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The Contextual Interference Effect in Adolescents with Down Syndrome

by

Jennifer Joy Kivi ©

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Name of Author: Jennifer Joy Kivi

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J Kivi

Jennifer Kivi
8510 111 Street, Apt. 1902
Edmonton, AB
T6G 1H7

Date: August 28, 2002

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled The Contextual Interference Effect in Adolescents with Down Syndrome submitted by Jennifer Joy Kivi in partial fulfillment of the requirements for the degree of Master of Science.

Dr. Brian Maraj

Dr. Marcel Bouffard

Dr. Graham Fishburne

Date: June 26, 2007

Abstract

This study examined the effects of contextual interference and cognitive processing strategies on motor skill acquisition and retention in individuals with Down syndrome. Sixteen adolescents with Down syndrome learned a sequencing task using either a blocked or random practice schedule. Additionally, half of the participants in each practice condition were asked questions designed to evoke active cognitive processing. Results showed that the temporal variables demonstrated no clear distinction between the blocked and random practice conditions, however, the error data revealed the typical contextual interference effect. Furthermore, the performance of the participants who received the processing questions was superior to that of participants who did not receive the questions, regardless of practice condition. These results indicate that a random practice schedule may enhance the learning of motor skills for persons with Down syndrome and active cognitive processing may be an important factor when teaching individuals from this population motor skills.

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I. Introduction

Previous research has indicated that persons with an intellectual disability (PWID) experience difficulty with learning, especially with the learning of motor skills (Wade, 1986). This may, in fact, be one of their most persistent and challenging educational difficulties (Porretta, 1988). As a result, finding valuable and significant ways to facilitate learning in PWID is a difficult, yet important undertaking.

The study of motor learning has traditionally investigated questions that have implications for underlying processes involved in skill acquisition or for application to skill instruction situations. The entire learning procedure, however, involves not only the performance of a task or skill, but the retention (learning) and transfer (generalization) of a skill as well (Porretta, 1996).

Over the past two decades, investigators have begun to examine instructional strategies that have the potential for enhancing the learning capabilities of PWID within the motor performance context (Poretta, 1996). One construct that has been a cornerstone in the study of motor learning, has been examined extensively in the general population, and may have significant instructional implications with respect to increased transfer and retention of motor skills, is the contextual interference (CI) effect.

Since Battig's (1972) original work in the verbal domain, and the preliminary study conducted by Shea and Morgan (1979) in the motor domain, the contextual interference effect has been a robust finding throughout the motor behaviour literature. The contextual interference effect is a learning phenomenon in which interference during practice is beneficial to skill learning (Magill & Hall, 1990). The contextual interference effect refers to the finding that when task variations are practised repeatedly in separate blocks of trials (blocked practice schedule), there is little contextual interference. Conversely, much contextual interference occurs when the variations of the task change randomly from one trial to the next (random practice schedule). The observed result of these differences in the quantity of contextual interference is that blocked practice schedules lead to better performance during acquisition than random practice schedules, although random practice results in better performance during tests of retention and transfer (Albaret & Thon, 1998).

Although the contextual interference effect may provide significant insight into motor skill performance and learning of PWID, research has been scarce. Additionally, no scientifically compelling study of the CI effect in PWID has yet been conducted. Only six studies investigating the CI effect in PWID have been carried out and the results of these studies are equivocal. Generally speaking, previous research has failed to establish that the CI effect, as demonstrated by the non-disabled population, is in fact present in PWID.

Definitions

Contextual Interference. The term contextual interference is used in this paper as intended by Battig (1972, 1979) who originally saw practice context components as potential sources of interference that would enhance learning rather than inhibit learning. The term itself appropriately indicates the important roles of contextual factors that are within and extraneous to the task being learned and to the processing activities of the learner. In this manner, the entire practice context, labelled as 'contextual variety' by Battig (1972, 1979), can be seen as potential sources of interference that could enhance learning. As such, contextual variety in a practice situation was seen as incorporating functional interference into the practice context. Experiencing contextual variety therefore, made learning less context dependent and involved learners in processing activity that led to better memory retrieval and performance adaptation to new or different context conditions.

Motor Performance. Motor performance can be defined as the observable attempt of an individual to produce a voluntary action. The level of a person's performance is susceptible to fluctuations in temporary factors such as motivation, arousal, fatigue and physical condition (Schmidt & Wrisberg, 2000).

Motor Learning. Motor learning can be defined as changes in internal processes that determine an individual's capability for producing a motor task. The level of an individual's motor learning improves with practice and is often inferred by observing relatively stable levels of the person's motor performance (Schmidt & Wrisberg, 2000).

Purpose

The primary purpose of this study was to examine how schedules of practice affect skill acquisition and learning in adolescents and young adults with Down syndrome (DS). A secondary purpose was to investigate cognitive processing strategies in individuals with DS in order to obtain a better understanding of the way in which persons from this population process movement related information.

Hypotheses

Two hypotheses for this study were formed. First, it was hypothesized that because individuals with DS are passive processors of information (Brown, 1974) and exhibit poor motivation when facing a new task (Borkowski, Johnston & Ried, 1987), they would not exhibit the contextual interference effect. Stated differently, it was hypothesized that individuals with Down syndrome would benefit more from a blocked practice schedule (low CI), as opposed to a random practice schedule (high CI) in both the performance and learning of a novel motor skill.

Second, it was hypothesized that if individuals with DS were supplemented with intra-task and inter-task processing strategies, they would be able to benefit from random practice in the learning of motor skills. Therefore, when persons with DS were facilitated to engage in strategic cognitive processing, it was theorized that they would exhibit the contextual interference effect consistent with that observed in the general population. Specifically, while a blocked practice schedule would enhance performance in acquisition, the performance of those participants who practiced in a random schedule would be superior in tests of retention.

Significance of the Study

From an exhaustive review of the literature, a total of six studies investigating the CI effect in PWID were found. In addition to the relatively small number of investigations conducted in this area, the results of the existing studies have been equivocal. As the conclusions of the current literature have been unclear, further steps must be taken in order to obtain a comprehensive picture of the effects of CI in this population.

While previous investigations have attempted to examine how variations in practice schedule influence motor skill acquisition and learning in PWID, they have failed to take into account the cognitive processing mechanisms of this population. Essentially, previous researchers have assumed that findings of the CI effect in PWID would be consistent with those of individuals from the typical population. Given the unique learning characteristics of PWID, this assumption is amiss. By recognizing that PWID often fail to produce the necessary cognitive tactics when confronted with tasks that require strategic intervention (Campione, Brown, & Ferrara, 1982), researchers can begin to look further into the benefits of blocked and random practice and begin to unveil the underlying processes involved in the CI effect in this population. As such, by facilitating the participants to become active learners, this study will help to provide a better understanding of the underlying cognitive mechanisms involved in the CI effect in individuals with DS.

In addition, numerous studies designed to investigate the organization and function of the cerebral hemispheres in persons with Down syndrome have been conducted over the past several years. In 1987, Elliott, Weeks and Elliott put forth a model of brain organization that suggests that although individuals with Down syndrome perceive speech with their right cerebral hemisphere, they depend on left hemisphere mechanisms for the production of speech as well as other complex movements. This dissociation of function results in persons with DS having particular difficulty performing tasks that involve both speech perception and the control of complex movement. In 1986, Edwards, Elliott and Lee investigated the effect of CI in individuals with DS, however no attention was given to the mode of instruction provided to the participants. If verbal instructions were utilized, the participants may not have performed to the best of their abilities and therefore, may not have benefited maximally from the practice trials. By utilizing a combination visual/verbal instructional approach during skill acquisition, this study provided participants with the opportunity to elicit their maximum performance and thus profit from acquisition.

Lastly, in 1987, Borkowski et al. provided evidence that children with learning impairments often develop motivational and personal problems as a consequence of their learning difficulties. The authors demonstrated that individuals who experience low motivation and poor self-esteem are less inclined to become active, strategic learners and the processes that underlie the acquisition and transfer of skills are therefore impeded. Previous studies on the CI effect in PWID have not examined the effects of motivation on participants' performance. Therefore, this study assessed participants' feelings toward the task in order to gain a broad understanding of the effects of emotion on motor skill performance and learning in different practice schedules.

At a practical level, the results from this study will help researchers to discover more about the way that individuals with Down syndrome learn motor skills. This information can be applied to educational and activity settings, such as physical education classes and recreational sports teams. Determining strategies that can facilitate the retention of motor skills will assist in determining the most optimal approach for teachers, physical educators, coaches, and therapists to organizing instructional sessions that are most conducive to learning for individuals with Down syndrome. Thus, individuals in this population may be able to better learn and execute motor skills, which may ultimately improve performance in game and activity situations.

II. Review of Literature

Motor Behaviour and Down Syndrome

Down syndrome, a condition of moderate to severe intellectual disability, is the most common of chromosomal abnormalities and occurs in all races and cultures. It is named after Dr. John Langdon-Down who first described the condition in 1866 (Selikowitz, 1997). Three types of DS exist: translocation, mosaicism, and trisomy 21, the latter accounting for approximately 95% of cases. Trisomy 21 is caused by nondisjunction, failure of chromosome pair 21 to separate properly before or during fertilization. This results in an extra chromosome and cells that normally have 46 chromosomes now have 47 (Burns & Gunn, 1993). Consequently, in individuals with DS a third copy of the 21^{st} chromosome is present in every cell of their body. It is this extra chromosome that causes the pattern of characteristic physical features and slower mental development (Selikowitz, 1997). The specific manner in which the chromosome disorder influences cerebral development to produce intellectual and information-processing deficits, however, is not well understood (c.f., Elliott et al. 1987).

The unique aetiology presented in individuals with Down syndrome affects many areas of development (Hartley, 1986). In addition to showing general problems in cognition, persons with DS have been shown to display difficulty in various aspects of motor performance (Weeks, Chua & Elliott, 2000). Over the past fifteen years, numerous studies have been conducted in order to investigate the relationship between the function and organization of the cerebral hemispheres and the motor behaviour of individuals with Down syndrome. An underlying assumption at the base of these studies is that atypical organization of brain function is in some way related to the information-processing difficulties experienced by this population (Elliott, Pollock, Chua & Weeks, 1995).

The momentum for research examining brain organization in individuals with Down syndrome originated from tests of dichotic listening. The dichotic listening test is considered noninvasive and is used to measure language lateralization. In the standard version, sequences of spoken digits are presented to participants through stereo headphones. Three digits are presented to one ear at the same time that three different digits are presented to the other ear. The participants are then asked to repeat as many of the six digits as they can (Pinel, 2000). Researchers (e.g., Hartley, 1981; Pipe, 1983) have demonstrated that individuals with DS display a left ear/right hemisphere advantage for speech sounds. This is unlike non-handicapped persons and individuals with an undifferentiated mental handicap who typically display a right ear/left hemisphere advantage for the perception of verbal stimuli.

Further investigations of manual asymmetries in rapid finger-tapping (Elliott, Weeks & Jones, 1986) and finger sequencing (Edwards & Elliott, 1989) have indicated that the production of movement in persons with DS is generally lateralized to the left hemisphere, similar to most non-handicapped persons. Additionally, dual-task paradigms involving uni-manual motor performance and concurrent speech have produced evidence consistent with the findings that persons with DS are left hemisphere dominant for the production of speech (Elliott, Edwards, Weeks, Lindley & Carnahan, 1987). Thus, it has been suggested that there is a dissociation between the systems responsible for the perception of speech and those systems responsible for the organization and control of complex movement (Elliott et al., 1987).

Based on the findings of dichotic listening tests and manual asymmetries in motor control, in 1987, Elliott et al. put forth a neurobehavioural model of brain organization in persons with Down syndrome to help explain some of the specific information-processing difficulties experienced by this population (see Appendix A). The model presents a schematic that shows speech perception to be housed in the right cerebral hemisphere and movement executive systems to be housed in the left hemisphere. Because of the separation of speech perception and movement production systems, when an individual with DS is required to produce a movement on the basis of verbal instruction there is an unclear transfer of information between the hemispheres. It is believed that this failing of communication leads to a breakdown in the quality of movement production (Elliott & Weeks, 1993).

Since its inception, many studies have built upon and supported the model of cerebral specialization in persons with Down syndrome (Edwards & Elliott, 1989; Le Clair & Elliott, 1995; Welsh & Elliott, 2001). However, while this model attempts to explain some of the information-processing difficulties experienced by this population during motor performance, few researchers have focused their attention on investigations of motor learning. The distinction between these two areas has been clearly outlined in the motor behaviour literature. Motor performance can be described as the observable attempt of an individual to produce a voluntary action. It does not deal with the long-term retention of a skill (Schmidt & Wrisberg, 2000). Motor learning, on the other hand, can be defined as a set of processes associated with practice or experience leading to relatively permanent changes in the capability for responding (Schmidt, 1988). Measures of learning describe the stability of behavioural changes over time. As a result, assessing changes in behaviour could provide insight into the effectiveness of instructional protocols that are utilized for skill acquisition (Maraj, Li, Hillman, Johnson & Robertson, 2002).

In an initial study, Elliott, Gray and Weeks (1991) investigated whether the verbal-motor performance difficulties exhibited by persons with DS would limit their ability to learn a novel motor task. Three groups of participants: individuals with DS, undifferentiated mentally handicapped adults and non-handicapped adults, practiced a verbally cued three-element movement sequence. During acquisition, participants were given verbal instructions about the movement to be completed and were verbally informed about the outcome of each trial. Participants completed 45 trials, and after a 5-minute rest, they completed an additional 36 trials, without any verbal instruction or feedback. The dependent measures included reaction time, movement time and number of movement sequencing errors. Results of retention indicated that Down syndrome participants took longer to organize and initiate their movements, however, they made no more errors and performed the motor sequence just as rapidly as did the other mentally handicapped participants. These results provided partial support for the notion that individuals with DS have difficulty organizing limb movements on the basis of verbal instruction, and that these difficulties may influence their ability to learn a novel motor task.

While the Elliott et al. (1991) study of verbal-motor learning in persons with Down syndrome was a sound beginning, further investigation into other areas of motor learning in this population is warranted. The study of motor learning has traditionally investigated questions that have implications for underlying processes involved in skill acquisition or for application to skill instruction situations. One area that has been extensively investigated in the general population and that has implications for both these directions, is the contextual interference effect (Magill & Hall, 1990).

The Contextual Interference Effect

The contextual interference effect, originally formulated by Battig (1966), has generated much interest in motor learning research. Battig (1966) first identified this practice peculiarity as an anomaly, or performance paradox, in verbal learning studies. Battig believed that under certain circumstances, interference could actually result in positive transfer. He argued that when certain materials must be learned adequately and yet the materials themselves are particularly difficult or are presented under conditions of high interference, the result will be “delayed retention that is at least as good and often better than for easier materials learned under non-interfering conditions” (Battig, 1979, p. 24).

This view was developed from Battig’s initial investigations of interference effects based on the acquisition, retention and transfer of paired-associates. Findings revealed that high levels of within-task interference typically led to poor performance during acquisition trials, but when transfer or retention trials were included in the experiment, positive transfer or better retention was produced by the high within-task interference acquisition situation (Battig, 1972). Battig incorporated these findings into a general conceptualization of memory, and expanded his interpretation of intra-task interference to represent more general “contextual interference.”

Battig (1972, 1979) defined the term “contextual interference effect” as the effect on learning of the degree of functional interference found in a practice situation when several tasks must be learned and are practiced together. The term contextual interference was preferred to the term inter-task interference, which Battig originally used, because the former more appropriately indicated the important role of context within and extraneous to the task being learned and to the processing activities of the learner. Thus, the entire practice context, including task, practice schedule and the processing engaged in by the learner were seen as potential sources of the contextual interference that could enhance learning.

Specifically then, contextual interference refers to the finding that practicing several related tasks in a randomized order (high contextual interference) results in degraded performance during acquisition but enhances learning in retention and transfer tests, relative to a blocked practice schedule. Conversely, when tasks are practiced in a blocked or repeating schedule (low contextual interference), acquisition is enhanced, while retention and transfer performances are impaired, relative to a random practice schedule (Brady, 1998).

Contextual Interference and Motor Skills

In 1979, Shea and Morgan conducted a pioneering study that first demonstrated the contextual interference effect in the acquisition of motor skills. In their experiment, 72 participants were required to knock over a sequence of barriers as rapidly as possible with a tennis ball in the dominant hand. Participants were randomly assigned to a blocked (low CI) or random (high CI) condition and performed 3 sets of 18 trials, one set for each of the three different spatial barrier configurations. Participants in the blocked group always completed all trials on one task before the next task was introduced. Participants in the random group completed trials on the 3 tasks in an unsystematic sequence such that no more than 2 trials on the same task would occur consecutively and that 6 trials of each of the 3 tasks were included in each block. Half of the participants in each group received 18 retention trials after a 10-minute delay, and the other half received 18 retention trials after a 10-day delay. The same 3 tasks that were practiced during acquisition were performed on the retention trials. For each group, nine retention trials were administered in a random sequence and nine trials were administered in a blocked sequence. Immediately following the retention test, all participants received one set of 3 trials on each of 2 transfer tasks. Dependent measures included total time, reaction time and movement time.

Results from this study revealed the contextual interference effect, as first described by Battig (1972). That is, the participants who experienced a low contextual interference schedule displayed superior acquisition performance, as compared to the participants who experienced a high contextual interference schedule. During tests of retention and transfer, performance following the random acquisition condition was superior to performance following the blocked acquisition condition.

Following Shea and Morgan's investigation in 1979, substantial empirical support for motor tasks using the contextual interference effect has accrued. One of the prominent issues to emerge regarding research into the contextual interference effect is the generalizability of this result to a variety of motor skill learning conditions. Factors such as task (Goodwin & Meeuwsen, 1996), age (Jarus & Goverouver, 1999), gender (Smith & Rudisill, 1993), experience (Del Rey, 1989), cognitive style (Jelsma & Pieters 1989), attention (Li & Wright, 2000), task difficulty (Albaret & Thon, 1998) and knowledge of results (Del Rey & Shewokis, 1993) have all been studied in efforts to demarcate the confines of contextual interference.

One task often used in the laboratory investigations of the contextual interference effect has been the multi-segment movement task, similar to the barrier knock down task used by Shea and Morgan (1979). This task is designed to require arm movements through a specified multi-segment movement pattern. Results from these studies have consistently shown the benefit of random over blocked practice schedules for both retention (Lee & Magill, 1983; Shea & Zimny, 1988) and transfer (Shea & Morgan, 1979). The anticipation-timing task is another laboratory task that has been used in investigations of the contextual interference effect. This task utilizes a Bassin Anticipation Timer that consists of any number of 16 lamp runways attached end to end. Participants are to depress a response button coincident with the arrival of the moving lights at the last lamp at the end of the runway. Variations in this task are created by altering the stimulus speeds to which participants must respond. Generally, findings from these studies also provide evidence that retention performance (Del Rey, 1982) and transfer performance (Del Rey, 1989) are enhanced by a random practice schedule compared to a blocked schedule. Additional laboratory tasks that have provided support for the contextual interference effect include: linear positioning (Lee & Weeks, 1987), computerized maze (Jelsma & Pieters, 1989), and computer keyboard (Wright, Li & Whitcare, 1992).

There is not only a relationship between the contextual interference effect and task related characteristics, but also there appears to be a relationship to certain subject related characteristics. To investigate the association between the CI effect and age, Jarus and Goverouver (1999) had 5, 7 and 11 year old participants learn a beanbag throwing task. Each participant was to throw beanbags at three target-circles drawn on the floor in either a random, blocked or combined practice schedule. Participants on a blocked practice schedule performed 10 consecutive trials on one target before moving to practice on the next target. Participants on a random practice schedule performed 30 trials in a random order so that there were 10 trials for each target. Participants on a combined practice schedule performed four consecutive trials on one target before moving to the other target and then 18 trials presented in a random order. After a 30-minute break, participants performed 12 retention trials, and 6 transfer trials to 2 new targets. The dependent measure was obtained by measuring the distance from the center of the target to the closest corner of the beanbag. The findings indicated that blocked and combined practice schedules produced better performance in acquisition and retention than random practice, but only for the 7 year olds. Practice schedule had no influence on the performance of the 5 or 11 year olds.

In other studies involving children, Del Rey, Whitehurst, and Wood (1983) investigated the effects of experience and contextual interference on learning in 8 year old children. They reported that blocked practice actually led to better transfer than random practice. Pigott and Shapiro (1984) found no blocked versus random schedule differences in 6 to 8 year old children who performed a bean bag throwing task. However they did find that a mixed random-blocked schedule, in which the participants practiced at one weight for three trials and then were randomly assigned to a different weight for the next three trials, was more beneficial than either a blocked or random schedule. Thus, there is some evidence suggesting that the contextual interference effect might be age related, however, the results seem equivocal.

Another individual characteristic that appears to interact with the contextual interference effect is cognitive style. In 1989, Jelsma and van Merrienboer examined the relationship between reflection-impulsivity aspects of individual learning styles and the CI effect. According to the authors, reflection-impulsivity predicts the quality of problem solving when the correct solution of the presented problem is not immediately obvious. In general, when several possible alternatives are available and there is some uncertainty over which one is the most appropriate, reflective persons gather information systematically, reflect on response alternatives and show an efficient deployment of attention. Impulsive persons, on the other hand, respond quickly and do not take the time to select the correct solution carefully (Jelsma & van Merrienboer, 1989). Participants were determined as demonstrating either a reflective or impulsive cognitive style by their scores on a computerized version of the Matching Familiar Figures Test (Van Merrienboer & Jelsma, 1988). On this test, standard pictures were presented with eight alternatives; participants were to choose the one alternative that was identical to the standard. For each participant, the 'reflectivity index' was computed as the standardized total time score minus the standardized total error score. By employing a computerized tracing task, Jelsma and van Merrienboer (1989) found that results of both the retention and transfer tests showed significant practice schedule by cognitive style interaction. Participants with reflective cognitive style showed a typical contextual interference effect while impulsive participants did not. These results, then, indicated that the degree of reflectivity exhibited by participants interacts in a positive way with effects of contextual interference and may be a crucial variable to consider in training program applications.

Several studies have also shown that an individual's level of experience in a particular task is associated with the CI effect. Since high contextual interference practice conditions are more difficult than low contextual interference conditions due to the increase in inter-trial variability, it seems reasonable that high CI conditions early in practice may pose a learning problem for beginners. Magill and Hall (1990) suggested that only after some degree of expertise or prior experience with related skills has been achieved would a high contextual interference practice situation be beneficial. Del Rey (1989) clearly demonstrated the relationship of prior practice and the CI effect. In this experiment, one group of female participants, from university tennis classes, was given specific training about prediction of a moving object in the context of tennis skills. This type of instruction was given because it is consistent with the cognitive processing demanded by the laboratory task. A second group of female participants, from university jogging classes, was not given any instruction about predicting moving objects. Both groups then performed 64 practice trials on an anticipation timing apparatus. Four stimulus speeds were practiced in either a blocked or random schedule. Results showed that for retention and transfer to a novel speed, the performance of the participants from the tennis classes, who were trained about prediction, was superior to the untrained females from the jogging class. Therefore, Del Rey (1989) proposed that experience, specific to the skill being practiced, is necessary before a high contextual interference practice situation would be advantageous.

Studies looking into the CI effect have also investigated its relationship to task difficulty. Assuming that random practice engages the subject in elaborate processing of movement related information, whereas blocked practice results in more superficial processing, Albaret and Thon (1998) hypothesized that the complexity of the task to be learned could modulate the effects of CI. They suggested that if the task is sufficiently complex, it could force the participants to rely on such elaborate processing that the beneficial effects of the contextual interference created by random practice could be obscured. In their study, 144 undergraduate students performed a drawing task of various complexity in either a blocked or random practice schedule. The results indicated a clear beneficial effect of random over blocked practice on delayed retention and transfer. However, this CI effect was only observed in participants who learned the simplest movements, and was not observed in participants who practiced the more complex task. Therefore, Albaret and Thon (1998) concluded that the level of cognitive effort in which the participants are engaged during training is a significant factor influencing long-term retention and transfer of motor skills. Specifically, if tasks are too difficult, the favourable effects of contextual interference will not be found.

Application of the Contextual Interference Effect

It has been suggested that theoretical models of motor learning should be validated in practical settings by translating them into instructional procedures that apply to the practitioner (Stallings, 1982). In accordance with this approach, several studies have been conducted to test the theory of the contextual interference effect outside of the laboratory surrounding. In 1994, Hall, Domingues and Cavozos randomly assigned 30 skilled college baseball players to one of three practice groups: control, blocked or random. Sessions consisted of 45 pitches: 15 fastballs, 15 curveballs, and 15 change-up pitches. On a transfer test, the random group improved 57%, the blocked group 25% and the control group 6%. Although there was no significant difference between the random and blocked groups in the acquisition phase, Hall et al. (1994) concluded that the contextual interference effect was very robust in applied settings, especially when dealing with highly skilled athletes.

In 1986, Goode and Magill investigated how CI affected the learning of badminton skills. Thirty female physical education students were randomly assigned to a blocked, random or serial practice schedule. In a serial practice schedule, also called a random-blocked practice schedule, the learner practices the skill variations in a predictable 1-2-3 arrangement of trials. Participants practiced long, short and drive serves for a total of 108 attempts. Acquisition results indicated no significant differences among groups. In retention and transfer tests, only performance on the short serve was superior for the random group.

The CI effect has also been investigated in the learning of volleyball skills. French, Rink and Werner (1990) had 145 ninth-graders learn three volleyball skills. Participants were randomly assigned to a blocked, random or blocked-random practice condition. During acquisition, participants performed 30 trials for nine days. Results indicated no differences among the groups for acquisition or retention.

Magill and Hall (1990) offered a plausible explanation for some of the weak findings of the contextual interference effect in applied settings. They suggested that most researchers compared extremes of the contextual interference continuum. It was proposed that the difficulty of high contextual interference practice may overwhelm novices in the early stages of skill acquisition and that learners need to be somewhat proficient before the beneficial effects of high contextual interference ensue. This idea of low skill level and task difficulty as precluding significant CI effects is found repeatedly throughout studies in applied settings. Additionally, Wrisberg and Liu (1991) suggested that the small number of practice trials often used outside the laboratory might also prevent effects of contextual interference.

In 1977, Shewokis and Snow conducted a study that summarized field-based research and gave substantial support to the generalizability of the contextual interference effect. Effect sizes (Cohen's *d*) were calculated from 10 studies in non-laboratory settings. For results of retention, effect sizes ranged from 0.27 to 0.71. In transfer, effect sizes ranged from a moderate 0.45 to a large effect of 1.1. According to Cohen's (1988) interpretation of effect sizes, these represent meaningful differences and the contextual interference effect can therefore, be generalized to applied settings. Schmidt's (1988) early support of the CI effect seems to summarize suitably the results of motor learning research thus far:

> "Whatever the theoretical explanation for those curious effects, it is clear that they are present in both laboratory and practical settings, lead to relatively large differences in learning, and seem to represent stable and dependent principles of motor learning." (p. 399)

<u>Theoretical Explanations of the Contextual Interference Effect</u>

Although the existence of the CI effect is widely accepted, there is little consensus as to *why* this effect occurs. That is, controversy has developed in attempts to identify the cognitive processing operations involved in the CI effect and explain how these operations produce the retention and transfer effects that are observed. There are three popular theoretical positions that have been put forward to account for this phenomenon. These views include: the elaboration hypothesis (Shea & Zimny, 1983), the action-plan reconstruction hypothesis (Lee & Magill, 1983, 1985) and the retroactive inhibition explanation (Shea & Graf, 1994). Each of these hypotheses' has been the subject of some empirical work.

Central to the elaboration hypothesis (Shea & Zimny, 1983) are two qualitatively different categories of information processing activities that the performer can engage during practice. Intra-task processing consists of individual task analyses that exclude any reference to information directly related to either the other task being acquired or other existing knowledge. In contrast, inter-task processing serves to highlight the similarities and differences between the tasks being acquired by between-task analyses. According to Shea and Zimny (1983), this latter processing mode is viewed as the one that richly embellishes the existing task representation and increases the extensiveness of the retrieval routes available to the performer to access task-specific information. They contend that in a low CI practice condition, such as blocked practice, individuals are limited to using only intra-task processing, as this form of practice requires the learner to focus on just one task at a time during practice. In contrast, random practice involves a continual interchange of information that resides within working memory in order to execute an appropriate response. As a result, the learner engages in both inter-task and intra-task processing since multiple tasks reside in working memory. This latter process facilitates identifying similarities and differences among the tasks being learned and consequently results in an embellished memorial representation of the tasks relative to a blocked schedule. Therefore, according to the elaboration view of contextual interference, random practice leads to a more enriched representation, whereas weaker encoding results under blocked conditions (Shea & Zimny, 1983).

Initial evidence for the elaboration hypothesis relied heavily on verbal report data (Zimny, 1981). These reports indicated that the participants in random practice engaged in a number of different strategies to aid learning during practice and that they made more comparisons between tasks than did participants in blocked practice. In contrast, blocked practice participants reports indicated almost automated responding with little evidence of strategic processing and virtually no evidence of making comparisons among the various tasks that were practiced. As a result, Shea and Zimny (1983, 1988) argued that evidence was provided showing support for increased multiple and variable processing during random practice and that this processing led to more distinctive and elaborative memorial representations.

Lee and Magill (1983, 1985) argued that the elaboration hypothesis was an inadequate explanation for the contextual interference effect. They claimed that it could not satisfactorily account for the random group's acquisition performance deficits and that the hypothesis suffered from circularity. Therefore, Lee and Magill (1983) proposed an alternative theoretical position, termed the "forgetting" or action-plan reconstruction hypothesis. This hypothesis originates from extensive work done in the verbal domain, namely the spacing of repetitions effect (Cuddy & Jacoby, 1982). Melton (1967) described spacing of repetitions as paradoxical in that it seems to suggest that forgetting helps memory. As the spacing of repetition increases, a subject is less likely to recognize an item as being a repetition; however, when a later test of retention is given, performance is higher when repetitions of an item are spaced rather than being massed during study. In line with this view, Lee and Magill (1983) suggested that during random practice, an action-plan for a particular task is forgotten – purged by intervening trials. The learner is forced to engage in more effortful reconstructive processing to regenerate the action-plan for subsequent performances. However, under a blocked schedule, the learner has little opportunity for forgetting because the action-plan resides in working memory and can be re-enacted on successive attempts with little reconstructive activity. The basic premise of this hypothesis is that the action-plan is remembered under blocked practice and reconstructed under a random schedule.

Lee, Wishart, Cunningham and Carnahan (1997) and Immink and Wright (1998) have provided data using a traditional learning paradigm to support the action-plan reconstruction hypothesis. Lee et al. (1997) conducted an investigation with three groups of participants: random alone, blocked alone, and random provided with modeled information prior to each trial. The authors argued that supplying a template of the next task would preclude the forgetting and action-plan reconstruction processes. Results supported the prediction that the random group with modeled information would perform similarly to the blocked group in acquisition and retention, and thus provided evidence for the action-plan reconstruction hypothesis for the contextual interference effect.

As empirical evidence has transpired to support both the elaboration hypothesis and forgetting hypothesis, several researchers have stressed that the rival theories may not be mutually exclusive because considerable commonality exits between them (Young, Cohen & Husak, 1993). Cuddy and Jacoby (1982) noted that the spacing effect produced greater dissimilarity among encoded versions of a repeated item. The greater variability in encoding produced a more elaborate and distinctive memory trace and increased the number of retrieval routes to memory. This is very similar to the levels of processing framework that were used to account for the elaboration hypothesis. Additionally, Brady (1998) suggested that the common denominator among the different hypotheses may be the enhanced cognitive activity or the more effortful processing provoked by random practice schedules and the deficient or decreased processing resulting from a blocked schedule.

In 1994, Shea and Graf proposed retroactive inhibition as a third major alternative to the elaboration and action-plan reconstruction explanations for the contextual interference effect. Retroactive inhibition refers to inferior retention of a task due to interpolation of another activity between the original activity and a retention task. The retroactive inhibition view focuses on the disadvantages of blocked schedules rather than the advantages of random ones. Shewokis, Del Rey and Simpson (1998) suggested that when blocked performers practice multiple tasks during acquisition, they experience a retention loss from retroactive inhibition during later testing. That is, if participants practice a block of task A, then a block of task B, and finally a block of task C, and then are later tested on these three tasks, retroactive interference may influence performance of tasks A and B while proactive interference may influence performance of tasks B and C. As a result, Shewokis et al. (1998) proposed that the focus of the CI effect might be due to task effects rather than the interference caused by practicing related tasks under a random schedule.

Several studies (Davis, 1988; Del Rey, Lui, & Simpson 1994; Poto, 1988; Shea & Titzer, 1993) have found evidence to support the retroactive inhibition explanation. Shea and Titzer (1993) examined the influence of reminder trials on contextual interference. Three motor tasks were performed under a random or blocked schedule, with one or no reminder trial for each task at the end of practice. Typical contextual effects were reported to the extent that retention performance was superior for the random group relative to the blocked one. Additionally, the authors reported that there were no significant differences in retention performance between the random group and the blocked group that received a reminder trial for each task. Therefore, Shea and Titzer suggested that this finding supported a retroactive inhibition hypothesis for contextual interference.

Contextual Interference and Persons with an Intellectual Disability

Despite disparities in the explanations as to why this effect occurs, in reviewing the literature, it seems clear that there is agreement among researchers that the contextual interference effect does indeed exist and that this effect is generalizable across many domains of motor skill acquisition. However, one domain in which the contextual interference effect has not been thoroughly investigated is in persons with an intellectual disability. Given the unique personality and learning characteristics of PWID, there are limitations in generalizing the results from the non-disabled population to these individuals. As such, a small number of studies have been conducted investigating the effects of contextual interference in this population.

In 1988, Poretta attempted to determine the effects of contextual interference on the retention and transfer of a beanbag tossing task by mildly mentally handicapped (MMH) children. Fourty-eight MMH participants (mean age 10.2 years) practiced under blocked, serial, or random practice conditions. Following 48 acquisition trials with beanbags of various weights, participants were immediately transferred to two novel weighted beanbags for four trials. Two days later the participants tossed the same weighted beanbag for another four trials. Absolute error was used as the dependent measure of overall performance. Both retention and transfer analyses showed that participants in the random condition did not exhibit significantly less errors than participants in either the blocked or serial practice conditions.

Del Rey and Stewart (1989) investigated CI effects with 21 MMH participants, aged 6 to 17 years, on a coincident timing task. Participants performed 45 acquisition trials at various speeds in either a blocked, random or sequenced practice schedule. After a one-minute retention interval, all participants completed 9 retention trials, immediately followed by 4 transfer trials. Dependent variables included absolute, variable and constant error. The retention results indicated that the sequenced and random groups performed with significantly less absolute error than the blocked group. However, while the MMH participants were able to retain the task following a one-minute rest interval, they were unable to apply their knowledge gained in practice to a new speed in the transfer task.

In 1989, Heitman and Gilley assigned MMH participants with a mean age of 17.5 years to either a random or blocked practice schedule on a pursuit rotor apparatus. Twenty participants performed 20 trials of 20 seconds in duration on 2 consecutive days. Analysis of time on target scores showed no significant differences between the two practice groups. Again, the authors were not able to demonstrate the CI effect in their investigation.

Edwards et al. (1986) assigned participants with Down syndrome (mean age 18.1 years) and non-handicapped participants (mean age 5.8 years) to either a blocked or random practice schedule. All participants responded to various speeds on a coincident anticipation-timing task for 64 trials. Following a ten-minute rest interval, participants were transferred to three different speeds, one within the previous speed range (8 trials) and two outside the previous (8 trials). Absolute constant error and variable error served as the measures of timing performance. Findings indicated that participants with DS did not exhibit a significantly greater degree of transfer when they practiced under random as opposed to blocked conditions.

Only two studies investigating the CI effect in persons with intellectual disabilities have provided statistically significant results similar to the conventional findings of the CI effect in non-mentally handicapped individuals. Porretta and O'Brien (1991) suggested that the marginal results previously found might be due to an insufficient number of trials and/or practice sessions. They hypothesized that since individuals with mental impairments take longer to learn motor skills, additional practice sessions employing high contextual interference conditions would result in better transfer and retention. As such, Porretta and O'Brien employed 48 MMH participants (mean age 11.9 years) to practice an anticipation timing task under a random, blocked or serial schedule of 48 trials for 2 consecutive days. The participants were transferred to a novel speed for 4 consecutive trials immediately following practice, and repeated this transfer task 2 days later. Retention and transfer results indicated that participants in the random practice condition performed with significantly less absolute constant error than participants in the blocked group. The performance of participants in the serial group did not differ significantly from performances of either the random or blocked group.

In 1994, Painter, Inman and Vincent conducted a study to investigate the CI effect in 24 MMH individuals and 24 chronologically age matched participants with no disabilities. The participants were assigned to either a blocked or random practice schedule and performed 45 acquisition trials using 3 context variations that resulted from tasks with different motor programs. Following a 10-minute filled retention interval, all participants completed 6 trials in a random order. Interestingly, results of acquisition performance showed that the participants in the random practice condition performed better than those in the blocked condition. Additionally, findings of retention showed that the MMH random practice group performed with significantly better accuracy than the MMH blocked group. Therefore, Painter, et al. (1994) suggested that random practice conditions in adapted physical education classes might facilitate the performance of MMH students in open game situations calling for random responses.

Predicting the Effects of Contextual Interference in PWID

As the findings of the aforementioned studies have produced equivocal results, further investigation is warranted so that the role of the contextual interference effect in PWID can be more fully understood. Two theoretical positions that describe learning and performance of PWID could assist in predicting the effects of contextual interference in this population.

First, the contextual interference effect involves the retention of a motor skill. The retention, or learning of a skill involves producing a skill acquired through practice at a later point in time. That is, a skill has been learned if and only if it can be retained relatively permanently. Thus, memory, which can be defined as the persistence of the acquired capability for responding, is directly related to learning (Schmidt, 1988). From this viewpoint, learning and memory are, as described by Adams (1976), different sides of the same behavioural coin.

According to Brown (1974), a memory task can be described as a problem-solving situation in which attempts at mediation are equivalent to problem-solving strategies. Traditionally, individuals in the general population employ strategic behaviours in their approach to memory tasks, as well as in problem solving situations in general (Spitz & Nadler, 1974). Persons with an intellectual disability, however, do not spontaneously employ the appropriate mediator for a specific task. The concept of active versus passive strategies extends this by suggesting that PWID not only fail to produce the appropriate strategy, but also generally fail to produce any strategy at all. Their behaviour is characterized by a passive acceptance of the task (Brown, 1974).

According to Shea and Zimny (1983), random practice causes the learner to engage in both intra-task and inter-task processing strategies. These strategies cause a continual exchange of information existing within working memory, which results in an embellished memorial representation of the task, and thus superior performance in tests of retention and transfer. Persons with an intellectual disability, who do not spontaneously employ memory strategies during skill acquisition, may have difficulties constructing an enriched representation of the task during random practice. Therefore, PWID may not benefit from a random practice schedule. However, under a blocked schedule, where the learner only focuses on one task at a time and is not required to spontaneously use strategies to analyse different tasks, PWID may be better able to efficiently learn a motor skill.

Evidence supporting the elaboration hypothesis for the contextual interference effect suggests that participants in random practice make more comparisons between tasks than do participants in blocked practice (Zimny, 1981). As such, it is suggested that PWID may be able to benefit from a random practice schedule if they are supplemented with strategies to encourage inter-task processing. Although PWID may have structural or capacity deficiencies and generally fail to produce a strategy when left to their own devices, the positive role of strategic processes on acquisition and retention of skills in this population has been supported (Del Rey & Stewart, 1989).

Evidence indicates that instructional interventions designed to induce higher levels of cognitive processing have helped PWID overcome strategy deficits. Training studies have shown that the deficiency of PWID in strategic intervention is one of production (can the participant use the strategy efficiently when induced to use it?) and not of mediation (can the participant use the strategy effectively when instructed in its use?). Thus, generally speaking, PWID can use relatively simple strategies to improve their performance and learning of motor skills (Campione, Brown, & Ferrara, 1982). Therefore, by providing PWID with the opportunity to plan, compare and evaluate different tasks, these individuals may be able to engage in more strategic and variable inter-task processing. This enriched processing may lead to a more distinctive memorial representation of the task, and inevitably more efficient learning of the skill under a random practice schedule.

The second reason that it is difficult to generalize results of the contextual interference effect from the general population to PWID deals with motivational factors and learned helplessness. In a series of studies, Borkowski et al. (1987) provided evidence that children with learning impairments often develop motivational and personal problems as a consequence of their learning difficulties. These problems may include low self-esteem, inaccurate perception of their talents, and a tendency to attribute failure to diminished abilities. Borkowski and colleagues developed a model of meta-cognition in which meta-cognitive process and attributional beliefs are intimately related. In general, the topic of meta-cognition includes knowledge concerning, understanding of, and access to cognition and cognitive resources (Campione, 1987). Attributional beliefs, according to Borkowski et al. (1987), are the tendency for an individual with self-perceptions of low ability to attribute failure to diminished abilities and success to luck. In a series of studies based on this meta-cognitive model, Borkowski et al. (1987) demonstrated that attributional beliefs are directly involved in the acquisition and transfer of leaning skills. Specifically, individuals entering into a novel situation with poor attributional beliefs, (i.e. low motivation and poor self-esteem), are less inclined to become active, strategic learners and the processes that underlie acquisition and transfer are therefore impeded.

According to Brady (1988), the common denominator among the different hypothesis for the contextual interference effect may be the enhanced cognitive activity or more effortful processing provoked by random practice schedules. Due to motivational difficulties, PWID therefore, may not benefit from random practice schedules because of their inability to become active, strategic learners.

In addition, Heitman and Gilley (1989) postulated that PWID enter into a novel situation unmotivated because they expect failure and need initial success to elicit maximum performance. The chances of early successful experiences would be greater with blocked practice because the practice condition is repetitive. Blocked practice then, may raise the motivation of PWID and elicit better performance.

The primary focus group of the present study is individuals with Down syndrome. The aforementioned theoretical positions can be directly related to this population. However, due to the specific learning characteristics of this group of individuals, further considerations must be made. Namely, the model of biological dissociation between speech perception systems in the right hemisphere and movement executive systems in the left hemisphere put forth by Elliott et al. (1987) must be taken into account. These authors suggest that this dissociation of function results in persons with DS having particular difficulty performing tasks that involve both speech perception and the control of complex movement, due to a partial loss of information resulting from inter-hemispheric transmission. Studies that have tested the validity of this model have shown that persons with DS have more difficulty performing a movement based on verbal, but not visual, instruction when compared to other mentally handicapped individuals (Elliott, Weeks, & Gray, 1990). As such, it is recommended that careful consideration be made in designing experiments involving motor tasks with individuals with DS. In particular, instructions for motor tasks given to persons with DS should have a visual component so that these individuals will be able to elicit their best performance and benefit most from practice.

In summary, this study investigated the effects of contextual interference on the performance and learning of a motor skill in persons with DS. The contextual interference effects refers to the finding that practicing several related tasks in a randomized order results in superior performance in retention and transfer tests but degrades performance during acquisition, relative to a random practice schedule. Conversely, when tasks are practiced in repeating schedule, acquisition is enhanced, while retention and transfer performances are degraded, relative to a random practice schedule. It was hypothesized that because individuals with DS are passive processors of information (Brown, 1974) and exhibit poor motivation when facing a new task (Borkowski et al., 1987), they would not exhibit the contextual interference effect. However, this study also assessed the role of cognitive processing on the CI effect in persons with DS. It was hypothesized that if persons with DS were facilitated to engage in strategic processing, they would exhibit the typical contextual interference effect. Additionally, previous research has shown that low levels of motivation may hinder the ability of individuals with learning impairments to engage in active cognitive processing (Borkowski et al., 1987). Therefore, this study assessed participants' feelings toward the task in order to gain a broad understanding of the effects of motivation on motor skill performance and learning in different practice schedules.

III. Methods and Procedures

Participants

The participants involved in this study included 16 adolescents and young adults with Down syndrome who were recruited with assistance from the Edmonton Down Syndrome Society (M age = 15.31 years; SD = 3.68 years). Refer to Appendix B for descriptive statistics of the participants.

All participants were volunteers from whom signed consent was obtained. All testing procedures were approved by the Faculty of Physical Education and Recreation Ethics Committee.

Design

Participants were assigned to either a low contextual interference (blocked) acquisition group or a high contextual interference (random) acquisition group using a stratified random assignment procedure. Participants were randomly placed in the low CI or high CI acquisition conditions, such that the mean chronological age of the two groups remained as similar as possible to ensure homogeneity of the groups.

A total of 54 acquisition trials were administered to both acquisition groups in 3 blocks of 18 trials, one set for each of the acquisition tasks. Participants in the first (i.e. blocked) group always completed all trials on one task before the next task was introduced. Participants in the second (i.e. random) group were given acquisition trials on the 3 tasks in a random fashion such that 6 trials on each of the 3 acquisition tasks were included in each block of 18 trials. The sequencing of trials for each task within each set of trials provided that no more than 2 trials of the same task occurred consecutively.

All of the participants received 36 retention trials one hour after the initial acquisition testing. A total of 12 trials were performed on each of the three acquisition tasks during the retention test. Eighteen trials (6 per task) were administered in a blocked sequence and 18 trials (6 per task) were administered in a random sequence. Knowledge of results was not provided during the retention trials. The order in which the blocked and random sequences were administered for retention trials was counterbalanced across participants in each of the retention groups. As such, half of the participants received the blocked retention trials first, and half of the participants received the random retention trials first.

In addition, one half of the participants in each acquisition condition (i.e. blocked and random) were randomly assigned to either a cognitive processing group or a no cognitive processing group. Participants in the cognitive processing groupAs such, 4 participants from the random group and 4 participants from the blocked group were given cognitive processing questions. Likewise, 4 participants from the random group and 4 participants from the blocked group were not given cognitive processing questions.

Apparatus

The TCLBR-01, (Tri Colour Light Box Rev-01) or more simply, the "Box of Lights," consists of 4 rows of 4 touch-sensitive lights. A high impedance grounding strap was used to safely, electrically connect the participant to the apparatus. This connection was required so that when the participant touched any of the LED (light emitting diodes) housings a completion of an electrical circuit (event trigger) could be measured. Refer to Appendix C for the apparatus used in the experiment.

The Box of Lights has an internal software timer that ran continuously while the computer was on. All event times were calculated. Event times included the total elapsed time between the onset of the auditory stimulus and the lift of the participant's finger from the start sensor, the lift from the start sensor and placement on the first light, lift from the first light and placement on the second light and finally, lift from the second light and placement on the third light. Start and stop times of each event were recorded and displayed in raw millisecond timing units. These two values were subtracted from each other to calculate the length of each event. The result of this software calculation was then displayed, out of view of the participant, as the "event time"

The software that controls, measures, calculates and displays all information relating to the Box of Lights is a custom written program that runs in the Lab View environment. Lab View (manufacturer: National Instruments) interfaces with a digital input/output (DIO) card that was plugged in the computer. The DIO card was also connected to the Box of Lights via a 50 pin ribbon cable. The entire apparatus was supported on a wooden table in front of the participant.

Task

Each participant performed a total of 3 tasks. In each task, the participant was required to respond as quickly as possible following an auditory tone. The participant moved their index finger from the home position after the instructions for the task were given and placed it on the appropriate start sensor. In response to the auditory stimulus, the participant touched the 3 vertically arranged lights above the start sensor in a prescribed order.

The sequence order in which the lights were to be touched was given to the participants in a simultaneous visual and verbal manner prior to each trial. The visual instructions involved each of the 3 lights above the start sensor illuminating and turning off, one at a time, in a specific order. As each of the three lights illuminated, the verbal instructions involved the examiner saying the name of the colour of each light.

As the participant touched each light during the trials, the light colour was illuminated. The first light in each row was the start sensor and did not illuminate. The second, third and fourth lights in each row illuminated in the colours red, yellow and green, respectively. After touching the 3 lights, the participant returned their finger to the home position. The three lights to be touched during a trial were all located within the same vertical column on the Box of Lights. The order in which the lights were to be touched was different for each task. All trials were completed using the preferred hand.

The 3 acquisition tasks consisted of touching the lights in one the following patterns of movement: Pattern A: third light, first light, second light; Pattern B: second light, first light, third light; Pattern C: first light, third light, second light. Each of the acquisition tasks took place on a different column of lights. As such, task one took place on the first column, task two on the second column and task three on the third column. The visual instructions for each task took place on the column corresponding to the task. The same three tasks practiced during acquisition trials were performed on retention trials.

Procedure

Prior to data collection the participant or their parent/guardian received a copy of the participant information sheet (see Appendix D and E, respectively). The participant received an information sheet if they were able to read. In the event that they were not able to read, their parent/guardian received the information sheet. Consent forms were also given to the participant or their parent/guardian (see Appendix F and G, respectively). If the participant was over 18 and able to read and write, they were given a consent form to sign. In the event that the participant was over 18 and could not read and write, or under 18 (regardless of reading and writing ability), the consent form was given to the parent/guardian to sign.

Also preceding data collection, participants performed a colour recognition test. Each participant was presented with a large rectangular card, on which were three squares in the colours red, yellow and green. The examiner instructed the participant to point to the corresponding square as she said the name of each colour aloud. The examiner called out the name of each colour five times, for a total of 15 trials. The names of the colours were called out in an unsystematic order. If the participant touched the appropriately coloured square at least four times out of five, they were considered to have a thorough understanding of the colour and no colour deficiencies in their vision.

During testing, the participant sat comfortably in front of the Box of Lights apparatus so that the box was located opposite to the midsection of the participant's body. Prior to each portion of the experiment (acquisition and retention) the participant was instructed that the objective of the task was to touch the lights in the order that they are presented and return to the home position, as quickly and accurately as possible in response to an auditory stimulus. The task was referred to as a "game" to the participants.

To signal the beginning of a trial, the experimenter said "ready," at which time the participant placed their index finger on the home position while waiting for the instructions to begin. Three seconds following the placement of the participant's finger on the home position, the visual/verbal instructions commenced. After the instructions had been given, the participant moved their finger from the home position to the start sensor of the appropriate row of lights (i.e. the row of lights that illuminated) and waited for the auditory stimulus. The auditory stimulus was under the control of the experimenter, who signaled the stimulus when the participant was on the correct start sensor and ready to begin the trial. At the onset of the stimulus, the participants performed the appropriate task as quickly as possible. After the participant touched the third light, the trial was over and they returned their finger to the home position.

During the acquisition trials, the experimenter provided knowledge of results in the form of prescriptive feedback. Knowledge of results concerning errors made during the trial was given 10 seconds after the completion of each participant's response. If the movement sequence was correct, the participant was encouraged to move a little more rapidly on the next trial. If the participant made an error (e.g., performed the movements in the wrong order) the error was noted and the experimenter explained the mistake and instructed the participant to listen carefully to the movement cues on the next trial. Ten seconds following knowledge of results, the experimenter said, "ready" to signal the beginning of a new trial. The inter-trial interval was approximately 20 seconds in duration. This procedure was followed for all trials throughout the experiment. However, knowledge of results was not provided on retention trials. In addition, a 3-minute rest interval was provided between each set of 18 acquisition and retention trials.

Additionally, during acquisition, 4 participants from the random group and 4 participants from the blocked group were asked questions designed to enable the participants to compare, plan and evaluate the tasks being performed (see Appendix H). Questions were asked once between the first and second block of trials and once between the second and third block of trials. Also, the participants who received these questions were warned prior to the beginning of the acquisition trials that they would be asked questions about the task and that they should try to pay careful attention to the Box of Lights and the game that they were playing. The answers given by the participants were recorded on paper by the experimenter immediately following their response.

Furthermore, all participants from both the blocked and random acquisition groups were asked 3 questions designed to obtain an understanding of their motivation during the tasks (see Appendix I). These questions were asked only after the completion of all blocks of acquisition trials. All participants' responses were recorded on paper by the experimenter.

Data Analysis

Mean number of errors, mean reaction time, mean movement time and standard deviation of movement time served as the dependent measures of performance. An error was counted if the participant made an incorrect movement in the task sequence, i.e. touched the wrong light sensor. An error was noted only once per task sequence, regardless of the number of incorrect lights that were touched. Reaction time was determined to be the time between the onset of the auditory stimulus and the lift of the participant's finger from the start sensor. Movement time was computed as the time between the lift of the participant's finger from the start sensor and the placement of the participant's finger on the third light sensor. Standard deviation of movement time was calculated as the deviation in the mean movement times for each participant across blocks of trials.

The acquisition data for mean reaction time and mean/standard deviation of movement time was analyzed using a 2 Practice Condition (blocked, random) x 2 Cognitive Processing Group (cognitive processing (CP), no cognitive processing) x 3 Block mixed ANOVA with repeated measures on the last factor. The retention data for mean reaction time and mean/standard deviation of movement time was analyzed using a 2 Practice Condition (blocked, random) x 2 Cognitive Processing Group (CP, No CP) x 2 Block mixed ANOVA with repeated measures on the last factor. The error data was analyzed using a 2 Practice Condition (blocked, random) x 2 Cognitive Processing Group (CP, No CP) x 5 Block ANOVA with repeated measures on the last factor. Alpha levels for all statistical analysis was set a priori at $p < 0.05$.

IV. Results

Acquisition and retention performance was evaluated based on mean reaction time (RT), mean movement time (MT), standard deviation of movement time (SD of MT) and participant errors. Examination of the descriptive statistics for each dependent variable indicated that a better performance was associated with a lower score (see Tables 1 and 2). All means for RT, MT and SD of MT are reported in milliseconds.

Responses to the questions designed to provide insight into participants' motivation towards the task were examined in order to examine any relationships between the participants' performance and their feelings towards the task. Additionally, participants' responses to the cognitive processing questions were examined in order to obtain a more thorough understanding of the effectiveness of the questions and the cognitive processing mechanisms that the questions evoked.

The results will be reported as follows: a) statistical analysis of participants' performance in acquisition based on RT, MT and SD of MT; b) statistical analysis of participants' performance in retention based on RT, MT and SD of MT; c) statistical analysis of the number of trials in which errors were made for each participant during both acquisition and retention conditions; d) qualitative description of participants' responses to motivational questions; e) qualitative description of participants' responses to cognitive processing questions.

Table 1

<u>Means and standard deviations for reaction time, movement time and standard deviation of movement time as a function of Practice Condition and Block</u>

Dependent Variable (msec)	Acquisition Blocks			Retention	
	1	2	3	Blocked	Random
RT M (SD)					
Blocked	804.5 (566.7)	630.0 (181.8)	653.5 (269.5)	663.3 (663.3)	668.0 (239.4)
Random	812.2 (1427.7)	805.0 (515.2)	676.5 (291.7)	619.0 (318.7)	702.5 (317.6)
MT M (SD)					
Blocked	3789.2 (1465.7)	3190.2 (1542.4)	3349.8 (1687.6)	3473.2 (1582.8)	3917.2 (1834.5)
Random	4810.0 (3042.1)	4308.6 (3472.9)	3999.9 (3798.1)	3967.2 (3824.3)	4231.1 (4787.4)
SD of MT M (SD)					
Blocked	1089.9 (538.6)	888.4 (598.6)	755.7 (414.4)	912.7 (403.5)	882.7 (538.5)
Random	1560.3 (1167.7)	982.2 (868.1)	1078.7 (1090.2)	1018.0 (1223.3)	1176.5 (1720.2)

Table 2

Means and standard deviations for reaction time, movement time and standard deviation of movement time as a function of Cognitive Processing Group, Practice Condition and Block

Dependent Variable (msec)	Acquisition Blocks			Retention	
	1	2	3	Blocked	Random
RT M (SD)					
CP					
Blocked	938.9 (825.1)	590.5 (196.7)	715.1 (368.9)	686.5 (173.8)	646.6 (185.6)
Random	662.8 (112.8)	703.8 (246.5)	706.0 (234.3)	708.5 (376.4)	724.1 (344.1)
No CP					
Blocked	670.1 (143.1)	669.6 (185.2)	592.0 (152.7)	640.1 (173.1)	689.5 (313.1)
Random	2307.1 (1715.0)	1187.6 (634.4)	873.0 (353.5)	755.9 (306.5)	794.5 (337.2)
MT M (SD)					
CP					
Blocked	3418.0 (1170.5)	2470.6 (726.5)	2651.3 (492.5)	2828.6 (669.4)	3317.3 (1254.6)
Random	3232.4 (947.7)	2995.4 (721.7)	2604.3 (620.4)	2755.0 (1086.2)	2802.8 (1195.1)
No CP					
Blocked	4160.5 (1809.7)	3909.9 (1908.6)	4048.4 (2258.8)	4117.9 (2071.2)	4517.2 (2306.3)
Random	6387.7 (3749.5)	5621.9 (4795.3)	5395.7 (5299.2)	5180.9 (5387.3)	5659.6 (6827.2)
SD of MT M (SD)					
CP					
Blocked	1152.9 (719.9)	661.7 (497.3)	542.7 (258.2)	704.4 (226.6)	744.7 (515.2)
Random	657.5 (144.6)	532.0 (211.8)	597.0 (323.9)	631.1 (456.9)	609.5 (447.1)
No CP					
Blocked	1027.0 (384.8)	1115.3 (672.2)	968.8 (461.6)	1121.0 (461.3)	1020.7 (600.5)
Random	2463.2 (993.7)	1432.5 (1083.8)	1560.6 (1431.7)	1405.0 (1696.3)	1743.7 (642.7)

Acquisition Data

The acquisition data was analyzed using a 2 (Practice Condition) x 2 (Cognitive Processing Group) x 3 (Block) ANOVA with repeated measures on the last factor. This analysis was performed for the dependent variables: mean reaction time, mean movement time and standard deviation of movement time. ANOVA summary tables of acquisition data are reported in Appendix J.

Reaction Time (RT). The analysis of mean RT data revealed a three-way interaction for Practice Condition, Cognitive Processing Group and Block (F (2, 24) = 3.674, $p < .05$) (see Figure 1). Post hoc analysis (Tukey's HSD $p < .05$) revealed that that at Block 1, the participants in the No Cognitive Processing (No CP) Group had significantly shorter reaction times for the blocked Practice Condition when compared to the random Practice Condition (M blocked = 670.1, M random = 2307.1). These differences were not statistically significant for Blocks 2 and 3.

Additionally, a significant main effect for Block (F (2, 24) = 3.712, $p < .04$) was found. Post hoc analysis (Tukey's HSD $p < .05$) revealed that the participants' response times in the Block 3 (M = 721.5) were significantly faster than their response times in Block 1 (M = 1144.7). However, the participants' performance in Block 2 (M = 787.8) did not significantly differ from the other Blocks.

Movement Time (MT). Examination of mean movement time data showed a main effect for Block, signifying that all participants performed the task significantly faster across blocks of trials (F (2,24) = 5.828, $p < .01$). Post hoc analysis (Tukey's HSD $p < .05$) revealed that the participants' movement time in Block 1 (M = 4299.6) was significantly slower than their performance in Block 2 (M = 3749.4) and 3 (M = 3674.9)

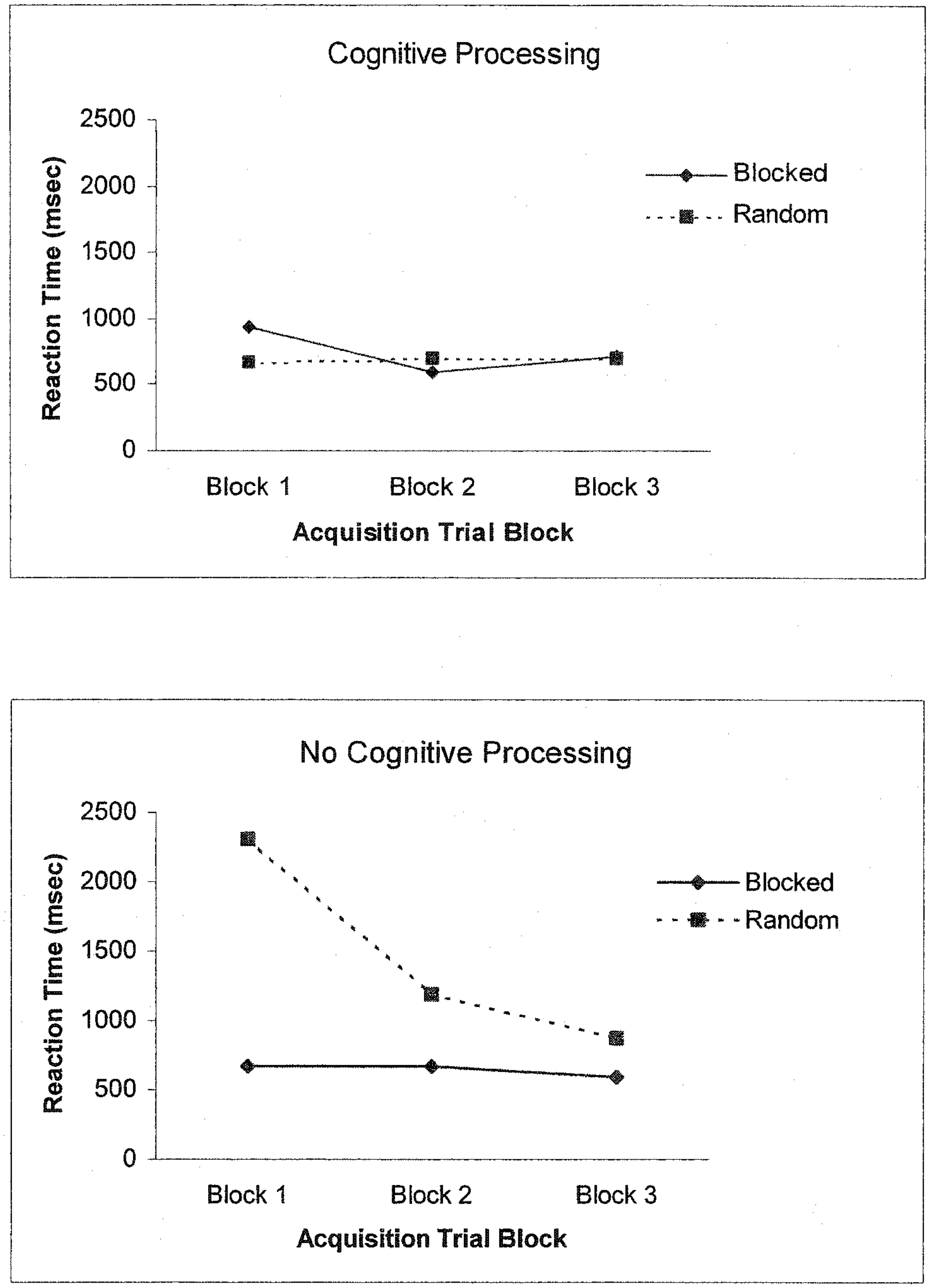


Figure 1. Three-way interaction effect for Practice Condition, Cognitive Processing Group and Block in acquisition based on reaction time.

(which were not significantly different from each other). No other effects were significant.

Standard Deviation of Movement Time (SD of MT). The analysis for SD of MT revealed a three-way interaction for Practice Condition, Cognitive Processing Group and Block (F (2, 24) = 10.8, $p < .001$) (see Figure 2). Post hoc analysis (Tukey's HSD, $p < .05$) revealed that at Block 1, the participants in the Cognitive Processing Group were significantly less variable in their movement times when they practiced in the random Practice Condition as compared to the blocked Practice Condition (M blocked = 1152.91, M random = 657.56). However, at Blocks 2 and 3, the variability between the two Practice Conditions was almost indistinguishable. Participants in the No Cognitive Processing Group, however, were significantly less variable in the blocked Practice Condition as compared to the random Practice Condition at Block 1 (M blocked = 1027.02, M random = 2463.20). Although this pattern of movement variability remained constant throughout Blocks 2 and 3, further significant differences between Practice Conditions were only observed in Block 3 (M blocked = 968.79, M random = 1560.57).

Additionally, main effects for Block (F (2, 24) = 13.25, $p < .001$) and Cognitive Processing Group (F (1, 12) = 4.732, $p < .05$) were found. Post hoc analysis (Tukey's HSD, $p < .05$) revealed for the Block main effect that participant movement variability in Block 1 (M = 1325.1) was significantly greater than for Blocks 2 (M = 935.3) and 3 (M = 917.2) (which were not significantly different from each other). For the latter main effect, participants who practiced in the CP Group (M: Block 1, 2, 3 = 905.2, 596.9, 569.9) were less variable in their movement time as compared to those individuals who practiced in the No CP Group (M: Block 1, 2, 3 = 1745.1, 1273.9, 1264.7).

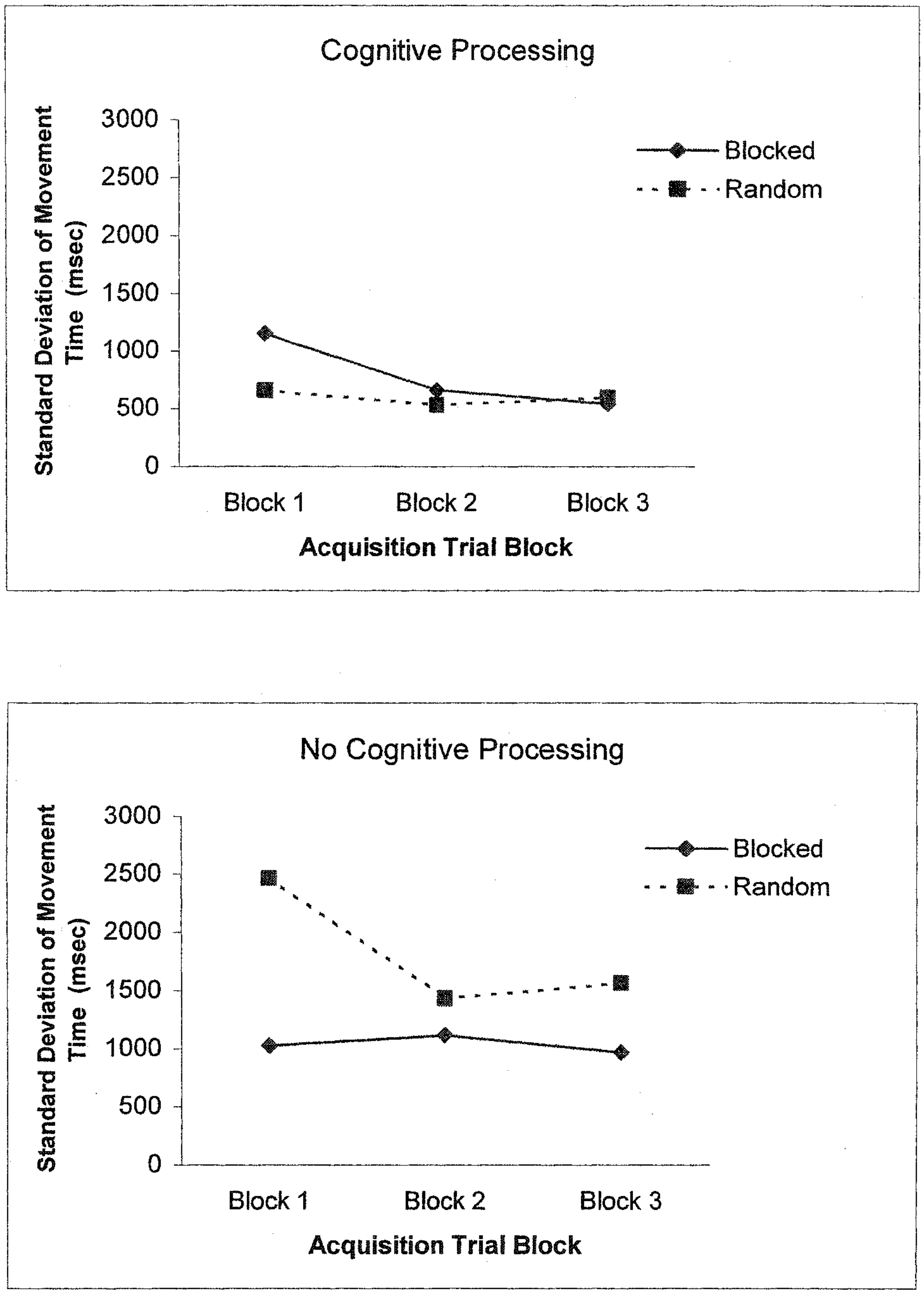


Figure 2. Three-way interaction effect for Practice Condition, Cognitive Processing Group and Block in acquisition based on standard deviation of movement time.

Retention Data

The retention data was analyzed using a 2 (Practice Condition) x 2 (Cognitive Processing Group) x 2 (Block) ANOVA with repeated measures on the last factor. For a complete listing of statistical results, see Appendix J. Because no Block differences were found, a 2 (Practice Condition) x 2 (Cognitive Processing Group) ANOVA was used to further examine potential group differences collapsed across retention blocks. For statistical results, see Appendix K. Both analyses of variance were performed for the dependent variables: mean reaction time, mean movement time and standard deviation of movement time.

Reaction Time. Analysis of mean reaction time data revealed no significant effects for Cognitive Processing Group or Practice Condition.

Movement Time. Examination of movement time data revealed no significant effects for Cognitive Processing Group or Practice Condition. However, the effect for Cognitive Processing Group approached conventional levels of significance (F (1, 28) = 3.122, $p < .08$). Participants who received cognitive processing in acquisition had faster movement times in retention than those participants who did not receive cognitive processing, regardless of Practice Condition (see Figure 3).

Standard Deviation of Movement Time. The analysis of variance revealed no significant effects for Cognitive Processing Group or Practice Condition based on standard deviation of movement time. However, effects for Cognitive Processing Group approached conventional levels of significance (F (1, 28) = 3.121, $p < .08$). The performance of participants who received CP in acquisition was less variable than those participants who did not receive CP during practice (see Figure 4).

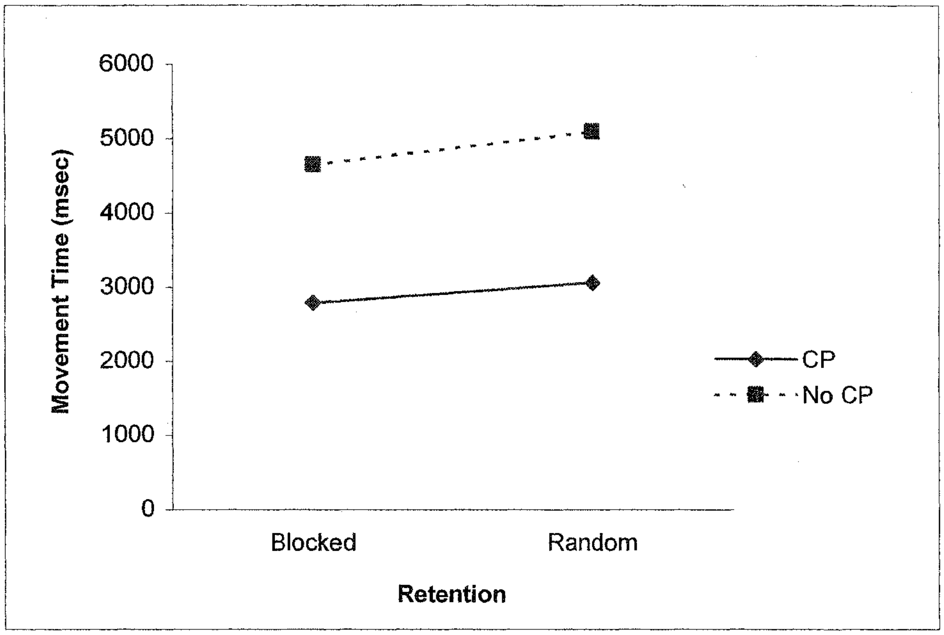


Figure 3. Performance of Cognitive Processing Groups in retention based on movement time.

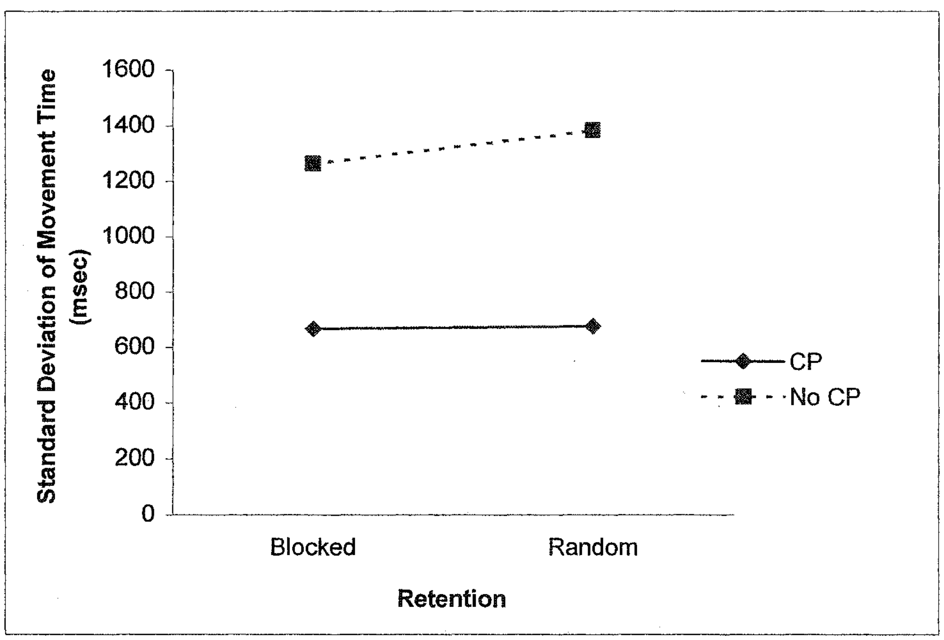


Figure 4. Performance of Cognitive Processing Groups in retention based on standard deviation of movement time.

Errors

Descriptive statistics for participant errors are presented in Tables 3 and 4. The error data was analyzed using a 2 Practice Condition (blocked, random) x 2 Cognitive Processing Group (CP, No CP) x 5 Block ANOVA with repeated measures on the last factor. For a complete listing of statistical results, see Appendix L.

Mean Errors. Examination of the mean error data revealed a significant two-way interaction for Practice Condition and Block (F (4, 48) = 10.23, $p < 0.001$) (see Figure 5).

Additionally, a significant main effect for Block (F (4, 48) = 9.17, $p < 0.001$) and Cognitive Processing Group (F (1, 12) = 11.11, $p < 0.006$) (see Figure 6) was found. For the Cognitive Processing Group main effect, participants who practiced in the CP Group made fewer errors (mean = 3.3) as compared to those individuals who practiced in the No CP Group (mean = 7.3).

Table 3

Participant errors as a function of Practice Condition and Block

Errors	Acquisition Blocks			Retention	
	1	2	3	Blocked	Random
M					
Blocked	5.63	3.50	3.38	5.50	9.13
Random	8.50	5.25	4.88	2.50	4.63
SD					
Blocked	5.73	3.85	2.72	4.17	4.16
Random	3.21	2.92	3.48	2.14	2.13
Median					
Blocked	4.00	2.00	3.00	5.00	9.00
Random	9.00	5.50	5.50	2.00	4.00

Table 4

Participant errors as a function of Cognitive Processing Group, Practice Condition and Block

Errors	Acquisition Blocks 1	2	3	Retention Blocked	Random
M					
CP					
Blocked	4.00	1.75	1.25	2.50	5.50
Random	6.25	3.00	3.75	1.25	3.75
No CP					
Blocked	7.25	5.25	5.5	8.50	12.75
Random	10.75	7.50	6.0	3.75	5.5
SD					
CP					
Blocked	2.45	1.26	1.26	1.73	1.00
Random	2.75	2.16	3.86	1.50	1.26
No CP					
Blocked	7.97	4.99	1.91	3.70	2.06
Random	1.71	1.29	3.16	2.06	2.65
Median					
CP					
Blocked	4.00	2.00	1.00	2.00	5.00
Random	6.50	3.50	3.50	1.00	4.00
No CP					
Blocked	6.50	4.00	6.00	8.00	12.50
Random	10.50	7.50	6.50	3.50	5.00

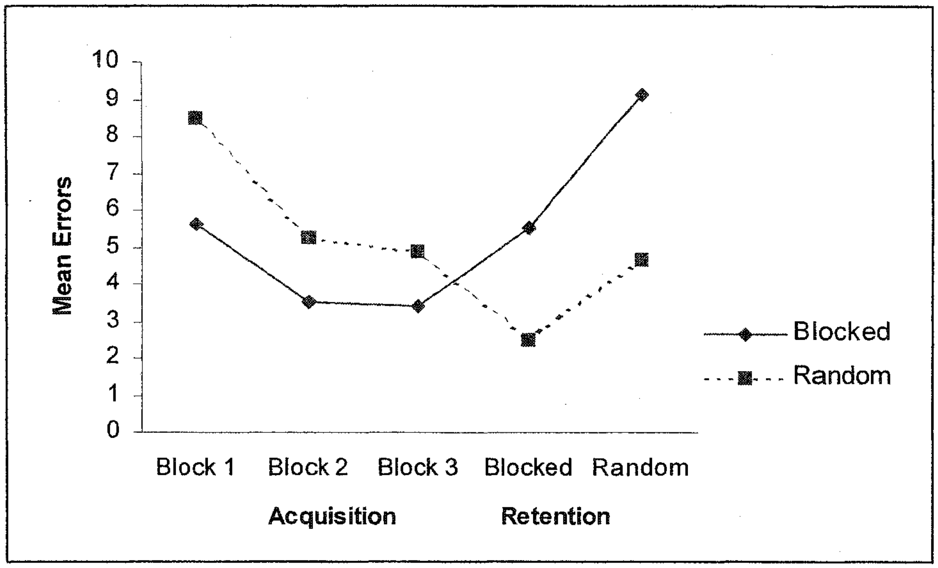


Figure 5. Two-way interaction effect for Practice Condition and Block in acquisition and retention based on participant mean errors.

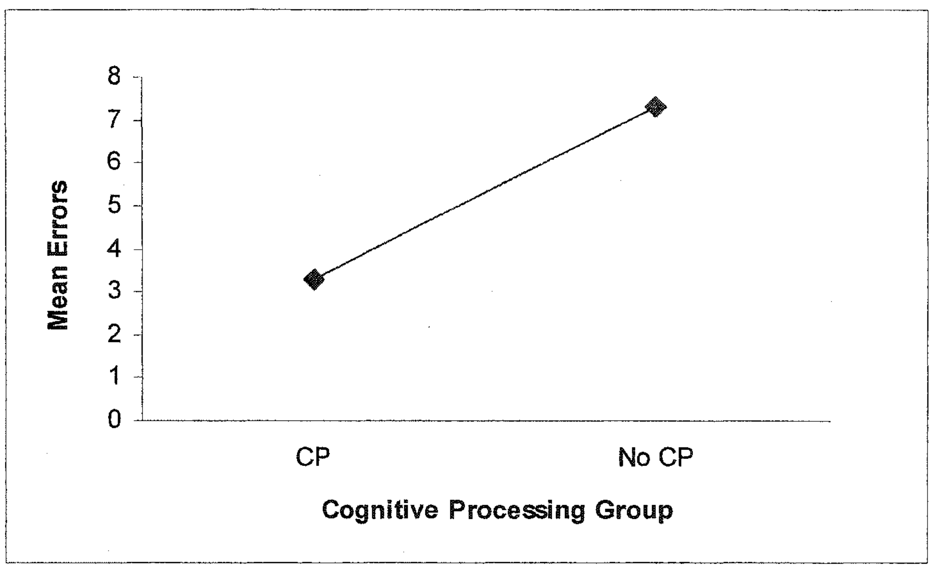


Figure 6. Main effect for Cognitive Processing Group based on participant mean errors.

Motivational Questions

In order to examine any relationships between the participants' performance and their motivation towards the task, all participants were asked 3 questions upon completion of acquisition trials. These questions were designed to provide insight into the participants' feelings about the task. The questions were as follows: 1) Did you think the game was fun or boring? 2) Did you find the game easy or hard? 3) Do you think you did well or poorly on the game? For a full list of participant responses, see Table 5.

The verbal skills among participants varied greatly, however, most participants' answers were brief and to the point. Only one participant gave no response to all three of the questions and one participant gave no response to question number two. Most of the participants' replies were positive, indicating that they thought the game was fun, that they found the game easy and that they felt that they did well at the game. Only two participants gave negative answers to the questions, i.e. they thought the game was hard. However, these negative responses were only given to one of the three questions for each participant (see answers for participants 8 and 9, questions 2 and 3, respectively). Additionally, 4 participants gave ambiguous answers, i.e. stating the game was both fun and boring. These answers may indicate that the participants were unable to understand the question, were not able to decide on an appropriate answer, or both.

Interestingly, positive responses to the questions were given regardless of how well the participant actually performed the task. For example, participant number 16, who made a total of 3 errors during the acquisition trials responded positively to all of the questions (i.e. liked the colours in the game, thought it was easy and thought she did well). Participant number 15, however, who made a total of 28 errors, also responded to

Table 5

Participant responses to motivational questions

Participant Number	Question #1 Did you think the game was fun or boring?	Question #2 Did you find the game easy or hard?	Question #3 Do you think you did well or poorly on the game?
1	I like to see all the colours.	Pretty easy, it got easier at the end.	I think I did well.
2	I liked everything about it! Fun, the best!	Easy.	I did good.
3	It was fun, but boring doing it over and over.	Easy.	I did good, except for one time.
4	No response	No response	No response
5	It was fun. It's fun when you get to find the colour.	Way easy. I knew I could do it all by myself.	I did well, I'm happy with it.
6	It was fun.	Easy.	I did good.
7	I liked it. It was cool.	Easy.	Yes, I did well.
8	Fun and interesting, but a little boring.	Pretty hard.	I did pretty well.
9	Actually, the voice saying 'go' was kind of scary. I liked touching the colours.	I think it's easy, but it tricked me.	Actually, I'm not very good at touching things, or fast.
10	I liked the red, green and yellow.	No response	Yes, I did well.
11	It's fun. It's very easy.	Sometimes it's easy.	Well.
12	Fun.	It's easy.	I did well.
13	I liked the colours, red, yellow and green are my favourite colours.	Easy and hard.	I think I did very well.
14	Fun.	Easy.	Participant gave the examiner 'thumbs up.'
15	Fun. Lots of colours.	Easy.	I won. I did good.
16	I was fun. I liked the red.	Easy.	Yes, I did very well.

the questions in a positive manner (i.e. thought the game was fun, easy and thought she did good).

Cognitive Processing Questions

In order to examine the role of cognitive processing strategies on the effects of CI in persons with DS, participants were asked questions designed to induce active, effortful processing. As such, between each block of acquisition trials, half of the participants in the blocked and random practice groups received questions designed to encourage evaluation, comparison and planning of the tasks. The questions were as follows: 1) How do you know which lights to touch? 2) What is the same and what is different about the game? 3) Can you tell me how to play the game? For a full list of participant responses, see Tables 6 and 7.

All of the participants were able to provide answers to the questions with little difficulty. Generally speaking, most of the answers were short and to the point. For questions 1, most of the participants indicated that they watched the lights and the colours. Responses to question 2 were commonly about the colours or the rows of colours being the same or different. The responses to question 3 varied among the participants, and these were the lengthiest answers. Most of the responses centred on the fact that the participants had to touch the coloured lights after they lit up.

Comparison of the answers given by the participants after block 1 and the answers given after block 2 revealed that most of the responses were similar. Any differences in the responses were seen in the answers to the questions that were asked after block 2. These answers were slightly longer and more detailed. Additionally, the answers given by the participants in the blocked practice condition appear to be quite comparable to the responses given by participants in the random practice condition. One difference may be that the responses given by participants in the random condition appear to be slightly more detailed than the responses by the participants in the blocked practice condition.

Table 6

<u>Responses to cognitive processing questions from participants in blocked practice</u>

Participant/ Block Number	Question #1 How did you know which lights to touch? (evaluate)	Question #2 What is the same and what is different about the game? (compare)	Question #3 Can you tell me how to play the game? (plan)
2			
Block 1	I watch the buttons, they're all going in different places.	Different patterns, same colours.	You do this the lights (pointing to the lights).
Block 2	I watch the buttons and they light up.	Different patterns, different rows.	I touched the buttons after I moved my finger, after he says 'go.'
12			
Block 1	They light up in red, yellow and green.	The colours light up different.	Touch red, yellow and green.
Block 2	The colours red, yellow and green lit up.	Different. (while pointing to the light sensors)	Touch the buttons when they go red, yellow, green, after you hear 'go.'
14			
Block 1	The lights lit up, each on their own.	Rows are different.	You have to touch the lights the same as they light up.
Block 2	You go red, yellow, green (pointing to lights)	Same colours, different rows.	You touch the lights, fast.
16			
Block 1	It's easy. You watch.	The colours are the same, everything is same.	I pressed on the buttons and they lit up after they showed me.
Block 2	The lights light up and you said the colours.	Same colours, same row.	The lights light up and I pressed the buttons how they lit up.

Table 7

Responses to cognitive processing questions from participants in random practice

Participant/ Block Number	Question #1 How did you know which lights to touch? (evaluate)	Question #2 What is the same and what is different about the game? (compare)	Question #3 Can you tell me how to play the game? (plan)
1			
Block 1	I look and listen.	Different rows.	The man says the colours, I put my finger on the sensor and when I hear "go" I touch the lights.
Block 2	I look hard.	They're different colours, all mixed up.	When I see the colours and go sound goes, I put them in the right order.
3			
Block 1	Because it shows me where the colour is first, second and third.	There is red, green and yellow in each row.	You got me to go in the order red, green, yellow, which is first, second and third.
Block 2	It shows the colour, which one is first, second and third.	There is same colour lights. It goes different ways for me for the lights to go on.	I did the same thing that it showed me to do. I touched the lights.
5			
Block 1	Because it is red, green and yellow, it's like when they light up I'm thinking.	The red, the yellow and the green are the same.	Different colours in different rows and makes it go different ways and I had to think, then I would touch them one by one.
Block 2	It lights up different colours and I'm always thinking and trying to get it correct.	The yellow, green and red are the same because they make sense.	The rows were different because the different colours light up, because they're all different in different rows and that's it!
7			
Block 1	I watch all of them and they light up.	It's different, mixed up all together, the colours.	I touched the lights.
Block 2	I touch all of them because the colours light up.	The colours were mixed up all over, different.	I touched them (pointing to the lights).

V. Discussion

This study was designed to examine the effects of practice schedule, supplementary cognitive processing, and motivation on the performance and learning of a novel motor skill in adolescents and young adults with Down syndrome. There were three research questions. First, will individuals with Down syndrome benefit more from a blocked practice schedule or a random practice schedule in the performance and learning of a motor skill? Second, when supplemented with questions designed to induce active cognitive processing, will individuals with DS display the typical contextual interference effect, as seen in the general population? More specifically, when augmented with cognitive processing strategies, will individuals with DS benefit more from a blocked practice schedule during motor skill performance, but profit from a random practice schedule, in the learning of a motor skill? The third element of this study investigated how the participants' motivation/feelings about the task affected their learning and performance.

Consistent with studies that have assessed the motor performance of PWID, during the acquisition phase, all participants regardless of practice condition or processing group were able to significantly improve their performance across trial blocks (Poretta & O'Brien, 1991; Poretta, 1988). This was evident through faster reaction times and movement times, and a decrease in movement time variability and mean errors across acquisition blocks. These findings are important in that they suggest that individuals with DS are able to improve their performance on a novel skill with repeated practice, a feature that is very important to the learning of a motor skill (Porretta, 1988).

Results showed that the temporal variables demonstrated no clear distinction between the blocked and random practice conditions. The error data however revealed the typical contextual interference effect as evidenced by a significant two-way interaction between Practice Condition and Block. Participants in the random practice condition performed poorly in acquisition and strong in retention, while the performance of the participants in the blocked practice condition was strong in acquisition but poor in retention. These findings are consistent with those predicted by Shea and Morgan (1979) and Lee and Magill (1983).

Prior studies have provided partial support for the contention that PWID can benefit from the effects of contextual interference. Studies involving different motor programs (Painter et al. 1994), a large number of acquisition trials (Porretta & O'Brien, 1991) and anticipation timing tasks (Del Rey & Stewart, 1989) have provided statistically significant results in favour of utilizing a random practice schedule in the learning of motor skills. The results of this investigation are therefore consistent with much of the contextual interference research in which PWID were participants. Additionally, this study further strengthens the notion that the contextual interference effect exists in individuals with mental retardation.

The findings of this investigation were contrary to the first proposed hypothesis, which suggested that because individuals with DS are passive processors of information (Brown, 1974) they would benefit more from a blocked practice schedule in both the performance and learning of a motor skill. Current hypotheses to account for the CI effect suggest that under a random practice schedule, the learner is forced to engage in more deep and elaborate processing of movement related information. It is the extensive and varied processing demands required in random practice that causes poor performance during acquisition but enhanced retention and transfer (Shea & Zimny, 1983; Lee & Magill, 1983). Although the participants in the present study did benefit from blocked practice during acquisition, they were able to profit from random practice during tests of retention. In line with the hypotheses for the CI effect, these findings suggest that persons with DS may not be passive processors of information, but in fact, they may be able to instinctively engage in more elaborate processing, and thus benefit from random practice.

To date, the majority of research examining the CI effect with PWID has involved individuals with mild mental handicaps (Del Rey & Stewart, 1989; Painter et al. 1994; Poretta, 1988; Porretta & O'Brien, 1991). Previous research has shown that mildly mentally handicapped persons may have the cognitive capabilities to spontaneously engage in the effortful processing required under random practice, and thus, may perform better on later retention and transfer tests. While approximately 90% of all mental retardation conditions are classified as mild, Down syndrome is classified as a moderate to severe form of intellectual disability (Stratford, 1989). The results of this investigation suggest that individuals with moderate to severe forms of mental retardation may also be able to benefit from contextual interference. Even though individuals with DS may have lower levels of cognitive functioning as compared to individuals with undifferentiated mental handicaps, it seems that they may be able to spontaneously engage in the more active and complex processing demanded in random practice conditions. As such, an unsystematic practice schedule may be most conducive to learning for individuals with DS and other populations with moderate to severe mental retardation.

Additionally, the present investigation provides support for the study by Edwards et al. (1986) in which participants were also persons with DS. Although the differences between practice groups were not significant, Edwards et al. (1986) found that participants with DS who received random practice were less variable than those who received blocked practice, during the last block of acquisition and the transfer block. As discussed by the authors, it is theoretically unclear why the participants with DS were less variable in random practice during acquisition, however results of the study support the utility of random practice schedules to enhance learning for individuals in this population.

The error results of the present study were in favour of blocked practice as being more beneficial than random practice in the acquisition of a skill and random practice being more beneficial than blocked practice in the retention of a motor skill. However, the temporal data did not support these findings. The lack of significant findings for practice condition for the temporal data may be accounted for by several factors.

First, the lack of significant differences for practice condition may have been due to the large between subject variability for all of the dependent measures. Disparity in the participants' data was most prevalent in the movement time measures. For example, the mean movement times in block one of retention ranged from 1594.4 msec to 13246 msec. Large discrepancies were also evident in the reaction time and standard deviation of movement time measures.

Second, the lack of significant practice condition findings may have been due to the fact that the participants were introduced to a novel task, and they were not able to become proficient at the task prior to acquisition. In 1989, Del Rey investigated the effects of prior practice on the CI effect. Her study illustrated that participants who were given training specific to the skill being practiced displayed superior performance compared to the participants who were not trained. Perhaps if participants in the present study were given exposure to a skill similar to the task presented, they may have been able to become more proficient and consistent in their temporal performance on the task, and thus the benefits of contextual interference may have been evident.

Finding significant ways to facilitate learning in PWID is an important undertaking as previous research has indicated that individuals from this population experience difficulty with the learning of motor skills (Wade, 1986). Previous investigations regarding the contextual interference effect in the general population have shown that when acquisition performance requires the learner make comparisons between tasks, subsequent retention is facilitated (Shea & Zimny, 1983). As such, this study examined the effects of encouraging persons with DS to engage in effortful cognitive processing on the performance and learning of a novel motor skill.

It was hypothesized that if individuals with Down syndrome were facilitated to utilize active cognitive processing mechanisms during practice, they would display the typical contextual interference effect. Examination of the temporal acquisition data revealed that the participants who received the cognitive processing questions were significantly less variable in their movement times as compared to those participants who did not received the cognitive processing questions. Furthermore, for the participants who were engaged in active cognitive processing, by the end of practice there were no significant differences in the performance of the blocked and random practice schedules.

Additionally, the error data showed that participants' performance in the Cognitive Processing Group was superior to that of participants in the No Cognitive Processing Group during both acquisition and retention. Specifically, participants who received cognitive processing questions performed the movement sequences with fewer errors as compared to those participants who did not receive the cognitive processing questions. Contrary to the hypothesis for the present study, within the cognitive processing group, there were no differences in the performance of participants who practiced in a random or blocked schedule.

These findings indicate that active cognitive processing may facilitate the performance and learning of a motor skill for individuals with DS. Moreover, if persons with DS are induced to engage in active processing, the type of schedule in which this population practices a motor skill may not be of great consequence. If persons with DS engage in more effortful processing, they may benefit equally from blocked and random practice.

In 1991, Poretta and O'Brien suggested that the lack of performance differences between practice conditions during acquisition may be due to similarities in the amount of effortful processing participants engaged in during random and blocked practice. The authors suggested that because of their mental deficits, PWID practicing under both blocked and random schedules may need to engage in active processing when learning motor skills. In contrast, persons from the general population may only need to engage in effortful processing during random practice.

Results of the present study support the suggestion by Porretta and O'Brien (1991). However, Porretta and O'Brien (1991) maintain that although mildly mentally handicapped persons may need to engage in active processing in both blocked and random practice, participants benefit more when practicing in a random schedule. In contrast, results of the present study suggest that more effortful processing evoked in persons with DS facilitates performance and learning regardless of the practice condition imposed.

In addition to the cognitive processing questions, participants were asked motivational questions in order to assess the effects of motivation on the performance and learning of a motor skill. Motivational factors did not seem to play a role in the performance and learning of the given task. Overall, participants' responses to the motivational questions were positive. In terms of participants' pleasure in performing the task, most responses indicated that task was fun and enjoyable. In terms of performance on the task, most participants indicated that the task was easy and that they thought they did well. Interestingly, these reports were given regardless of which schedule the participant practiced in, and how well the participant actually performed on the task.

One explanation of these findings is that the motivational questions may not have produced reliable and valid responses from the participants. In a paper examining the utility of self-report measures as they apply to PWID, Kabzems (1985) described factors of developmental level and social desirability that may have great effects on the accuracy and validity of self-reports. Kabzems (1985) suggested that PWID may lack sufficient verbal fluency and/or the introspective skills to make a valid measure of constructs such as self-concept. As such, the participants in this study may not have been able to accurately reflect on their own feelings towards the task, or they may not have had the verbal ability to express their true emotions. Additionally, Kabzems (1985) suggested that self-reports were especially subject to faking because there is usually one answer that is more socially desirable than others. PWID, therefore, may choose a socially desirable answer because of a lack or insight, denial of limitations or heightened motivation for social reinforcement. Participants in the present study may have felt pressured to provide positive responses to the questions to please the examiner or their parents.

Assuming that participants' responses were in accordance with their true feelings, the answers given from the motivational questions do not agree with previous research by Borkowski et al. (1987) that suggests that PWID often enter into a novel situation with low motivation and poor self-esteem. Participants in the present study did not seem to have motivational difficulties related to the task. Evidence of this was seen in the enthusiastic and affirmative responses given to the motivational questions. Furthermore, if the participants did not experience motivational difficulties, then according to the proposed hypothesis, they should have been free to become active strategic learners, and thus benefit from a random practice schedule. In fact, participants benefited more from blocked practice than from random practice. It is still believed that a blocked practice schedule would raise the motivation of PWID, as the chance of early success is greater. However, because positive responses to the motivational questions were given regardless of practice schedule, it is suggested that motivation may not play a large role in the effects of practice schedule.

VI. Conclusions

Summary and Conclusions

The present study investigated the effects of practice schedule and supplementary cognitive processing strategies on the performance and learning of a novel motor skill in adolescents and young adults with Down syndrome. Additionally, the effects of motivation on motor performance and learning in different practice schedules was examined.

Overall, the results of this investigation provided evidence that persons with DS are able to benefit from the effects of contextual interference. The performance of the participants practicing in a blocked schedule was superior in acquisition, however, participants practicing in a random schedule displayed superior performance during tests of retention. These results did not support the first hypothesis, specifically, that individuals with Down syndrome would benefit more from a blocked practice schedule, as compared to a random practice schedule, in both acquisition and tests of retention. The present study endorses the utility of a random practice schedule when teaching individuals with DS motor skills.

Additionally, the findings revealed that when individuals with DS were asked questions designed to evoke cognitive processing strategies, they did not display the typical CI effect. Specifically, the performance and learning of persons with DS who were encouraged to engage in cognitive processing strategies was superior to that of individuals with DS who did not engage in active cognitive processing. Furthermore, the performance and learning of persons with DS who practiced in a blocked or random schedule was not markedly different when they were engaged in dynamic cognitive processing. According to Diewert and Stelmach (1978), the manner in which practice is organized is an important factor in motor learning. The results of this study suggest that for persons with DS, an important factor to motor learning may also be the cognitive processing mechanisms involved in acquiring skills.

Additionally, examination of participants' feelings towards the task revealed that motivation did not seem to play a pivotal role in the effects of contextual interference. Regardless of practice schedule or actual performance, participants' responses to the motivational questions were positive, indicating that they enjoyed playing the game, they thought it was easy, and that they deemed they did well.

At a practical level, the results of this study support the utility of a random practice schedule as the best approach to teaching persons with DS motor skills. Teachers and coaches should recognize the importance of variety and diversity in a training program in order to help persons with DS learn motor skills most effectively. It is essential for parents and educators to understand that sacrificing performance during the acquisition of a skill will ultimately result in increased long term retention.

Additionally, if physical educators provide persons with DS with the opportunity to evaluate, compare and plan their actions for a given skill, learning may be enhanced. By engaging in these higher cognitive processing mechanisms, persons with DS may be able to function more effectively in game and activity situations.

Future Recommendations

The present study may have been limited by the absence of transferring the participants to a different, but related task. While providing a balanced design for both random and blocked retention, as suggested by Painter et al. (1994), this study failed to investigate the role of CI in a transfer task. Since the generalization of a skill to different situations is an important factor in many game and activity settings, future studies should incorporate a transfer task in their design.

While there is a growing body of evidence that suggests that the contextual interference effect does exist in PWID, much of the research has been conducted with persons with mild mental retardation. Future research should focus on individuals with moderate to severe forms of mental retardation to demarcate the role of contextual interference in this population.

The present study also provided new information regarding the processes involved in contextual interference in persons with DS. The role of active cognitive processing strategies in both blocked and random practice for this population warrants further investigation. Specifically, future research should investigate why cognitive processing strategies seem to benefit performance and learning in blocked and random practice to the same degree. The effects of different amounts of processing strategies, the time when strategies should be evoked, and how different strategies themselves affect the performance and learning of motor skills needs to be better understood.

References

Adams, J.A. (1976). Issues for a closed-loop theory of motor learning. In. G.E. Stelmach (Ed.), Motor Control: Issues and trends (pp. 87-107). New York: Academic Press.

Albaret, J-M, & Thon, B. (1998). Differential effects of task complexity on contextual interference in a drawing task. Acta Psychologia, 100, 9-24.

Battig, W.F. (1966). Facilitation and interference. In E.A. Bilodeau (Ed.), Acquisition of skill (pp. 215-244). New York: Academic Press.

Battig, W.F. (1972). Intratask interference as a source of facilitation in transfer and retention. In: R.F. Thompson & J.F. Voss (Eds.), Topics in learning and performance (pp. 131-159). New York: Academic Press.

Battig, W.F. (1979). The flexibility of human memory. In: L.S. Cermak and F.I.M. Craik (Eds.), Levels of processing in human memory (pp. 23-44). Hillsdale, NJ: Erlbaum.

Brady, F. (1998). A theoretical and empirical review of the contextual interference effect and the learning of motor skills. Quest, 50, 266-293.

Borkowski, J.G., Johnston, M.B., & Ried, M.K. (1987). Metacognition, motivation and the transfer of control processes, in S.J. Ceci (Eds.), Handbook of cognitive, social, and neuropsychological aspects of learning disabilities (pp.147-173). Hillsdale, NJ: Earlbaum.

Brown, A.L. (1974). The role of strategic behavior in retardate memory. In: N.R.Ellis (Eds.), International review of research in mental retardation: Vol. 7. (pp. 55-111). New York, NY: Academic Press.

Burns, Y. & Gunn, P. (1993). Down syndrome: Moving through life. London: Chapman & Hall.

Campione, J.C. (1987). Metacognitive components of instructional research with problem learners. In F.E. Weinhert & R.H. Kluwe (Eds.), Metacognition, motivation, and understanding (pp. 117-142). Hillsdale, NJ: Erlbaum.

Campione, J.D., Brown, A.L., & Ferrara, R.A. (1982). Mental retardation and intelligence. In F.J. Sternberg (Ed.), Handbook of human intelligence (pp. 392-490). New York: Cambridge University Press.

Cohen, J. (1988). Statistical power analysis for the behavioural sciences. Hillsdale, NJ: Lawrence Erlbaum.

Cuddy, L.J. & Jacoby, L.L. (1982). When forgetting helps memory: An analysis of repetition effect. Journal of Verbal Learning and Verbal Behavior. 21, 451-467.

Davis, G.S. (1988). The effect of contextual and retroactive interference on the retention of a motor skill. Unpublished doctoral dissertation, Pennsylvania State University, University Park.

Del Rey, P. (1982). Effects of contextual interference on the memory of older females differing in level of physical activity. Perceptual and Motor Skills, 55, 171-180.

Del Rey, P. (1989). Training and contextual interference effects on memory and transfer. Research Quarterly for Exercise and Sport, 60, 342-347.

Del Rey, P., Lui, X., & Simpson, K.J. (1994). Does retroactive inhibition influence contextual interference effects? Research Quarterly for Exercise and Sport, 65, 120-126.

Del Rey, P., & Shewokis, P. (1993). Appropriate summary KR for learning timing tasks under conditions of high and low contextual interference. Acta Psychologica, 83, 1-12.

Del Rey, P., & Stewart, D. (1989). Organizing input for mentally retarded subjects to enhance memory and transfer. Adapted Physical Activity Quarterly, 6, 247-254.

Del Rey, P.M., Whitehurst, E. & Wood, J. (1983). Effects of experience and contextual interference on learning and transfer. Perceptual and Motor Skills, 56, 581-582.

Diewert, G.L., & Stelmach, G.E. (1978). Perceptual organization in motor skill learning. In G.E. Stelmach, (Ed.), Information Processing in Motor Control and Learning (pp. 241-265) New York: Academic.

Edwards, J.M., & Elliott, D. (1989). Asymmetries in intermanual transfer of training and motor overflow in adults with Down's syndrome and nonhandicapped children. Journal of Clinical and Experimental Neuropsychology, 11(6), 959-966.

Edwards, J.M., Elliott, D., & Lee, T.D. (1986). Contextual interference effects during skill acquisition and transfer in Down's Syndrome adolescents. Adapted Physical Activity Quarterly, 3, 250-258.

Elliott, D., Edwards, J.M, Weeks, D.J., Lindley, S., & Carnahan, H. (1987). Cerebral specialization in young adults with Down syndrome. American Journal of Mental Deficiency, 91(5), 480-485.

Elliott, D., Gray, S., & Weeks, D.J. (1991). Verbal cuing and motor skill acquisition for adults with Down syndrome. Adapted Physical Activity Quarterly, 8, 210-220.

Elliott, D., Pollock, B.J., Chua, R., & Weeks, D.J. (1995). Cerebral specialization for spatial processing in adults with Down syndrome. American Journal on Mental Retardation, 99(6), 605-615.

Elliott, D., & Weeks, D.J. (1993). Cerebral specialization for speech perception and movement organization in adults with Down's syndrome. Cortex, 29, 103-113.

Elliott, D., Weeks, D.J., & Elliott, C.L. (1987). Cerebral specialization in individuals with Down syndrome. American Journal of Mental Retardation, 92(3), 263-271.

Elliott, D., Weeks, D.J., & Gray, S. (1990). Manual and oral praxis in adults with Down's syndrome. Neruropsychologia, 28(12), 1307-1315.

Elliott, D., Weeks, D.J., & Jones, R. (1986). Lateral asymmetries in finger-tapping by adolescents and young adults with Down syndrome. American Journal of Mental Deficiency, 90(4), 472-475.

French, K.E., Rink, J.E., Werner, P.H. (1990). Effects of contextual interfence on retention of three volleyball skills. Perceptual and Motor Skills, 71, 179-186.

Goode, S.L., & Magill, R.A. (1986). Contextual interference effects in learning three badminton serves. Research Quarterly for Exercise and Sport, 57, 308-314.

Goodwin, J.E., & Meeuwsen, H.J. (1996). Investigation of the contextual interference effect in the manipulation of the motor parameter of over-all force. Perceptual and Motor Skills, 83, 735-743.

Hall, K.G., Domingues, D.A., & Cavozos, R. (1994). Contextual interference effects with skilled baseball players. Perceptual and Motor Skills, 78, 834-841.

Hartley, X.Y. (1981). Lateralisation of speech stimuli in young Down's syndrome children. Cortex, 17, 241-248.

Hartley, X.Y. (1986). A summary of recent research into the development of children with Down syndrome. Journal of Mental Deficiency Research, 30, 1-14.

Heitman, R.J., & Gilley, W.F. (1989). Effects of blocked versus random practice by mentally retarded subjects on learning a novel skill. Perceptual and Motor Skills, 69, 443-447.

Immink, M.A., & Wright, D.L. (1998). The contextual interference effect: A response planning. Human Experimental Psychology, 51, *A*, 735-754.

Jarus, T. & Goverover, Y. (1999). Effects of contextual interference and age on acquisition, retention and transfer of motor skill. Perceptual and Motor Skills, 88, 437-447.

Jelsma, O., & Pieters, J.M. (1989). Instructional strategy effects on the retention and transfer of procedures of different difficulty levels. Acta Psychologica, 70, 219-234.

Jelsma, O., & van Merrienboer J.J.G. (1989). Contextual interference interactions with reflection-impulsivity. Perceptual and Motor Skills, 68, 1055-1064.

Kabzems, V. (1985). The use of self-report measures with mentally retarded individuals. The Mental Retardation and Learning Disability Bulletin, 13, 106-114.

LeClair, D.A., & Elliott, D. (1995). Movement preparation and the costs and benefits associated with advance information for adults with Down syndrome. Adapted Physical Activity Quarterly, 12, 239-249.

Lee, T.D., & Magill, R.A. (1983). The locus of contextual interference in motor skill acquisition. Journal of Experimental Psychology: Learning, Memory and Cognition, 9, 730-746.

Lee. T.D. & Magill, R.A. (1985). Can forgetting facilitate skill acquisition? In D. Goodman, R.B. Wilberg & I.M. Franks (Eds.), Differing perspectives in motor learning, memory and control (pp. 3-22). Amsterdam: North Holland.

Lee, T.D., & Weeks, D. J. (1987). The beneficial influence of forgetting on short-term retention of movement information. Human Movement Science, 6, 233-245.

Lee, T.D., Wishart, L.R., Cunningham, S., & Carnahan, H. (1997). Modeled timing information for random practice eliminates the contextual interference effect. Research Quarterly for Exercise and Sport, 68, 100-105.

Li, Y., & Wright, D.L. (2000). An assessment of the attention demands during random and blocked practice schedules. The Quarterly Journal of Experimental Psychology, 53A(2), 591-606.

Magill, R.A., & Hall, K.G. (1990). A review of the contextual interference effects in motor skill acquisition. Human Movement Science, 9, 241-289.

Maraj, K.V., Li, L., Hillman, R., Jeansonne, J., & Robertson, S.D. (2002) Verbal and visual instruction in motor skill acquisition for persons with Down syndrome. Manuscript submitted for publication.

Melton, A.W. (1967) Comments on professor postman's paper. In C.N. Conder (Eds.), Verbal Learning and Verbal Behavior (pp. 179-191). New York: McGraw-Hill.

Painter, M.A., Inman, K.B., & Vincent, W.J. (1994) Contextual interference effects in the acquisition and retention of motor tasks by individuals with mild mental handicaps. Adapted Physical Activity Quarterly, 11, 383-395.

Pigott, R.E., & Shapiro, D.C. (1984). Motor schema: The structure of the variability session. Research Quarterly for Exercise and Sport, 55, 41-45.

Pinel, J.P.J. (2000). Biopsychology, 4th Edition. Needham Heights: Allyn & Bacon.

Pipe, M-E. (1983). Dichotic-listening performance following auditory discrimination training in Down's syndrome and developmentally retarded children. Cortex, 19, 481-491.

Poto, C.C. (1988). How forgetting facilitates remembering: An analysis of the contextual interference effect in motor learning. Unpublished doctoral dissertation, Louisiana State University, Baton Rouge.

Porretta, D.L. (1988). Contextual interference effects on the transfer and retention of a gross motor skill by mildly mentally handicapped children. Adapted Physical Activity Quarterly, 5, 332-339.

Porretta, D.L. (1996). Contextual interference and its application to individuals with mental retardation. Brazilian International Journal of Adapted Physical Education Research, 3(1), 67-78.

Porretta, D.L., & O'Brien, K. (1991). The use of contextual interference trials by mildly handicapped children. Research Quarterly for Exercise and Sport, 62, 244-248.

Schmidt, R.A. (1988). Motor control and learning: A behavioural emphasis. Champain, IL: Human Kinetics.

Schmidt, R.A., & Wrisberg C.A. (2000). Motor learning and performance: A problem based learning approach. Champain, IL: Human Kinetics

Selikowitz, M. (1997). Down syndrome: The facts. New York: Oxford University Press Inc.

Shea, J.B., & Graf, R.C. (1994). A model for contextual interference effects in motor learning. In C.R. Reynolds (Eds.), Cognitive assessment: A multidisciplinary perspective (pp. 73-87). New York: Plenum Press.

Shea, J.B. & Morgan, R.L. (1979). Contextual interference effect on the acquisition, retention and transfer of a motor skill. Journal of Experimental Psychology, Human Learning and Memory, 5, 179-187.

Shea, J.B. & Titzer, R.C. (1993). The influence of reminder trials on contextual interference effects. Journal of Motor Behavior, 25, 264-274.

Shea, J.B., & Zimny, S.T. (1983). Context effects in memory and learning movement information. In R.A. Magill (Eds.), Memory and control of action (pp. 345-366). Amsterdam: North Holland.

Shea, J.B., & Zimny, S.T. (1988). Knowledge incorporation in motor representation. In O.G. Meijer & K. Roth (Eds.), Complex movement behaviour: The motor action controversy (pp. 289-314). Amsterdam: North Holland.

Shewokis, P.A., Del Rey, P., & Simpson, K.J. (1998). A test of retroactive inhibition as an explanation of contextual interference. Research Quarterly for Exercise and Sport, 69, 70-74.

Shewokis, P.A., & Snow, J. (1997). Is the contextual interference effect generalizable to non-laboratory tasks? Research Quarterly for Exercise and Sport (Abstracts from completed research), A-64, 68.

Smith, P.J.K., & Rudisill, M.E. (1993). The influence of proficiency level, transfer distality and gender on the contextual interference effect. Research Quarterly for Exercise and Sport, 64(2), 151-157.

Spitz, H.H., & Nadler, B.T. (1974) Logical problem-solving by educable retarded adolescents and varying aged normal children. Developmental Psychology, 10(3), 404-412.

Stallings, L.M. (1982). Motor learning from theory to practice. St. Louis, MO: C.V. Mosby.

Stratford, B. (1989). Down's syndrome: Past, present and future. London, England: Penguin Books.

Van Merrienboer, J.J.G., & Jelsma, O. (1988) The Matching Familiar Figures Test: computer or experimenter-controlled administration? Educational and Psychological Measurement, 48, 161-164.

Wade, M.G. (Ed.) (1986). Motor skill acquisition of the mentally handicapped: Issues in research and training. Amsterdam: Elsevier Science Publishers B.V.(North Holland)

Weeks, D.J., Chua, R, Elliott, D. (2000). Perceptual-motor behaviour in Down syndrome. Windsor: Human Kinetics.

Welsh, T.N. & Elliott, D. (2001). Gender differences in a dichotic listening and movement task: lateralization or strategy? Neuropsychologia, 39, 25-35.

Wright, D.L., Li, Y., & Whitacre, C. (1992). The contribution of elaborative processing to the contextual interference effect. Research Quarterly for Exercise and Sport, 63, 30-37.

Wrisberg, C.A. & Lui, Z. (1991). The effect of contextual variety on the practice, retention and transfer of an applied motor skill. Research Quarterly for Exercise and Sport, 62, 406-412.

Young, D.E., Cohen, M.J. & Husak, W.S. (1993). Contextual interference and motor skill acquisition: On the processes that influence retention. Human Movement Science, 12, 577-600.

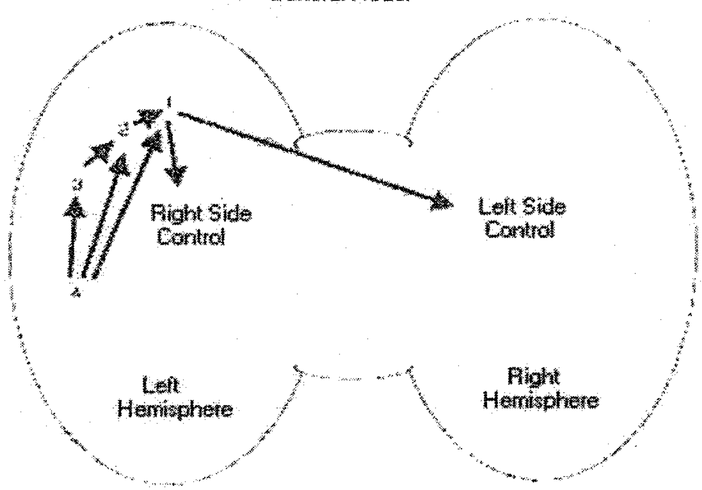
Zimny, S.T. (1981). The use of verbal protocol analysis to investigate the basis of contextual interference effects in the learning of a motor task. Unpublished master's thesis, University of Colorado at Boulder, CO.

Appendix A

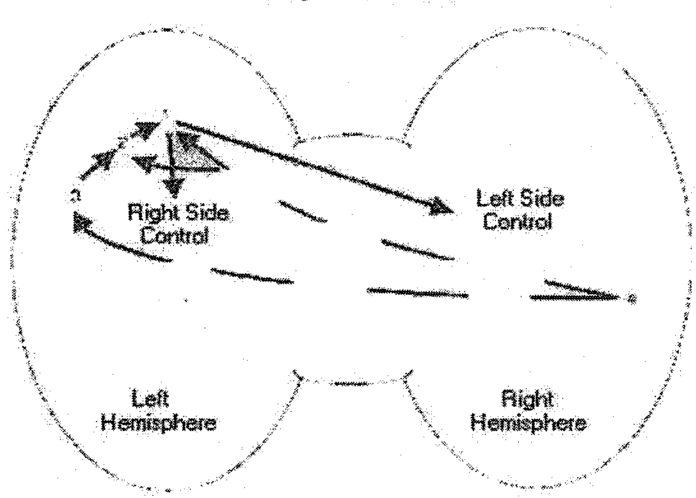
Figure A1. Model of functional cerebral organization in the general population and in persons with Down syndrome: 1.Movement executive; 2.praxis control; 3. speech production; 4. speech perception.

Note. From Perceptual-motor behaviour in Down syndrome (p.313) by Weeks, D.J., Chua, R, Elliott, D, 2000, Windsor: Human Kinetics. Copyright 2000 by Daniel J. Weeks, Romeo Chua, and Digby Elliott. Reprinted with permission.

General Model



Down Symdrome Model



Appendix B

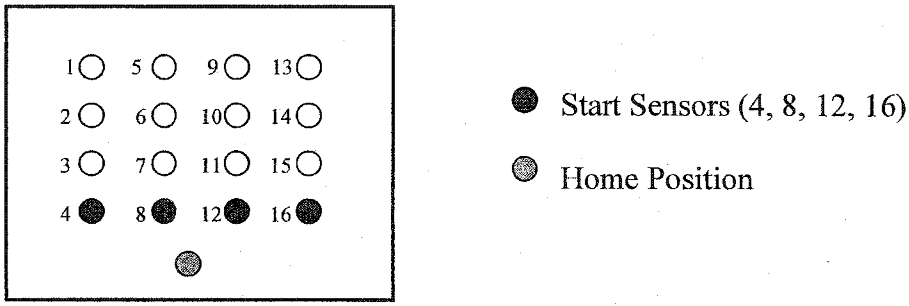
Table B1

Descriptive statistics of participants as a function of Practice Condition and Cognitive Processing Group

Practice Condition/ Processing Group	N	Chronological Age (yrs)		Sex	
		M	SD	Male	Female
Blocked	8	15.36	3.06	1	7
Random	8	15.25	4.44	2	6
CP					
Blocked	4	15.46	2.14	1	3
Random	4	16.31	4.62	1	3
No CP					
Blocked	4	15.27	4.15	0	4
Random	4	14.19	4.65	1	3
Total Participants	16	15.31	3.68	3	13

Appendix C

Figure C1. Box of Lights Apparatus.



Appendix D

Participant Information Letter (Participants)

Title: **The Contextual Interference Effect in Adolescents with Down Syndrome**

Principal Investigator: Jennifer Kivi, Graduate Student
Faculty of Physical Education and Recreation
E-436 Van Vliet Centre
Edmonton, AB
T6G 2H9

Supervisor: Dr. Brian Maraj, Assistant Professor

Phone: 780-953-3713 Fax: 780-492-2364 E-mail: jkivi@ualberta.ca

Dear Participant:

I am studying the different ways that people learn how to make movements. I am trying to find the best ways to help teach you to make movements and to see how well you have learned them. I want to know if it is better for you to practice only one movement at a time or to practice different movements in a mixed up order. I am doing this study for my Master's thesis.

Individuals with Down syndrome will take part in this study. The information that I learn can be used at schools and on sports teams. It will help teachers and coaches to teach in a way that will help you and others to learn better.

First, we will work together on a task where you have to move your hands to touch targets that light up on a box. There are 3 different coloured lights on this special box. The colours are red, green and yellow. I will let you know which of the lights to touch first, second and third by telling you which of the lights to touch in order (for example: red, green, yellow) and at the same time, the lights on the special box will turn on to show you the order. Then you will get a turn to touch the lights in the same order as you saw and heard. You will have to do 54 turns at this. Then you get to rest for an hour and try it again, but only for 36 turns. The total time it will take will be about 2 hours.

Your name will not be used and your personal information will be coded and stored in a locked file cabinet/office/lab to which only myself, and my advisor will have access. I will review your results for this study, but your name will not be used. To ensure confidentiality, raw data will be coded and stored in a locked office to which only the investigators will have access. Normally data is retained for a period of five years post publication, after which it will be destroyed.

You are free to withdraw from the study at any time without consequence. If you decline to continue or you withdraw from the study your information will be removed from the study upon your request. There are minimal risks to you when doing this study.

The University of Alberta creates and collects information for the purposes of research and activities directly related to its education and research programs. All of the information provided from participants through research, and other information gathered from research projects will be protected and used in compliance with Alberta's Freedom of Information and Protection of Privacy Act.

If you have any questions about what I am doing, you may call me, or my advisor, Dr. Brian Maraj at 492-0578. If you want to talk with someone who is not directly involved in this project, then you can call the Chair of the Faculty of Physical Education and Recreation Ethics Committee, Dr. Wendy Rodgers at 492-5910.

Thank you.

Jennifer Kivi

Appendix E

Participant Information Letter (Parents/Guardians)

Title: **The Contextual Interference Effect in Adolescents with Down Syndrome**

Principal Investigator: Jennifer Kivi, Graduate Student
Faculty of Physical Education and Recreation
E-436 Van Vliet Centre
Edmonton, AB
T6G 2H9

Supervisor: Dr. Brian Maraj, Assistant Professor

Phone: 780-492-0578 Fax: 780-492-2364 E-mail: jkivi@ualberta.ca

Dear Parent/Guardian:

This study is being conducted to achieve a more in-depth understanding of the effect of schedules of practice on learning. Specifically, the study will examine the effect of a random practice schedule vs. a blocked practice schedule on the learning of a novel motor task in individuals with Down syndrome. This investigation is being conducted as a partial requirement for completion of my Master's degree.

All participants in this study will include individuals with Down syndrome. The results from this investigation will help researchers to discover more about the way that individuals with Down syndrome learn. This information can be applied to educational and activity settings, such as physical education classes and recreational sports teams. Determining strategies that can facilitate the retention of motor skills will assist in determining the most optimal approach for teachers, physical educators, coaches, and occupational therapists to organizing instructional sessions that are most conducive to learning for individuals with Down syndrome.

During the testing, the participant will be seated comfortably in front of the "Box of Lights" apparatus. The task will involve the participant touching 3 different coloured light sensors in a prescribed order. The experimenter will instruct the participant which of the lights to touch first, second and third by *telling* them which of the lights to touch in order (for example: red, green, yellow) and at the same time, the lights on the Box of Lights will turn on to *show* them the order. The participant will then touch the lights in the same order as they saw and heard. The participant will complete 54 trials at this. They will received a one hour rest period, after which, they will perform an additional 36 trials. The total time it will take will be approximately 2 hours.

The participant's name will not be used and personal information will be coded and stored in a locked file cabinet/office/lab to which only myself, and my supervisor will have access. I will review the participant's results for this study, but their name will not be used. To ensure confidentiality, raw data will be coded and stored in a locked office to which only the investigators will have access. Normally data is retained for a period of five years post publication, after which it will be destroyed.

The participant is free to withdraw from the study at any time without consequence. If the participant chooses to withdraw from the study, their information will be removed from the study upon request. There are minimal risks to the participant when doing this study.

The University of Alberta creates and collects information for the purposes of research and activities directly related to its education and research programs. All of the information provided from participants through research, and other information gathered from research projects will be protected and used in compliance with Alberta's Freedom of Information and Protection of Privacy Act.

If you have any questions about this investigation, please feel free to call me, or my advisor, Dr. Brian Maraj at 492-0578. If you want to talk with someone who is not directly involved in this project, then you can call the Chair of the Faculty of Physical Education and Recreation Ethics Committee, Dr. Wendy Rodgers at 492-5910.

Thank you.

Jennifer Kivi

Appendix F

Consent Form (Participants)

Title: **The Contextual Interference Effect in Adolescents with Down Syndrome**

Principal Investigator: Jennifer Kivi, (780) 492-0578
Graduate Student, Faculty of Physical Education and Recreation

Supervisor: Dr. Brian Maraj, (780) 492-0578
Assistant Professor, Faculty of Physical Education and Recreation

Do you understand that you have been asked to participate in a research study?

Yes No

Have you read and received a copy of the information sheet?

Yes No

Do you understand the benefits/risks involved in taking part in this study?

Yes No

Do you have any questions about the study?

Yes No

Do you understand that you are free to refuse to participate or to withdraw
Yes No
from this study at any time, without consequence, and that your information will be withdrawn at your request?

Do you understand that your information will be private?

Yes No

Do you understand who will have access to your information?

Yes No

The study has been discussed with me and all my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above.
I agree to take part in this study.

Signature of Participant Date

Witness Date

Investigator Date

Appendix G

Consent Form (Parents/Guardians)

Title: **The Contextual Interference Effect in Adolescents with Down Syndrome**

Principal Investigator: Jennifer Kivi, (780) 492-0578
Graduate Student, Faculty of Physical Education and Recreation

Supervisor: Dr. Brian Maraj, (780) 492-0578
Assistant Professor, Faculty of Physical Education and Recreation

Do you understand that the participant has been asked to be in a research study?

Yes No

Have you read and received a copy of the information sheet?

Yes No

Do you understand the benefits/risks involved in this study?

Yes No

Do you have any questions about the study?

Yes No

Do you understand that the participants is free to refuse to participate or to withdraw from this study at any time, without consequence, and that their information will be withdrawn at your request?

Yes No

Do you understand that the participant's information will be private?

Yes No

Do you understand who will have access to the participant's information?

Yes No

The study has been discussed with me and all my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above.
I certify that I have read this consent form and that by completing this signature below I have given consent for the participant to participate.

Signature of Parent/Guardian	Date
Witness	Date
Investigator	Date

Appendix H

Cognitive Processing Questions

Participant #: _______________
Practice Condition: ______________
Date: ___________________

1. How did you know which lights to touch? (evaluate)

2. What is the same and what is different about the game? (compare)

3. Can you tell me how to play the game? (plan)

Appendix I

Motivation Questions

Participant #: _______________
Practice Condition: ______________
Date: __________________

1. Did you think the game was fun or boring?

2. Did you find the game easy or hard?

3. Do you think you did well or poorly on the game?

Appendix J

Table J1

Summary of ANOVA for main and interaction effects, based on mean reaction time, mean movement time and standard deviation of movement time in acquisition and retention

Dependent Measures	Variance	Acquisition			Retention		
		df	F	p	df	F	p
RT							
	Practice Condition	1	2.49	0.140	1	0.335	0.573
	Processing Group	1	1.909	0.192	1	0.043	0.839
	Block	2	3.712	0.039*	1	0.085	0.775
	Practice x Processing	1	3.304	0.094	1	0.048	0.830
	Practice x Block	2	1.379	0.271	1	0.172	0.685
	Processing x Block	2	2.018	0.154	1	0.186	0.674
	Processing x Practice x Block	2	3.674	0.040*	1	0.534	0.479
MT							
	Practice Condition	1	0.528	0.481	1	0.059	0.811
	Processing Group	1	2.506	0.139	1	1.371	0.264
	Block	2	5.828	0.008**	1	0.151	0.704
	Practice x Processing	1	0.423	0.527	1	0.177	0.681
	Practice x Block	2	0.764	0.476	1	2.311	0.154
	Processing x Block	2	0.067	0.935	1	0.313	0.586
	Processing x Practice x Block	2	1.347	0.279	1	0.135	0.719
SD of MT							
	Practice Condition	1	0.762	0.399	1	0.132	0.722
	Processing Group	1	4.732	0.050*	1	1.399	0.259
	Block	2	13.25	0.000***	1	0.793	0.390
	Practice x Processing	1	2.056	0.177	1	0.306	0.590
	Practice x Block	2	2.246	0.127	1	0.368	0.555
	Processing x Block	2	0.498	0.614	1	1.399	0.259
	Processing x Practice x Block	2	10.800	0.000***	1	0.269	0.613

Note: *significant at p<0.05, **p<0.01, ***p<0.001

Appendix K

Table K1

Summary of ANOVA based on mean reaction time, mean movement time and standard deviation of movement time in retention

Dependent Measures	Variance	Retention df	Retention F	Retention p
RT				
	Practice Condition	1	0.721	0.403
	Processing Group	1	0.092	0.762
	Practice x Processing	1	0.103	0.750
MT				
	Practice Condition	1	0.135	0.715
	Processing Group	1	3.122	0.088
	Practice x Processing	1	0.403	0.530
SD of MT				
	Practice Condition	1	0.294	0.591
	Processing Group	1	3.121	0.088
	Practice x Processing	1	0.682	0.415

Appendix L

Table L1

Summary of ANOVA for main and interaction effects, based on mean errors in acquisition and retention combined

Dependent Measure	Variance	Acquisition and Retention df	F	p
Errors				
	Practice Condition	1	0.053	0.821
	Processing Group	1	11.115	0.005**
	Block	4	9.173	0.000***
	Practice x Processing	1	0.538	0.477
	Practice x Block	4	10.234	0.000***
	Processing x Block	4	0.213	0.929
	Practice x Processing x Block	4	2.034	0.104

Note: *significant at $p<0.05$, **$p<0.01$, ***$p<0.001$