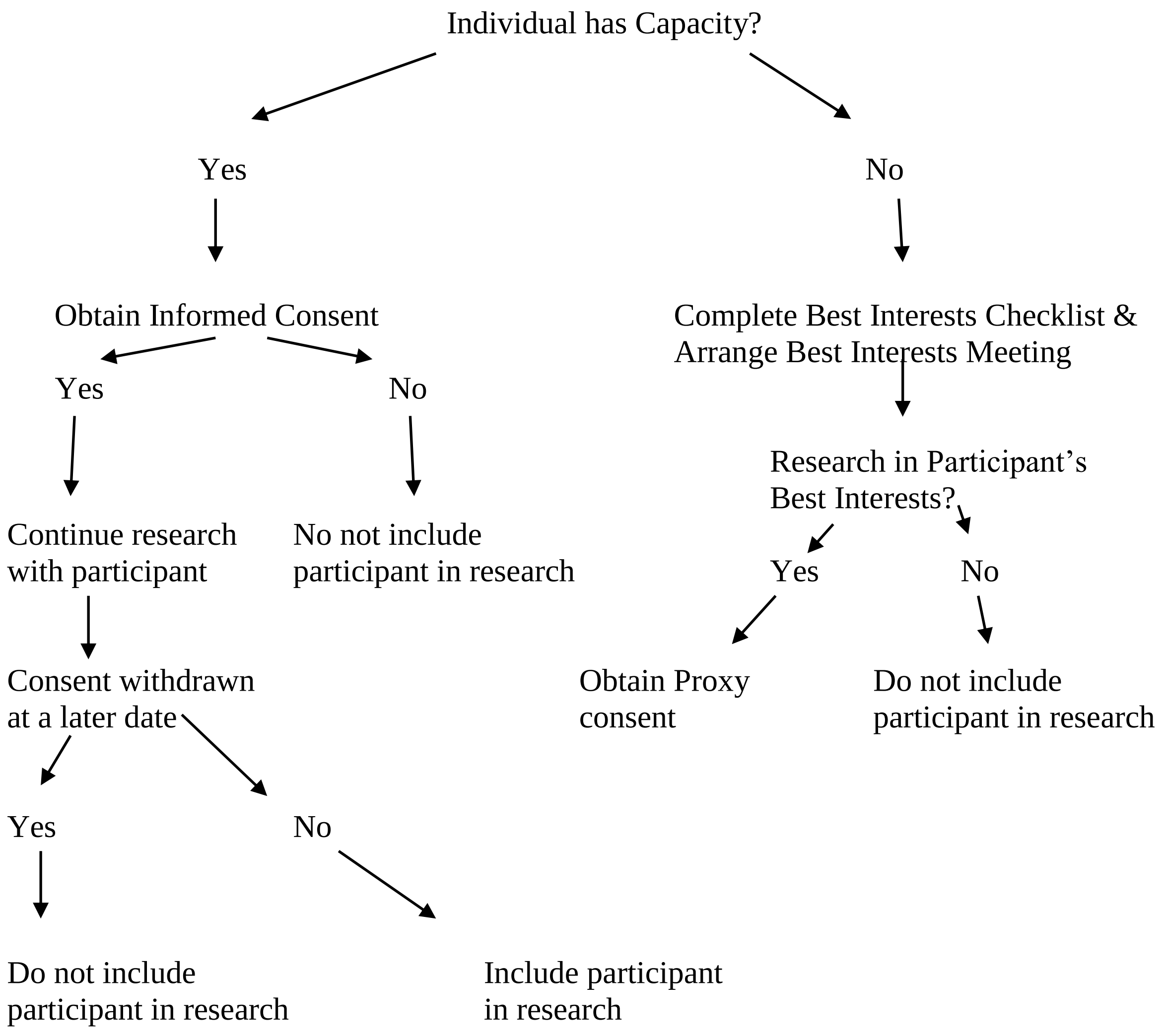


2TR 2L (two-target reversal, two limbs)

The process for obtaining consent from participants for us to use their information in this way is shown below.

Flow Chart of the Capacity & Consent Process

Functional Assessment of Capacity to give Consent to Participate in Research Study



Confidentiality & Data Protection

All data from participants will be anonymous. Data entered into the database will be password protected. All paperwork relating to capacity and informed consent will be locked in a filing cabinet in the School of Sport, Health and Exercise Sciences, Bangor University. Only researchers directly involved in the project will have access to the information.

At the end of the study

The overall findings of the research will be summarised and circulated to all participants. The results from the research may be published, again to inform wider understanding.

Any questions?

If you have any questions regarding this research, please contact, Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, George Building, ***Bangor***, Gwynedd, LL57 2PZ. Or alternatively phone 01248 388256 during normal office hours, or email the researcher (see below).

Niamh Reilly

pepa2d@bangor.ac.uk

Supervised by:

Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, Bangor University
Mr. Wayne Crocker, Director of Mencap Cymru.

Appendix 7

Accessible Participant Information Sheet for Thesis Chapter 5

Information Sheet

What we want to know?

We would like to find out how you move and how you learn movements.

What we want you to do?

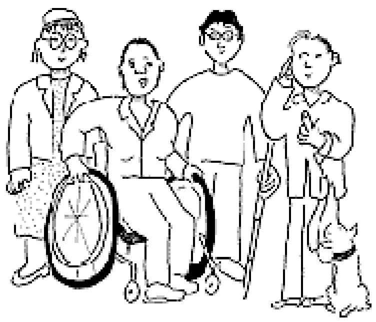
We would like you to dribble the ball around the cones. We would like you to try to do this as fast as you can but to NOT hit the cones or lose control of the ball.

You will be video recorded for some of the trials and this will be sent to a professional football coach. You will receive feedback about your football skills from this coach. If you are fast and make few mistakes your name will appear on a leader board. If you are the fastest and most accurate you will receive a trophy.

What will happen?

1. **We will ask you for your permission**
2. **We will collect information about your age, your health and which foot you prefer to kick with.**

3. **We will put the information on to a computer with a password, but we won't use your name, age or address.**
4. **If you agree, we will look to see if you and lots of other people make movements in a similar or different way.**



5. **We will use the information to help us understand more about how you move and how you learn movements.**
6. **This will help Mencap to see what kind of help you and the people you live with might need to learn movements and skills.**

Can I say no?

- **It's OK to say no if you want to.**
- **You can say no now, or if you change your mind later.**
- **You can tell us, or a member of staff at any time.**

Questions?

- **You can ask us anything you want now.**
- **Or, you can ask a member of staff to phone us.**

Appendix 8

Information Sheets about Study for Support workers and Parents/Guardians for Thesis

Chapter 5

Study Information Sheet

Purpose of Study

The purpose of this study will be to examine how anxiety affects the football dribbling performance of individuals with Down syndrome and whether learning with anxiety can improve subsequent anxious performance. This study will be carried out under the guidance of Niamh Reilly, Dr. Gavin Lawrence, Bangor University and Wayne Crocker, Director of Mencap Cymru.

What will be involved?

After giving informed consent and completing the Mental Readiness Form: MRF-3 (see appendix 2), participants will be required to wear a heart rate monitor (this will be worn for the duration of the testing) and then perform 5 football dribbling trials around a 10 m slalom course before being asked to complete the MRF-3 again. Following this, all participants will then complete 20 further dribbling trials (in blocks of 5 to prevent fatigue) before completing the MRF-3 for a third time. Following a 5 minute break, the participants will complete two final tests. Both of which consist of completing the MRF-3 before performing 10 further dribbling trials. The first set of five trials will be performed under normal conditions (low anxiety) whilst the second ten will be performed under anxiety conditions (see below for manipulation of anxiety).

To induce anxiety participants will be told that their performance will be video recorded and these recordings will be sent off for analysis to an experienced disability football coach. Feedback will be given to each participant in regards to their own technique (see appendix 1).

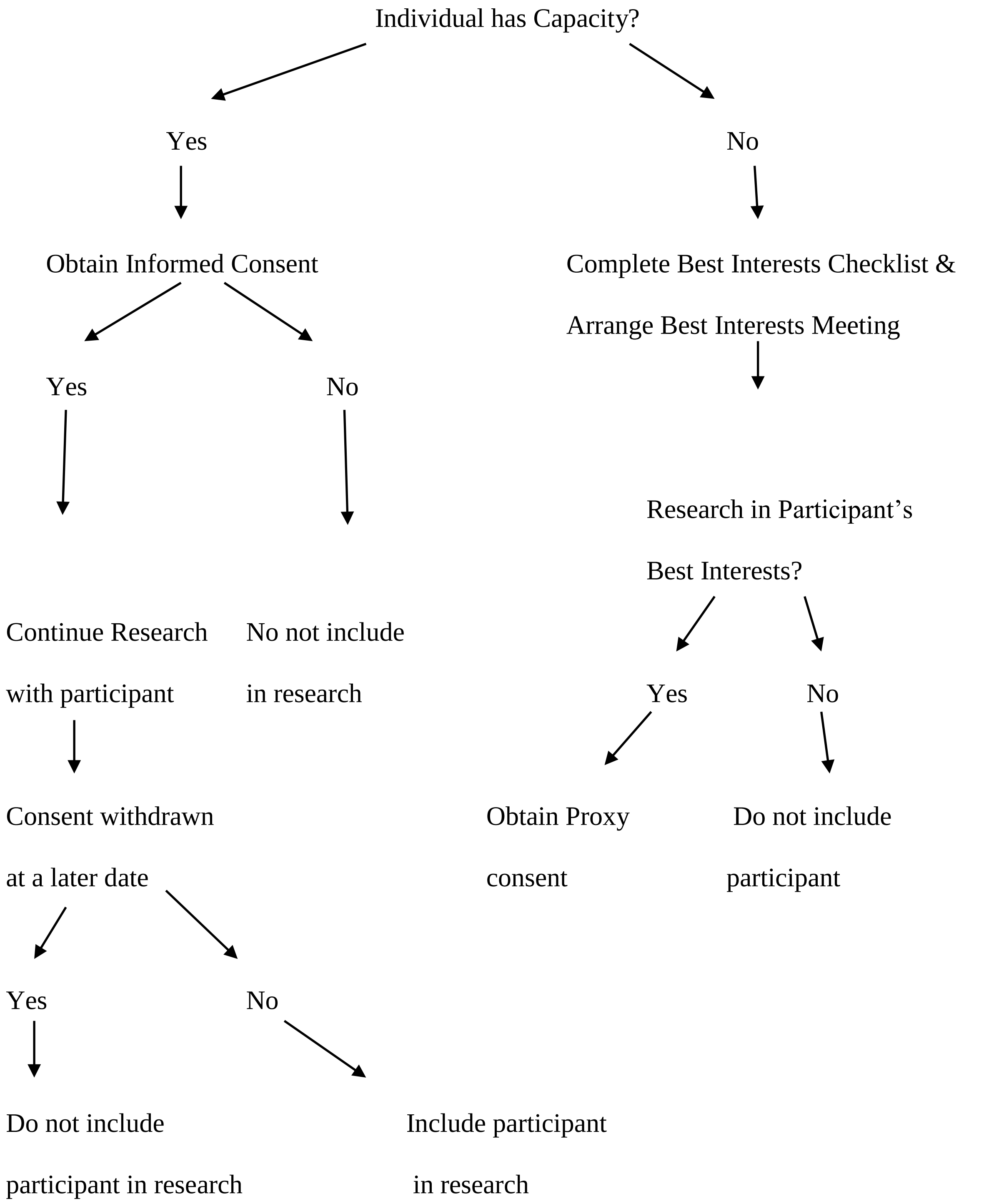
Participants will also be told that if they are in the top 5 of all participants for speed and accuracy their performance will appear on a leader board. They will also be informed that the leader of the final ten trials will receive a winner's trophy. Inducing anxiety is necessary as the study aims to examine the effects of anxiety on the skill performance of individuals with a learning disability. Specifically, the performance differences in subsequent anxiety situations for participants who have experienced practice under either high anxiety or low anxiety conditions. After the experiment, participants will be given a letter thanking them for their time and it will tell them when to expect the feedback from the football coach. Finally, providing they are within the top 5 performers, they will be asked if they wish for their scores to be posted on the leader board.

For practical purposes the participants will need to wear appropriate clothing (males and females – sports trousers or shorts and a sports top).

Throughout the study the participant's errors in relation to the dribbling task will be measured. In order to protect anonymity, we will remove the names, dates of birth and addresses of each participant from their consent forms and questionnaires. We would like to ask each participant if they would kindly allow the anonymous movement results to be used to inform other people of the findings. These findings may then be used to help improve the movement acquisition of individuals with an intellectual disability. The process for obtaining consent from participants for us to use their information in this way is shown below.

Flow Chart of the Capacity & Consent Process

Functional Assessment of Capacity to give Consent to Participate in Research Study



Confidentiality & Data Protection

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At the end of the study

The overall findings of the research will be summarised and circulated to all participants. The results from the research may be published, again to inform wider understanding.

Any questions?

If you have any questions regarding this research, please contact, Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, George Building, ***Bangor***, Gwynedd, LL57 2PZ. Or alternatively phone 01248 388256 during normal office hours, or email the researcher (see below).

Niamh Reilly

pepa2d@bangor.ac.uk

Supervised by:

Dr Gavin Lawrence, School of Sport, Health and Exercise Sciences, Bangor University

Mr. Wayne Crocker, Director of Mencap Cymru.

Appendix 9

Adapted Mental Readiness Form-3 and Perceived Effort form for Thesis Chapter 5

PRACTICE
Mental Readiness Form (MRF-3)

1. My thoughts are:

1 2 3 4 5 6 7 8 9 10 11

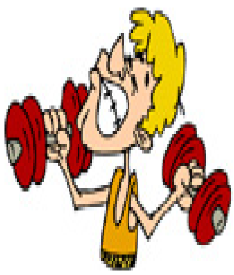
Not Worried **A Little Worried** **Very Worried**

---

2. My body feels:

1 2 3 4 5 6 7 8 9 10 11

Not Tense **A Little Tense** **Very Tense**



---

3. I am feeling:

1 2 3 4 5 6 7 8 9 10 11

Very Confident **A Little Confident** **Not Confident**

PRACTICE
Effort Form

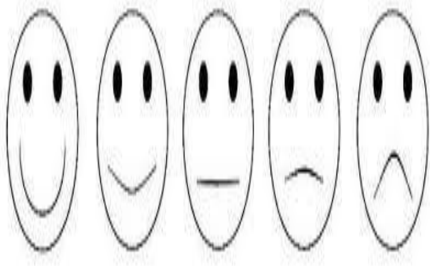
The amount of effort I used was:

1 2 3 4 5 6 7 8 9 10 11

No Effort **A Little Effort** **A lot of Effort**

Appendix 10

Coach Football Technique Feedback Form for Thesis Chapter 5

Technique 						**Tips for Improvement** 
	Great	Good	OK	Needs Improvement	Needs a lot of improvement.	
Do you get your knees bent?						
Do you get into a crouched position?						
Do you get your head over the ball?						
Do you get your head up so you can see where the cone is?						
Once past the cone, do you increase speed?						
Do you change direction quickly?						
Do you use the correct part of the boot (inside for dribbling, outside when running with ball)?						
Do you keep the ball close to you at all times?						

(www.footballcoachingcourses.com/dribblingckecklist)