Auditory and visual cues in sequence learning: comparing typically developing children and adults

by

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Abstract

One of the many ways learning can be achieved is through implicit learning. The current study explored the effect of vision and the combination of vision and audition when learning a commonly used implicit learning sequence task. Changes in median reaction time provided an index of implicit learning. Eighteen typically developing children 7–9 years-old and twenty adults 18–35 years-old completed a sequencing task in either a visual-only or audio-visual condition where they responded to images on a screen using a button response box. Both groups learned the sequence implicitly demonstrated through decreased reaction times, where by comparison the adults consistently had faster reaction times. The child group demonstrated significant improvement in retention. In motor skill recall (auditory-only test), adults were able to cross modalities with greater accuracy and speed than the child group.

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Dedication

This thesis is dedicated to my husband and my parents.

For their guidance, support, and encouragement.

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Glossary of Abbreviations

SRT: serial reaction time

SRTT: serial reaction time task

TD: typically developing

RT: reaction time

LTM: long term memory

STM: short term memory

STSS: short term sensory store

DCD: Developmental Coordination Disorder

MSR: motor skill recall

EXP test: Explicit Awareness Test

Chapter 1: Introduction

1 Preamble

One of the many ways that learning is acquired is through implicit learning (Seger 1994). Implicit learning is to learn without awareness or intent of learning (Magill 1998); as opposed to explicit learning, which is to learn with conscious awareness (Seger 1994). The optimal type of learning, whether implicit or explicit, typically depends on what is being learned. Tasks that are declarative are typically best acquired through explicit learning tasks, and tasks that are procedural are typically best acquired through implicit learning tasks. The current study explored how typically developing (TD) adults and typically developing children learn a sequence of button presses implicitly. An implicit sequence learning task involves learning a repeat sequence task without conscious awareness of learning the task using a motor skill input such as button presses. Researchers have explored implicit learning during sequence tasks using tactile conditions (Abrahamse et al 2008; Abrahamse et al 2009), visual conditions (Wilson, et al 2003; Nissen & Bullemer 1987; Gheysen, et al 2011; Lejeune et al 2013), and multi-tasking conditions (Nissen & Bullemer 1987). To my knowledge, no one has explored if adding audio-visual stimuli influences performance in, and learning of, a sequence task. The current study explored implicit learning of a sequence task using two separate conditions: visual and audio-visual. Based on the literature investigating simple key-presses and saccadic eye movement in response to visual and auditory combinations (Miller, 1982; Corneil, Van Wanrooij, Munoz, & Van Opstal, 2002), I

predict there will be a faster reaction times in the audio-visual practice condition versus the visual only practice condition in both the typically developing adult (18 – 35 years old) and typically developing children (7 – 9 years old) groups. This prediction is based on the findings in past literature exploring sequence learning in children and adults (Nissen & Bullemer, 1987; Gheysen et al, 2011; Lejeune, et al 2013) and literature exploring audio-visual and visual cues in motor learning tasks (Seitz, Kim, and Shams, 2006; Shams and Seitz, 2008). The findings from the present study will be important for informing effective instructional strategies in schools, sporting environments, and possibly rehabilitation.

In the literature review below I outline existing literature on memory, learning, and performance as they relate to motor sequence learning. In the *Memory* section I describe capacity, retention, declarative and procedural knowledge. On the topic *Learning* I will expand on: how we learn, what fosters learning, distractions in learning, and implicit learning. With *Performance*, the following will be discussed: relation of motor and perceptual requirements in movement, such as tracking tasks and sequence tasks using visual and auditory stimulation.

2 Significance

The purpose of the present study was to evaluate the effectiveness of visual and audio-visual information on implicit learning in typically developing children and adults. This information may be beneficial in determining the most effective ways for implementing learning tasks in schools, sporting environments, and possibly in rehabilitation; including what sensory information may support learning most effectively.

The present study also serves as a control study to further explore testing the same task and conditions in special population groups such as Developmental Coordination Disorder.

Chapter 2: Literature Review

2.1 MEMORY

2.1.1 Retrieval, Retention, Capacity

Memory is the persistency for retrieval of information, thus playing a crucial role in skill acquisition (Norman 1968). A brief timeline regarding the foundations of memory derive from William James' (1890) address of the fundamental structure of memory, outlining the basis of what he termed primary and secondary memory, now primary and secondary memory are familiarized as short-term and long-term memory. In later years, Atkinson and Shiffrin (1968) proposed the two-component memory model, which expands on James' (1890) basis of primary and secondary memory, differentiating memory into working memory and long-term memory. To expand on working memory and long-term memory, Ratcliff (1978) proposed the theory of memory retrieval. The theory of memory retrieval is supported by item recognition paradigms in that our ability to remember something involves probing for traits that are most familiar, thus retrieving from what we have already encountered or know (Ratcliff 1978).

The memory retrieval system highlights the evolution of the memory system to its currently known components: short-term sensory store (STSS), short-term memory (STM), and long-term memory (LTM), each playing a specific role. In motor learning, the

capacity to retain information and the ability to retrieve information from memory and reproduce it is an aspect of learning that can be used to infer how well something is learned (Schmidt & Lee, 2014). Briefly, the short-term sensory store (STSS) retains information for a very short duration, just long enough to send sensory information for processing in short-term memory (STM) (Schmidt & Lee, 2014). For example, Sperling (1960) suggests that visual information presented may not last longer than one second in STSS before transferring over to STM. STM processes sensory information, thus given the name 'working memory', because it is thought to be where information is utilized. Further, if information is retrieved repeatedly and used in working memory it is more likely that the information will be retained. Any information of importance is encoded and processed then sent to long-term memory. It is through repetitive practice of the task that requires repetitive retrieval of information from long-term memory into working memory that refines performance of that task (Figure 1). For example, a novice musician must practice their instrument numerous times in order to improve their performance, thus repetitive practice refines the retrieval process to perform the musical notes learned.

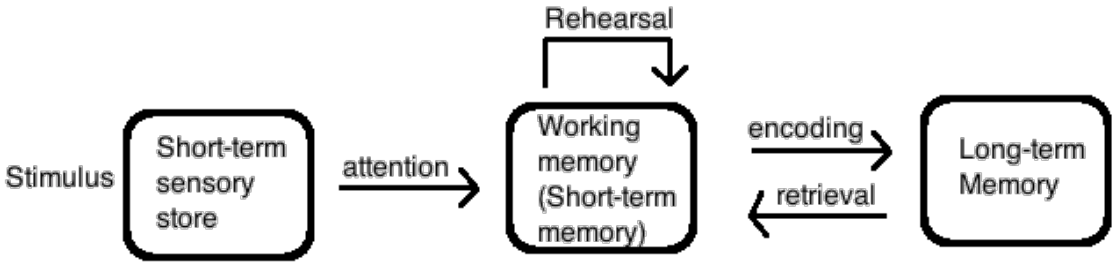


Figure 1: Memory
Adapted from Magill (2011)

The capacity of LTM is considered to be unlimited in that authors have theorized that there is no ceiling limit to how much information can be stored in long-term memory (Allan & Reber, 1980). Thus, LTM has the capacity to potentially retain all information practiced. Several authors have proposed that information learned and practiced can be consolidated into long-term memory store within 2 to 6 hours post-acquisition (McGaugh 2000; Izquierdo, Bevilaqua, Rossato, Bonini, Medina, & Cammarota 2006). Though, as previously noted, the frequency and ability for information retrieval from long-term memory to short-term memory reflects the learning that may have occurred (Schmidt & Lee, 2014).

In contrast to repetitive practice, which assists in refined learning and ability to recall a task, decay and interference are ways that hinder and interrupt the ability to retrieve information. Decay refers to deterioration of what was learned, typically due to lack of rehearsal (Altmann & Schunn 2012). Information is absorbed in STSS and processed into STM, and with adequate rehearsal this information can be transferred to long-term memory. When information is not frequently retrieved and rehearsed, pathways that were once refined with information learned begin to decay. Interference is another way that learning can be hindered. Interference involves the presence of other stimuli that could disrupt the ability to maintain information (Carlson, 2012). For example, if a novice learner is repeatedly practicing a new skill the presence of an irrelevant stimulus during skill acquisition could interrupt learning.

2.1.2 Procedural Knowledge and Declarative Knowledge

Procedural knowledge and declarative knowledge are ways that we reproduce what we know (Willingham, Nissen, & Bullemer 1989). Procedural knowledge is one of the three systems of long-term memory as proposed by Tulving (1985). This system, commonly referred to as the 'how to' system, relates specifically to the ability to store and retrieve information about motor skills. Procedural knowledge allows an individual to perform a skill, typically without verbal guidance or difficulty in relaying verbal guidance (Magill, 2011).

Declarative knowledge differs from procedural knowledge where, with declarative knowledge the individual uses verbal guidance. This type of knowledge is specific in 'what to do', making declarative knowledge distinct from procedural knowledge as an individual may be aware of 'what to do' but may not know 'how to' perform the skill.

Theories developing the concepts of procedural and declarative knowledge include the two-component model theorized by Atkinson and Shiffrin (1968), following this progressed to the theory of memory retrieval processes by Ratcliff (1978), and lastly into procedural and declarative knowledge (Tulving 1985). A more recent study by Mattar & Gribble (2005) demonstrates how learning can occur through observation of another individual learning a task on a video, followed by a test to see how well the participants recalled the observed learning and performed the task themselves. The study involved the use of a robotic arm that imposed perturbed movements in any specified direction. Participants familiarized themselves with using the robotic arm by completing a series of movements to move a cursor to one of several targets on the screen. The participants were instructed to watch a video of an individual either

learning how to move a robotic arm or completing a task similar to their own. Participants were then required to complete a similar task where the participants had to move a robotic arm to a target. Results from this study compared two groups: the first watched a video of an individual learning the task; the second was a video of an individual performing the task. The participants who viewed the individual learning the task performed better than the participants who watched a video of the individual only performing the task (Mattar & Gribble 2005). To find that observing the learning process is beneficial for learners is also supported by Hodges et al. (2007) who proposed a model of observational learning. Observational learning was defined as a situation where an individual focuses more on what the actor's perceived intention and focus is during the task, rather than completing the task itself. For example, in the study by Hodges et al. (2007) participants' focus of attention was not on how a task was performed but rather how the actor planned their movements and the focus of attention the actor used during the task. A couple of the main findings concluded by the authors were: that the sensory information used by the learner is based on the nature of the task and any surrounding constraints associated with completing the task, and not all features of a movement can be replicated based on observation alone (Hodges et al. (2007). A study by Weeks & Anderson (2000) explored participants performing a volleyball serve with varying doses of observational learning of an expert volleyball player prior to performing 30 volleyball serves. The participants were required to watch a video of an expert performing the skill, followed by practicing the skill. The three conditions of observational learning in the study were as follows: 1. Pre-practice group:

viewed 10 demonstrations of a serve, then performed 30 serves; 2. Interspersed demonstration group: viewed one pre-practice demonstration, performed a total of 30 serves, halting every 3 serves to preview another demonstration video; 3. Combination demonstration group: viewed 5 demonstrations prior to practice, 5 more after completing 15 serves, and then completed the last 15 serves for a total of 30 serves. The acquisition phase of testing was followed by two retention tests, one immediately after the acquisition and 48 hours post acquisition. In the condition where the participants pre-viewed the skill prior to and throughout acquisition, the retention test and acquisition phase had a similar pattern of results demonstrating that exposure to modeling before practice and during early stages of practice are optimal for performance in acquisition and retention. Collectively, these findings (Mattar & Gribble 2005; Weeks & Anderson 2000) suggest that the ability to recall a learned task and demonstrate improved performance on that task may change depending on the content of the information observed during the acquisition phase.

2. 2 LEARNING

Learning is the acquisition of knowledge and a relatively permanent change in knowledge of the task and ability to execute the learned motor skill due to practice and experience (Salmoni, Schmidt, & Walter 1984). Motor learning specifically is defined as the capability of a person to perform a skill and is inferred from a relatively permanent improvement in performance as a result of practice (Magill, 2011). Authors have demonstrated that an individual's task performance is subject to memory recall, but does not always require conscious awareness of it (Nissen & Bullemer, 1987). Nissen

& Bullemer (1987) assessed learning and attentional requirements in learning through evaluation of performance in a serial reaction time task. A serial reaction time task (SRTT) involves a sequence of 10- elements, where each element is responded to using the corresponding key and each response is timed (Nissen and Bullemer 1987). Nissen and Bullemer (1987) conducted several experiments, the first being a basic experiment involving repeating a random sequence; the second and third experiments involved dual-task processing with sequences, where the participants were required to perform the sequencing task while counting the number of tones that occurred. Nissen and Bullemer (1987) reported that performance measures in memory are strongly dependent on attentional processing. For example, Nissen and Bullemer (1987) performed several experiments, where each subsequent experiment increased in difficulty compared to the previous. The findings in experiment 1 involving a single-task did not parallel the findings in experiment 2 involving a dual-task as expected. In the first of three progressive experiments on implicit sequence learning, Nissen and Bullemer (1987) conducted a study measuring the response latency between two groups with the following conditions: 1) repeating pattern and 2) random pattern. Improvement in performance was defined by a decrease in reaction time. The participants in both groups were unaware of any occurring pattern. Nissen and Bullemer reported a 50% reduction in response latency, therefore faster responses in the repeat pattern group, and found very little improvement in the random pattern group. The improvement in performance over the blocks of trials in the repeat group versus the random groups demonstrates that learning is then determined by the divergence between the reaction

times in the repeating blocks versus the random blocks (Nissen & Bullemer, 1987). Overall, the study by Nissen & Bullemer (1987) demonstrates motor learning through improved performance represented as a decrease in reaction time with repeat practice, versus the consistent performance seen in participants with random practice. Experiment 2 involved a dual-task that required the participants to complete the sequence task while counting auditory tones. The attentional divide resulted in an increase in reaction time in the sequence task. The authors reported that the findings in experiment 2 were possibly due to the attentional divide that was required to process the sequence and the auditory tone. The same result was reported in experiments 2, 3 and 4 despite the addition of distractions during acquisition (Nissen & Bullemer, 1987).

2.2.1 Implicit and Explicit Learning

Implicit learning provides another avenue for how we learn. Implicit learning is defined as the acquisition of knowledge through repetitive attempts, where the participant is not consciously aware of the learning that is occurring (Reber, 1989). Prior experience and exposure to a skill can influence subsequent performance of a task through means of conscious knowledge, non-conscious knowledge, and the combination of both (Nissen & Bullemer, 1987). Reber (1989) proposed that a unique feature of implicit learning is that the effects of learning are robust over time despite distractions or interference while learning a task. A counterpart to learning implicitly is explicit learning, which is learning with conscious awareness and intention. These two concepts are not independent of one another; a learner may begin a task unaware of a sequence, and with repeated practice will gain conscious awareness of the sequence

(Seger, 1994). Related to motor learning, implicit learning can be achieved through repetitive practice of many motor tasks (i.e. a sequencing task).

Studies exploring implicit learning have studied a range of population groups from: typically developing (TD) children, TD adults spanning from young to old, to special population groups: individuals with amnesia, developmental coordination disorder, attention deficit disorder, Alzheimer's disease, and Parkinson's disease (Nissen & Bullemer 1987; Gheysen et al. 2013; Wilson et al. 2003; Lejeune et al. 2013). Researchers have studied different ways implicit and explicit learning independently yield better retention in learning (Jimenez & Vazquez, 2008; Dennis, Howard, & Howard, 2006; Maxwell, Masters, & Eves, 2002; Vinter & Perruchet, 2000; Magill, 1998; Curran, 1997; Cherry & Stadler, 1995; Seger, 1994; Willingham, Nissen, & Bullemer, 1989). A study by Dennis, Howard, and Howard (2006) explored using a SRT with young adults (20±1.64 years old) and older adults (71±4.3 years old) using visual and auditory stimulation. The participants completed 8 blocks of 80 trials, using the repeat sequence as used in the study by Nissen and Bullemer (1987). Blocks 1 – 6 and 8 were a repeat sequence, and block 7 was a random sequence. The objective of their study was to determine the motor and perceptual demands in a SRTT. The reported findings relevant to implicit learning were that both the young and older adult groups were able to learn the repeat sequence, where the mean RTs steadily decreased for the repeat sequence blocks.

In summary, authors have explored implicit learning with varying population groups, age groups, and using different types of tasks, and many factors involved in

SRTT such as: perceptual and motor demands, selective attention, and interference. This extensive exploration has continued to support the findings of Nissen and Bullemer (1987) regarding long-term retention of an implicitly learned task. That is, with a sequence task, consistent repeat practice yields better long-term retention versus random practice, even with the influence of distractions.

2.2.2 Sleep and Implicit Learning

Diekelmann, Wilhem, & Born (2009) reported in a review that sleep enhances consolidation of procedural memories and assists with recall in testing declarative knowledge (Walker et al, 2003; Fischer et al, 2002). Walker, Brakefield, Seidman, Morgan, Hobson, & Stickgold (2003) reported that sleep can assist in making our declarative memories of motor skills more resistant and stable to interference. The authors conducted a four-button sequential finger-tapping task, involving six participant groups of varying combinations of learning sessions and sleep-to-wake intervals, followed by re-test sessions. The authors used four different interval sessions to test motor skill learning over time: group 1: 36 hours; group 2: 24 hours; group 3: 24 hours plus two additional training sessions; group 4: 72 hours. Walker and colleagues (2003) concluded that motor skill learning is further enhanced with more nights of sleep for continued improvement, and furthermore proposed that stability in learning occurs within 6 hours post-learning.

Fischer, Wilhelm, and Born (2007) explored the effects of sleep on implicit learning in children and adults using a SRTT by means of a finger tapping task, and a 2D object identification task. The study involved two participant groups: children 7 – 11

years old and adults 20 – 30 years old. The participants were required to complete a series of button presses on a six-button response pad using the index, middle and ring finger of each hand. Each participant completed an acquisition session and retest session. The retest session composed of one of two delay periods: a period of wakefulness 11 hours post-acquisition or a period of overnight sleep 11 hours post-acquisition. Authors reported that both age groups demonstrated improved learning following a period of sleep, by means of decreased reaction times and decreased errors compared to the groups who did not sleep. The adult group demonstrated a greater decrease in reaction time in both the SRTT and 2D object identification task following a period of sleep, versus a period of wakefulness. With the group of children, the effect of sleep on retention and performance was dependent on the type of task performed. The child group demonstrated a much smaller improvement in the SRTT than the adult group. The authors concluded that the effects of sleep on learning are dependent on age and stage of development (Fischer, Wilhelm, & Born 2007).

2.2.3 Distractions and Fostering Learning

Many dual task studies have evaluated the capacity for learning in the presence of a distraction. For example, a button pressing task while also counting auditory tones, or a pursuit rotary task with tone counting (Nissen & Bullemer, 1987; Cohen, Ivry & Keele, 1990; Eysenck & Thompson, 1966; Rowland & Shanks, 2006; Jimenez & Vazquez, 2008). In studies evaluating learning with a distraction the presence of a distraction hindered the participants' performance, but did not affect task knowledge gained, as measured by retention and transfer tests. Eysenck & Thompson (1966)

measured performance of a pursuit rotary task (Lafayette) in five groups of thirty participants. A pursuit rotor task uses a stylus and turntable with a small target, the turntable turns and the individual is required to maintain contact with the target as it spins. The device turn speed can be set and the number of times the stylus misses the target is also recorded. The pursuit rotary task involved no distraction, little distraction, medium distraction or considerable distraction, and a control group. The participants were grouped and given massed practice with the assigned level of distraction. The task involved pressing a left or right foot pedal in response to one or two distinct signals, a high or low pitch tone while also keeping the stylus on target of the rotating turntable. A distraction tone was presented in three of the four conditions. The conditions were as follows: without a tone, one with an easy distraction of 20 tones per minute, a medium distraction of 47 tones per minute, and a considerable distraction with 72 tones per minute (Eysenck & Thompson 1966). Authors reported that participants' performance on the task was affected in proportion to the amount of distraction given, but found that though performance declined, performance in retention and transfer demonstrated that what is learned is retained despite distractions. Following the testing session, one half of the participants performed a retention test involving no distraction where the results presented a linear increase in performance from the practice sessions to the retention test supporting that distractions during the practice sessions do not affect consolidation.

Nissen & Bullemer (1987) conducted a sequencing task study with similar conditions where the level of distraction ranged from no distraction in the first experiment to dual-task conditions in the following experiments. Nissen & Bullemer

(1987) reported that in experiments involving a single task, the mean reaction time decreased for the repeat sequence, but found no change when using a random sequence.

Progressing from the study by Nissen and Bullemer (1987) involving an implicit sequence learning task, several studies have explored whether learning can be amplified or hindered with the addition of other sensory information (Teder- Sälejärvi, Di Russo, McDonald & Hillyard, 2005; Rowland & Stein, 2007; Dennis, Howard Jr & Howard, 2006). Teder- Sälejärvi, Di Russo, McDonald, and Hillyard (2005) conducted an implicit learning task using three conditions: an audio condition using an intense noise burst, a visual condition using a bright flash of light, and a third condition that was a combination of the first two conditions. The authors found that participants responded to the bimodal target much faster and were able to identify the target more accurately than the uni-modal target stimuli. Studies by Abrahamse et al. (2008, 2009) explored a different source of sensory information using vibro-tactile and visual information for learning a sequence task. The authors found that the addition of tactile stimulation did not benefit the bimodal training group, reporting that the vision and bimodal groups performed similarly in both testing and in the transfer phase, where the tactile only group did not perform as well as the vision and bimodal groups. Overall, participant's implicit acquisition of a skill appears to be dependent on exposure to varying types of interference.

2.2.4 Multisensory

In a review by authors Shams and Seitz (2008), a summary of multisensory interactions in various tasks and settings indicate that the multisensory stimulation provides repetitive exposure necessary to gather more information regarding a task, versus that of uni-sensory exposure. That is when an individual is exposed to more than one sensory stimuli, it exposes the individual to more information for processing. Furthermore, reports from the memory literature have shown that exposure to multisensory training results in faster recognition and responses than uni-sensory training, as multisensory activations contribute to more efficient retrieval processes by utilizing more than one sensory system to process information. Seitz et al (2006) conducted a study comparing audio-visual and visual stimuli during a motion detection and discrimination task reporting that the audio-visual group reported a greater percentage of correct responses than the visual group immediately after the first session, and continued to record a greater percentage of correct responses upon the next ten consecutive sessions. The participant group that under went audio-visual training reached an increase of up to 60% of improvement more quickly than the group that trained in the visual only condition (Seitz, Kim, & Sham, 2006).

2.3 PERFORMANCE

2.3.1 Video Gaming and Performance

The role of video games in motor learning has been extensively explored where much of the interest has focused on what effect video games have on an individual's ability to perform similar tasks, non-similar tasks, attentional control, learning, and the development of processing speed (Green & Bavelier, 2003; Green & Bavelier, 2007;

Dye, Green, & Bavelier, 2009; Bavalier, Achtman, Mani, & Focker, 2012; Green & Bavelier, 2012; Bavelier, Green, Pouget, & Schrater, 2012). The possible effects of video game experience on attentional capacity and motor learning of a novel task, as well as specific experience with action and puzzle video games, are explored below.

2.3.1.1 Attentional capacity

Green and Bavelier (2003) executed a five-part experiment involving young adult habitual video-game players and young adult non-habitual video-game players, 18 – 23 years old, to measure the change in visual attentional capacity due to video game usage. The habitual video-game players were described as participants who used action video games a minimum of four days a week for a minimum of one hour a day within the past six months. The non-habitual video game players were described as participants who had little to no video game usage in the past six months. The study involved five experiments: 1. Flanker compatibility test, 2. Enumeration, 3. Useful field of view, 4. Attentional blink, and 5. Training: involving experiments 2- 4. Throughout the five-part study, participants were required to complete a target-identifying task involving distractors of varying difficulties and varying levels of video game training prior to testing. Green and Bavelier (2003) used compatibility tasks with both participant groups to measure each participant's capacity for attentional resources. In the compatibility tasks the habitual video-game players demonstrated consistent results as the task difficulty transitioned from easy to hard, whereas the non-habitual video-game players demonstrated a decreased ability to successfully complete the task as the difficulty moved from easy to hard. In experiment 5, the non-habitual video game players were

trained in video game playing for an extended duration resulting in their attentional capacity increasing with better performance results in the compatibility tests. Green and Bavelier (2003) reported that overall, the habitual video-game players demonstrated greater visual attentional capacity in comparison to the non-habitual video-game player group. In a study by Green and Bavalier (2007) exploring video game players and non-video game players the results were consistent with the findings of Green and Bavalier (2003). The study involved action video game players and non-action video game players completing a matching test involving target shapes with distractor shapes appearing simultaneously and asynchronously. The action video game players were able to determine the orientation of the shape even with the presence of the distractor more accurately than the non-action video game players. Supporting the authors' theory that action video game playing may enhance how well one is able to process visual information (Green and Bavalier, 2007). In a review by Bavalier, Green, Pouget, & Schrater (2012), the authors summarized the literature exploring attentional demand in those who are classified as action video game players and non-action video game players. Action video game players demonstrated better performance results than non-action video game players in top-down attentional control (a processing strategy breaking down information into steps), but no significant differences in bottom-up attentional control (a processing strategy piecing together a system's components).

2.3.1.2 Action and puzzle video games in training

A study by Subrahmanyan & Greenfield (1994) tested the effects of video game playing and computerized game playing on spatial skills. The study tested 61 children

(n= 33 girls) 10.5 – 11.5 years old, dividing the group into two: control group (n= 18 girls, 13 boys) and an experimental group (n=15 girls, 15 boys). The experimental group played an action video game for 2 hours 15 minutes across three equal sessions; the control group played a puzzle for the same time duration, broken into the same duration of sessions. The participants were tested in 10 subtests on a computer: 5 were static spatial skills and 5 were dynamic spatial skills. In the pre-assessment, the authors (Subrahmanyan & Greenfield, 1994) reported performance in the computerized spatial skills battery tests were greater for boys than girls. But, in post-assessment there were no significant differences between genders. Overall, video game practice was significantly more effective in improving spatial skills than computerized puzzle games.

Authors Green, Pouget, & Bavelier (2010) conducted a study testing video game players (VGP) and non-video game players (NVGP) using three experiments: a visual motion direction discrimination task, an auditory tone location discrimination task, and video game training. In the first experiment VGP and NVGP were tested in a dynamic random dot motion task identifying whether the target is on the left or right by pressing one of two key presses. They were advised to respond as quickly and as accurately as possible. This part of the study looked at how video game playing affects the ability to respond accurately and quickly. The authors reported that VGP were able to learn and adapt to the task, making better guesses for the next move versus the NVGP group. Experiment 2 involved a similar task to experiment 1 but used three different auditory tones: low, medium and high tones, where the VGP logged results 48% better than the NVGP. In experiment 3, the NVGP participated in 50 hours of video game playing,

where the participants were assessed pre and post testing where Green, Pouget, & Bavelier (2010) reported an increase in accuracy by the NVGP. Overall, the authors (Green, Pouget, & Bavelier, 2010) concluded that with experience in action video game playing participants made more efficient use of auditory and visual sensory information versus non-video game players.

A review by authors Dye, Green and Bavelier (2009) reported that across several speed-choice reaction time task studies the findings were consistent in that participants who frequently engaged in action video-games, such as *Halo* and *Grand Theft Auto,* consistently demonstrated better capacity for attentional focus, reaction time, and better hand-eye coordination than participants who do not engage in action video-game playing and instead engaged in games like *Tetris*.

2.3.2 Perception and Action

Perception and action coupling involves the spatial and temporal coordination of vision and limb to perform coordinated movement tasks (Magill, 2011). Authors Lejeune and colleagues (2013) have argued that a serial reaction time task is motor based, but the study by Abrahamse and colleagues (2008) involving a visuo-tactile task supports that with the exposure to varying degrees of sensory modalities performance can be affected, thus perceptual contributions may also be involved.

Gheysen, Van Waelvelde, & Fias (2011) studied the effects of learning in a sequencing learning task where the participants performed the task using button presses on an independent device in response to targets on a computer monitor. The authors noted that though SRTT performance requires simple task demands, the task

required attentional demand from both perceptual contribution and the motor system since optimal performance in the task requires simultaneous processing of visuo-spatial information, stimulus-response mapping and motor selection (Gheysen et al. 2011). Gheysen et al (2011) found that general learning of the visuo-motor task was acquired over time and all participants across both groups, control and development coordination disorder (DCD), demonstrated some amount of explicit awareness during test recall. Lejeune, Catale, Willems, & Meulemans (2013) reproduced the study by Gheysen at al. (2011) paralleling the use of a serial reaction timed task, but modified the task slightly. Lejeune et al. decreased the motor demand by using a touch screen for the participants' responses; in other words they decreased the amount of perceptual-motor transformations required to complete the task (i.e., participants did not have to press a button that was physically removed from the stimuli). Both studies, Gheysen et al. (2011) and Lejeune et al. (2013), demonstrated successful acquisition of the task but differed in performing the task to demonstrate improved learning. Both studies used similar population groups: a special population group (DCD group) and a control group, but the participants with DCD in the study by Gheysen et al (2011) failed to learn the sequence successfully despite being able to recall the sequence in the explicit awareness test. Lejeune et al (2013) modified their study by decreasing the motor demand and found that both groups demonstrated similar improvement in performance of the sequence task as defined by a decrease in reaction time per block of trials.

A combination of perception and action are required to complete daily motor tasks, where each component plays a specific role with varying weight depending on the

task. For example, pressing buttons, using a touch screen, or a stylus. Based results reported by Gheysen et al (2011) and Lejeune et al (2013), the relative perceptual-motor demands of a task may impact performance and learning of that task.

2.3.3 Audio and Visual

As previously noted, many authors have explored serial reaction time tasks using visual conditions (Nissen & Bullemer 1987; Wilson et al 2003; Gheysen et al 2011; Lejeune et al 2013), and other cross-modal sensory conditions such as vibro-tactile and vision (Abrahamse, van der Lubbe & Verwey, 2008; Miller, 1982; Abrahamse et al 2009). Corneil and colleagues (2002) looked at saccadic reaction times exploring the following conditions: visual only, auditory only, and audio-visual. Saccadic reaction times are quick eye movements directed toward targets. Corneil et al (2002) reported that audio-visual saccades were more accurate, and had better saccadic reaction times compared to visual only or auditory only saccades. Miller (1982) conducted a bimodal detection task with three conditions: visual only, audio only, and audio-visual arguing that the availability of multiple channels of information allows for faster processing of information. Focusing on reaction time, findings of both studies (Corneil et al, 2002; Miller, 1982) report a decrease in reaction time in the bimodal condition versus the single sensory conditions, implying an improvement in performance.

A study by authors Teder- Sälejärvi, Di Russo, McDonald, and Hillyard (2005) reported similar findings in reaction time when testing cross-modal integration of audio and visual stimuli. The participants in the study were required to respond to one of eight possible audio and visual combinations:

A=audio V=visual $_L$=Left $_R$=Right		
A_L	Combo 1	
V_L	Combo 2	
A_L V_L	Combo 3	
A_L	Combo 4	V_R
V_L	Combo 5	A_R
	Combo 6	A_R
	Combo 7	V_R
	Combo 8	A_R V_R

Figure 2: Audio-Visual Combinations
Figure adapted from Teder-Sälejärvi, Di Russo, McDonald, & Hillyard (2005)

Two pairings of LEDs and speakers were placed on the left and right of the participant, and placed 1.20m away. In overall stimuli detection, the visual target was detected more accurately than the auditory target in the unimodal task, but in the bimodal task was detection of audio and visual was more accurately detected with faster RTs. The same pattern was found when analyzing reaction times with the unimodal to bimodal conditions, where the participants demonstrated faster RTs in the visual condition compared to the auditory condition, and the participants demonstrated even faster reaction times than the visual condition in the bimodal condition. When analyzing the detection rate and reaction times of the bimodal condition in same versus different target locations, there were no significant differences between the two (Teder-Sälejärvi, Di Russo, McDonald, & Hillyard, 2005).

2.3.3.1 Auditory and Visual Development in Children and Adults

Studies exploring the rate of development in infancy through to adulthood have found that children between the ages of 3 – 5 years are able to distinguish and declare basic speech sounds, with further improvement in this skill gained between 6 – 8 years of age (DiSimoni, 1975). A study by Birch (1978) found that school-age children who are 7-10 years old are able to perform well, with results comparable to a healthy adult population in an auditory matching task, therefore demonstrating that school-age children have reached comparable adult levels in detecting auditory tones by 10 years old. Similar findings have been discovered for the development of visual perception in children, where 8 – 12 year-olds' visual perception is developed to near adult levels (Haywood & Getchell, 2009).

Adults and children demonstrate similar performance ability to complete single stimulus tasks once a typically developing child reaches the age of 7 – 9, when their vision and audition near adult levels. An unpublished study by authors Czyzewska, Hill and Lewicki (1991), cited in Lewicki, Hill, & Czyzewska (1992), conducted a visual search task study in preschool children that indicated the 4 -5 year-old children could implicitly acquire knowledge about patterns in a task. Moving up in age categories to 5 – 12 year- olds, Mayberry, Taylor, & O'Brien-Malone (1995) conducted an implicit learning task in children. The learning task used by Mayberry and colleagues was adopted from the matrix developed by Lewicki in an earlier study that required the participant to detect and process co-variations of information of a picture on a 4x4 matrix and two other stimuli occurring, the first group with children 5 – 7 years of age,

and the second group of children 10 – 12 years of age. The results of the study demonstrate that the 10 – 12 year old group performed better overall in comparison to the 5 – 7 year old group, specifically in explicit knowledge of the task. In another implicit sequence learning task Thomas and Nelson (2001) adopted the random and ten-item repeat trials pattern used by Nissen and Bullemer (1987) to explore developmental differences in children between 4 – 10 years of age. In the study by Thomas and Nelson (2001) 50% of the participants were randomly selected to receive explicit information about the pattern. The trials alternated between random and repeat trials in the learning phase as follows:

100 random trials
200 repeat trials
100 random trials
100 repeat trials

The findings indicated that overall all groups showed improvement demonstrating that there was not a significant difference in learning. The 4 year old group showed 72% of sequence specific learning (SSL), the 7 year old group showed 87% of SSL, and the 10 year old group showed 100% of SSL. The findings by Thomas and Nelson (2001) are consistent with that of Meulemans and colleagues (1998) supporting that the repeat sequence can be learned just as well among varied ages of children.

Cherry and Stadler (1995) conducted a sequence task focusing on young adults and older adults. Cherry and Stadler (1995) evaluated the performance between the two groups of adult participants (young adult group mean age: 22.9 years; older adult group mean age: 67.2 years) who learned a set of non-verbal sequences. The findings indicated that both groups performed well overall, but when analyzing each participant

separately it was found that older adults with higher ability (defined as years of education and type of occupation) obtained results similar to the young adult group, whereas the older adults with lesser ability performed more poorly compared to the young adult population group (Cherry & Stadler, 1995).

2.3.4 Reaction Time

Reaction time is the time taken from a 'go' signal to initiation of a response, and is one of the components of response time (Figure 3). In serial reaction time tasks, reaction time is the time from stimulus to response, and is an important indicator of performance; a decrease in response latency demonstrates ability to process information more efficiently.

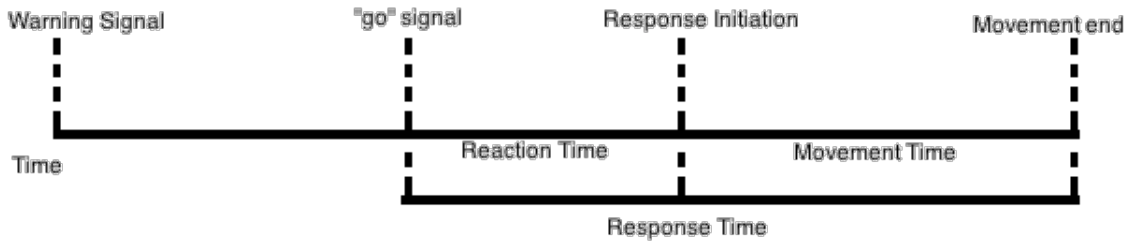


Figure 3: Components of Response time
Adapted from Schmidt & Lee, 2014

The Henry-Rogers Experiment by Franklin Henry and Donald Rogers in 1960 explores a simple reaction time task involving different complexities ranging from a single movement to several movements, with each consecutive condition building on the previous condition. Although movement complexity increased, the initial movement in each condition remained constant regardless of the complexity of the task. Reaction

time increased proportionately as the task complexity increased which supports the position that rapid movement in reaction time tasks require an attentional demand to movement planning (Henry & Rogers 1960).

Research by Henry & Rogers (1960) fostered further exploration into reaction time testing where Klapp (1996) conducted an experiment producing the following set of findings: reaction time increases as more limbs are introduced and must be coordinated in the movement, and reaction time increases as the duration of the movement becomes longer, and when more elements are added to the movement.

In a SRTT, reaction time is a key performance variable. As participants refine their movements and become more efficient in planning and execution, their reaction time will decrease. In a button-response style SRTT, the participant uses the index and middle fingers of the right and left hand, thus increasing the complexity because they must coordinate two digits and two limbs to press the correct button corresponding to the target. The length of time from the 'go' signal to response initiation, RT, determines how refined the individual's movement planning is, but as a task becomes more complex, the time taken for movement planning also increases.

Shorter RTs are indicative of more efficient movement planning and greater efficiency in response initiation. In a SRTT task, the greater reduction in response latency, the more proficient the individual has become at the task.

2.3.4.1 Serial Reaction Time Tasks (SRTT)

SRTT involve a chained sequence of discrete movements where performance is measured by the ability to respond to the sequence as quickly and accurately as possible. There have been many SRTT studies that have explored tasks focusing on a single sensory (Abrahamse & Van Der Lubbe, 2008; Abrahamse, Van Der Lubbe, & Verwey, 2009; Nissen & Bullemer, 1987), dual-sensory, (Abrahamse & Van Der Lubbe, 2008), and dual-task (Cohen, Ivry, & Keele, 1990) studies.

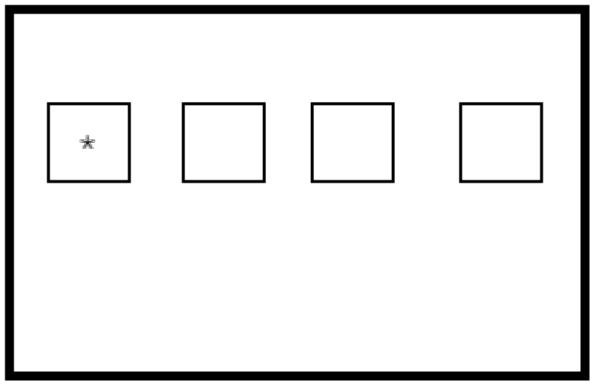


Figure 4: Four-choice testing
Example of the monitor and four squares. The asterisk displayed determines which button to press. 3, 5, 7 or 9 respectively from left to right.

There were two groups of participants used in the study by Nissen and Bullemer (1987): random pattern group and repeat pattern group, where both groups were unaware of the sequence, and were advised to respond both quickly and accurately in response to the target stimuli. In the study, the median RTs of both groups were compared where the random group did not improve, but the repeat group's RTs began to decrease as they went through numerous practice trials. The authors propose this finding reflects the amount of learning that is occurring across both groups. In other words, with repeat practice of the sequence, the participants began to respond with greater accuracy and

shorter reaction times. An example of demonstrating acquired learning, a study by Wilson, Maruff, and Lum (2003), explored sequence learning of a visual only task with a 10-element long sequence task on a small population of children with developmental coordination disorder (DCD) (n=10, 8 boys) and a small group of age-matched controls (n=10, 8 boys). Based on the results, the authors concluded that both groups, DCD and control, were unaware of the pattern throughout testing, and both groups improved at similar rates demonstrating increased performance in procedural learning.

A study by Wilson and colleagues (2003) used a SRTT similar to other SRTT studies by Gheysen et al (2011), Lejeune et al (2013) and Nissen and Bullemer (1987) using a repeat sequence task. Some of the major differences between the study performed by Wilson et al (2003) and the similar studies listed above had been the use of a smaller participant group, the study by Wilson et al (2003) had ten participants in the DCD group and age-matched control group, the other major difference had been that Wilson et al (2003) used five blocks of testing, where blocks 1 – 4 were a repeat sequence, and block 5 was a random sequence.

Study	Block 1	Block 2	Block 3	Block 4	Block 5
Wilson et al 2003	Repeat	Repeat	Repeat	Repeat	Random

Table 1: Block designs
Block design of study by Wilson et al (2003).

Following the study by Wilson et al (2003), Gheysen et al (2011) reproduced the study with the following modifications: increase in participant number and the addition of a sixth block as a repeat sequence. By increasing the participant number and adding another block of repeat sequence practice, Gheysen et al (2011) reported a significant difference between the DCD group and control group, this finding was different than what Wilson et al (2003) reported. Gabriel, Stefaniak, Maillart, Schmitz, & Meulemans (2012) performed a study with two similar experiments, only differing in method of response. Gabriel et al. (2012) reported in their study that performance on an SRTT can be affected by deficits in manual dexterity or in difficulties matching the targets to the response keys. Lejeune et al (2013) modified their reproduction of the previous study by Gabriel et al (2012) and decreased the motor demand by using a touch screen instead of the button presses. The participants of the study were required to use a stylus to touch the appropriate target on the touch screen. The results of the study indicated that both groups (DCD and control) demonstrated an increase in performance, such that there was no difference in performance between the two groups. Though, a limitation to the Lejeune et al (2013) study would be that the motor demand had been greatly decreased, slightly altering the task difficulty in the study. Despite slight adjustments in each study, Wilson et al (2003), Gheysen et al (2011), and Lejeune et al (2013) were able to demonstrate an increase in performance, reinforcing that learning occurs even without awareness in both typically developing children and DCD group participants.

A study using vision and tactile sensory modalities in a SRTT (Abrahamse, van der Lubbe & Verwey, 2008) explored using the following conditions: vision only, tactile only, and vision and tactile, where they found that visual aid in performing the SRTT yielded better performance results than using a vibro-tactile stimulation. Transfer effects were evaluated between the two sensory modalities and found that the differences reflected between groups had been on performance only, and not on sequence learning, which did not show any significant difference. Abrahamse, van der Lubbe & Verwey (2009) expanded on the conditions by adding a bimodal condition involving visual and tactile in a SRTT. The results in the visual condition and the bimodal conditions were found to have similar performance results, where as the tactile only condition replicated the previous study in having longer RTs.

Overall, the literature demonstrates that using serial reaction time tasks with various sensory modalities consistently fosters the ability for implicit learning to occur. In the literature, vision has been a consistent condition used and has been combined with different forms of audition, and tactile stimulation to either enhance or distract the participant. Yet, using a form of audition relevant to the target stimulus has not yet been explored in the visual condition with a serial reaction time task.

The current study will explore using visual and auditory cues in a serial reaction time task in typically developing children 7 – 9 years old, and typically developing adults 18 – 35 years old. The purposes of exploring a uni-modal task (vision) and bimodal task (audio-visual) in the two age groups is to see which sensory combination yields

better performance results and better retention in learning, and what the comparison between age groups are with each condition.

2.4 Objectives

The purpose of the current study was to determine if unimodal (visual) or bimodal (audio and visual) stimuli, yield different patterns of learning for children versus adults, using a serial reaction time task (SRTT) using a repeat sequence as originally presented in the literature by Nissen and Bullemer (1987). The populations were typically developing children 7 – 9 years old, and typically developing adults 18 – 35 years old.

2.5 Hypotheses

Based on the literature exploring implicit learning in a SRTT and the effects of multisensory learning, I propose that both the typically developing child and adult groups will implicitly learn the repeat sequence and will have shorter reaction times in the audio-visual condition versus the visual only condition. Comparing the child and adult groups in the visual condition, I anticipate that both groups will learn the repeat sequence at a comparable rate, where as in the audio-visual condition, I anticipate that the adult group will have shorter reaction times compared to the child group due to an increased ability to efficiently process multisensory information.

2.6 Summary

In the current study, the participants were asked to 'catch' the image of an animal on the computer monitor as quickly as possible by pressing the button that corresponds with that image. The sequence in which the animals were presented was a 10-element repeating sequence: 1, 3, 4, 2, 3, 1, 5, 2, 1, 4. As the 10-element sequence repeats, I predict the participants' button responses will become more efficient and therefore decrease their reaction times as found in previous studies (Nissen & Bullemer, 1987; Wilson, Maruff & Lum 2003; Dennis, Howard, & Howard, 2006; Gheysen, Van Waelvelde & Fias, 2011; Lejeune, Catale, Willems & Meulemans, 2013). Since the study by Nissen and Bullemer (1987) exploring implicit learning in a SRTT, authors have continually explored the concept of learning through a repeat sequence by increasing the complexity of the task with the addition of a dual-task (Wilson, Maruff, & Lum, 2003), changing the perceptual and motor demand by modifying the type of response method used (Dennis, Howard, & Howard, 2006), focusing on other aspects of the task related to learning, such as focus of attention using a search task (Jimenez & Vazquez, 2008), and using a variety of population groups ranging from special population groups (Gheysen, et al, 2011; Lejeune et al, 2013), and children (Thomas & Nelson, 2001). The common finding among studies has been that practice with a repeat sequence fosters implicit learning despite modifications made to the task or the population group studied.

Studies exploring the effects of multisensory learning (Seitz, Kim, & Shams, 2006; Dennis, Dennis, & Howard, 2006; Shams & Seitz, 2008) have reported findings

that the addition of audition to visual learning facilitates faster learning versus the use of visual learning alone in tracking tasks and stimulus response tasks.

The performance measures that were evaluated to infer learning include the participants' reaction time trial-to-trial, median reaction time from block-to-block, and response accuracy.

Chapter 3: Method

3.1 Participants

Eighteen typically developing (TD) children between 7 – 9 years old (mean = 7.7 years (SD = 0.94), 6 females) and twenty typically developing (TD) adults between the ages of 18 – 35 years (mean = 23.1 years (SD = 5.08), 13 females) participated in the current experiment. The adult group had eleven participants in the visual only condition, and 9 in the audio-visual condition. Data collected for a participant of the audio-visual condition had been incomplete and therefore eliminated from analysis. Participants did not have any knowledge of the purpose of the study or the sequence used. Both the children and adult participants completed a demographics questionnaire containing the following information: gender, age, handedness, normal vision or corrected-to-normal vision, normal hearing or corrected-to-normal hearing, whether they participate in video or computer games, including the frequency per week and type: action or puzzle, and whether they participate in physical activity, including the frequency per week. Handedness was determined by self-report and observation of hand used to fill out the

assent/consent form. A summary of participant demographics is presented in Table 2. The typically developing adult participants in the study completed an informed consent form. The typically developing children completed an assent form, and a parent or legal guardian of the typically developing child completed a parent/legal guardian consent form. All procedures were approved by the Education and Nursing Research Ethics Board at the University of Manitoba.

	Adult Group (n = 20)	Child Group (n = 18)
Age		
Mean	23.1 years	7.7 years
SD	5.08	0.94
Range	18 - 35 years	7 - 9 years
Gender		
male/female	7/13	12/6
% male	54%	66.6%
Handedness		
Right/Left	20/0	18/0
Vision		
Normal	11	17
CTN	9	1
Hearing		
Normal	20	18

Table 2: Participants Demographics
CTN: corrected to normal

3.2 Design and Apparatus

A between participant design was used for the present experiment. There were two different age groups: typically developing adults 18 – 35 years old and typically developing children 7 – 9 years old. Each of these age groups were divided into two conditions: visual and auditory-visual for a total of four groups:

1. Adult – Visual Condition

2. Adult – Audio-Visual Condition
3. Child – Visual Condition
4. Child – Audio-Visual Condition

The SRT task involved a four choice response task, where four 3.81 cm x 3.81 cm squares appeared across a 15" display monitor (refresh rate: 60Hz, resolution rate 1920x 1080)(figure 5).

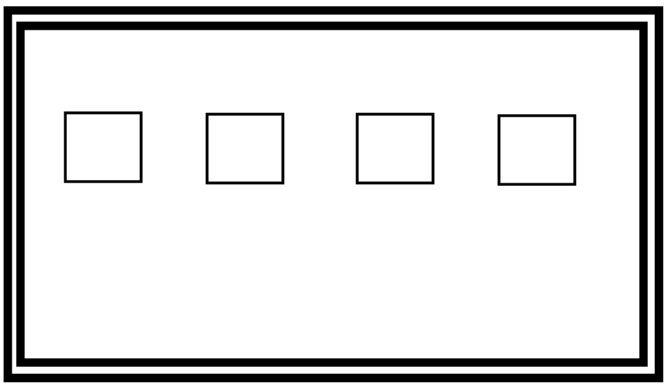


Figure 5: Testing Display
Rendition of the monitor where the images appear (not drawn to scale).

A ten item repeating sequence and a random sequence were presented to participants by displaying one of four animal images on the screen (figure 7B – figure 7E). Each animal image corresponded to one of the locations where the numbers 1, 2, 4 and 5 coincided with the images of a cartoon cat, bird, pig and dog: cat = 1; bird = 2; pig = 4; dog =5. The numbers served as a coding system used for data analysis. The 10-item repeating sequence used in the present experiment is the same sequence used in related studies (Nissen & Bullemer 1987; Wilson et al 2003; Gheysen et al 2011; Lejeune et al 2013). The specific repeating sequence was as follows: cat (1), pig (4), dog (5), bird (2), pig (4), cat (1), dog (5), bird (2), cat (1), and dog (5).

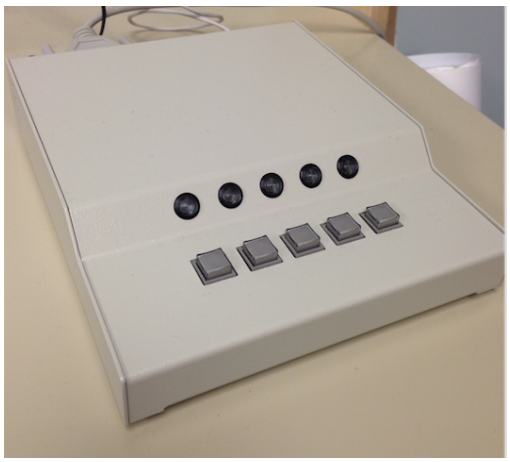


Figure 6: Serial Response Box
Serial Response Box (SR Box) is a response collection device made specifically for the experimental programming software E-Prime 2.0 from Psychology Software Tools, Inc..

The response box used was a Serial Response box (SRBox) (figure 6) custom built for the E-Prime 2.0 software (Psychology Software Tools, Inc). There were five buttons side-by-side in a horizontal row on the SRBox. For the purpose of the present study participants responded using four of the five buttons on the SRBox (Psychology Software Tools, Inc), specifically the two outer buttons from the left and right side, ignoring the centre button. The participants were not informed of the sequence prior to or during testing. The buttons are press and release buttons each measuring 1 cm by 1 cm. Participants responded to the targets by placing the index and middle finger of each hand on the two buttons to the left and to the right of the centre button.

The images used for testing were chosen based on being four commonly known animals: dog, cat, bird, and pig (figure 7B – figure 7E). Each image appeared in one of four boxes on the display monitor simultaneously after each other in either the repeating sequence or a random sequence on the display monitor. The sound files used in the

audio-visual condition played through standard computer speakers. Each sound file was 20msec and corresponded with the animal presented, i.e. cat image was accompanied by a meow sound clip, the bird image was accompanied by a chirp sound clip, the pig image was accompanied by an oink sound clip, and the dog image was accompanied by a bark sound clip. Each block was initiated by the investigator. First, a blank set of squares appeared for 1000ms before the first target appeared. Consecutive targets appeared as soon as the participant pressed the corresponding button to respond to the target. Accuracy, reaction time, and response time data was collected through custom software designed in E-Prime 2.0 (Psychology Software Tools, Inc).

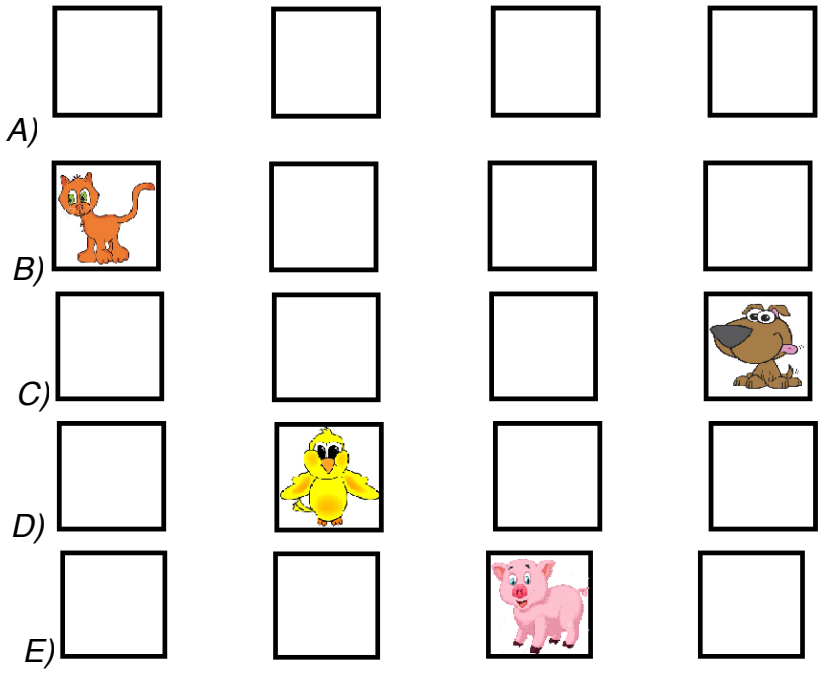


Figure 7: Images in testing

The row of figures above are examples of the images that participants saw during the experiment. The above images are not drawn to scale. In the experiment, the squares are centered on the screen where each square is 3.81 cm by 3.81 cm and placed 3.81 cm apart A)

The blank horizontal boxes that is initially seen by participants at the start of each block of testing. B) - E) The images of the common animals presented in testing.

3.3 Procedure

On Day 1 of testing the TD children participants and TD adult participants were assigned to one of the two sub-groups: visual condition group or the audio-visual condition group. On Day 1 participants completed testing in only the condition assigned. Group assignment alternated as participants took part in the study. The alternating conditions for each participant occurred in each age group independently, i.e. participant 1: adult – visual condition, participant 2: adult – audio-visual condition, participant 3: adult – visual condition, etc). Once divided and assigned into the designated group, each participant completed a familiarization session. The testing session followed the familiarization session with 6 blocks of acquisition (blocks 1-4 and 6 included ten repetitions of the sequence and block 5 included a random sequence). A mandatory and timed 60-second break was taken after each block of testing. Day 2 of testing occurred approximately 24 hours later and included testing using the same response box as was used during day 1 (SRBox) and the Explicit Awareness test that was completed manually with pen and paper. The test using the SRBox included a block in each of the following: a retention test (performance of the sequence in the same conditions as day 1), transfer test (performance of the sequence in the opposite condition from day 2) and a motor skill recall test (auditory-only test: performance of the sequence with only auditory cues). The order of the retention test, transfer test and auditory-only test rotated to ensure each possible combination of testing was tested

equally across participants. A mandatory and timed 60-second break was taken after each block of testing.

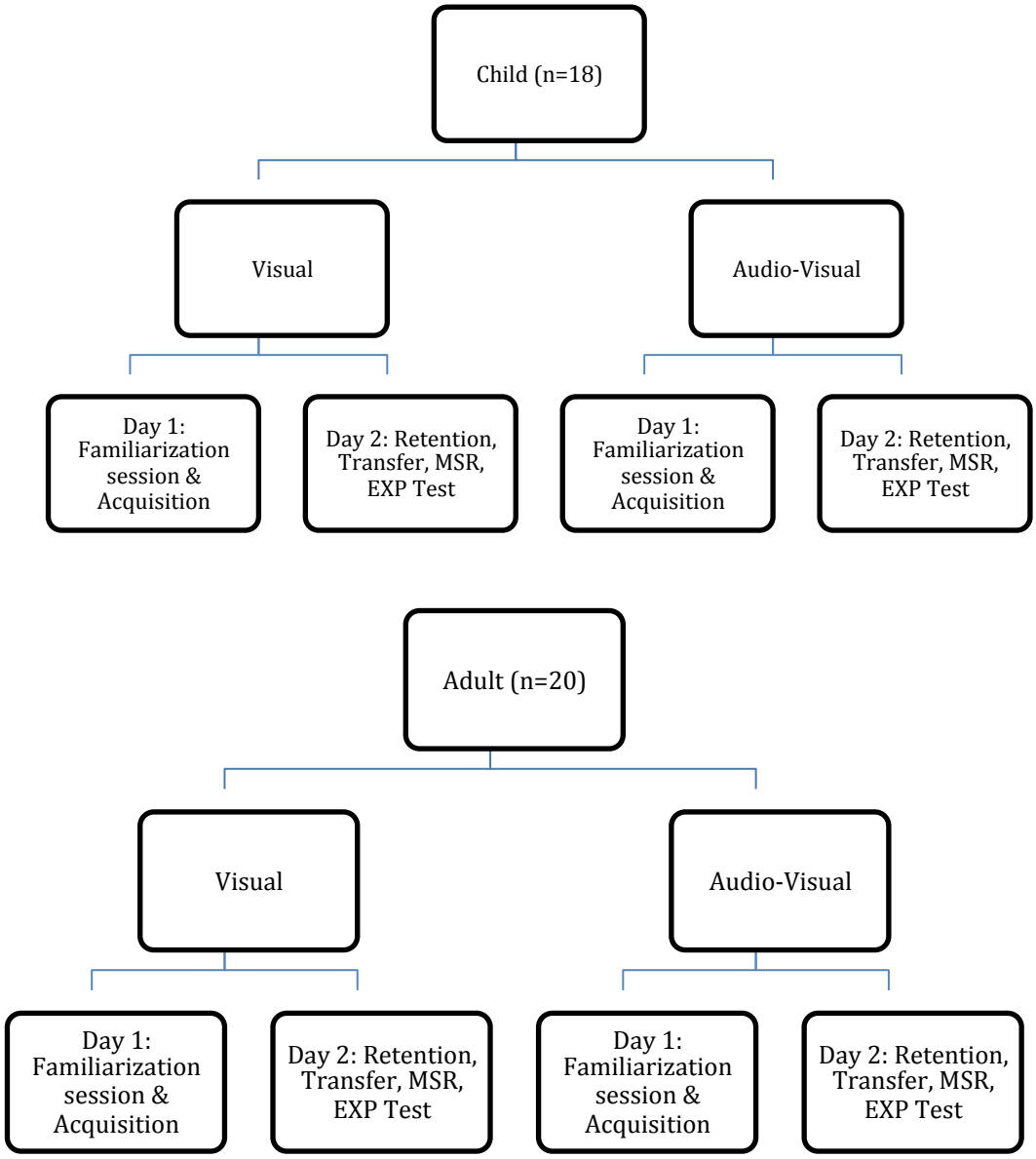


Figure 8: Process of testing for participants

An example for how testing occurred is as follows: Participant 01-1 (adult) completed testing on Day 1 in the visual condition for acquisition blocks 1 – 6. The participant completed a 60 second timed break after completing each block of practice. On Day 2 of testing, the participant completed one block of the following retention tests and transfer test in this specific order: visual only condition, audio-visual condition, and the audio-only condition. These tests were completed using the SRBox and computer monitor, and was followed by a manual completion of the explicit awareness test completed with pen on paper.

The time and date of each testing day and the start time for each block was recorded for each participant. Any necessary notes were recorded in the event that the information needed to be cross-referenced with the data collected, such as the start time for each block and confirmation of whether the participant completed the block of testing without any issues or distractions that could affect their results.

3.3.1 Testing Day 1: Familiarization Session

All participants first completed the same familiarization block of trials. The familiarization condition was a 20 button press random sequence; the sequence used was different than what was used for the random block during the testing session. The purpose of the familiarization condition was to ensure all participants had an opportunity to familiarize themselves with the images on the screen, practice using the SRBox, and had the same amount of practice prior to the testing sessions. The following script was used to describe the familiarization session:

Familiarization Session: "*You will be completing the baseline session. This will allow you to become familiar with seeing the pictures on the screen and using the response box. When completing the baseline session, the pictures of the animals on the screen will appear without sound*."

3.3.2 Testing Day 1: Familiarization and Acquisition Session

The testing session was completed during day 1 of testing. Whether the participant completed the testing session in the visual condition or audio-visual condition, the number of blocks remained the same. Testing consisted of six blocks total: blocks 1 – 4 and 6 (immediate retention) were the repeating sequence, and block

5 was a random sequence. The random sequence in block 5 was the same for every participant. Each block consisted of 80 button presses, which resulted in the 10 item repeating sequence being repeated 8 times within one block. The random block was placed between the last two repeat blocks to account for the possibility of fatigue by performing a sequence different from the repeat pattern (Gheysen et al 2011). During testing the participants were allotted a timed 60-second break between blocks and took breaks as needed. All start and break times between blocks were recorded as it ensured the investigator was aware of the break period start and end and prevented short or prolonged break periods. A specific script was used to instruct the participant of the condition they were tested in. The script that was used to describe each of the conditions were as follows:

Visual Condition: "*The condition you are being tested in is the visual condition. When completing the visual condition, the pictures of the animals on the screen will appear without sound similar to the baseline session*."

Audio-Visual Condition: *"The condition you are being tested in is the audio-visual condition. In this condition you will hear sounds paired with the pictures of the animals on the screen. The sounds are the same sounds as the pictures on the screen, for example a dog and a bark, and this will occur at the same time."*

3.3.3 Testing Day 2: Retention, Transfer, Auditory-only, and Explicit Awareness test

The second day of testing occurred approximately 24 hours after the first testing session (Table 3).

Adult Group (n = 20)	Child Group (n = 18)

Delay Period (mean)	24.14 hours (SD=0.31)	23.67 hours (SD=1.53)

Table 3: Delay period per participant group

Three different conditions of testing occurred in this session: a retention test, where the participant was tested in the same condition as their first testing day, a transfer test where the participant was tested in the opposite condition, and an auditory only condition. The three conditions were counterbalanced for every participant to ensure that each condition was tested in all combinations equally. The participants completed one block of 80 trials in each condition, with the mandatory and timed 60-second break between blocks. At the start of Day 2 of testing, the participants were informed of the three different conditions they would be tested in with a brief explanation of what to expect in that condition regarding images and sound. The script used was as follows: Auditory Only Condition: "*The condition you are being tested in is the auditory-only condition. In this condition the pictures of the animals will not appear, and the black squares will remain blank throughout the duration of the block of trials, but you will hear the sounds of the animals. Once you hear the sound, respond by pressing the appropriate button as quickly and as accurately as you can*."

3.3.4 Retention Test

The retention test was administered as one of three testing conditions performed on Day 2 of testing. This test was completed approximately 24 hours after Day 1 of testing. The participants were required to complete 1 block of 80 trials in the *same* condition as performed on Day 1 of testing. The investigator debriefed the participant about what condition they would be tested in, and that the protocol is similar to the

previous day requiring responses to be made as quickly and accurately as possible. The participant's start time was recorded, and any other necessary notes were taken, i.e. breaks, correction in hand positioning, or any frustration. Reaction time, response time, and error were recorded using custom software designed in E-Prime 2.0 (Psychology Software Tools, Inc).

3.3.5 Transfer test

The participants were required to complete one block of 80 trials in the *opposite* condition performed on Day 1 of testing and the retention test. i.e. if the participant completed the visual condition on Day 1 and in the retention test, they were required to complete the transfer test in the audio-visual condition. The participants were briefed about the condition the transfer test was in and what to expect in terms of stimuli (pictures or pictures plus sound). The participant's start time and any other necessary notes were recorded, i.e. additional breaks or postural corrections. The reaction times, response times, and errors were recorded using E-Prime 2.0 (Psychology Software Tools, Inc).

3.3.6 Motor Skill Recall (Auditory Only)

In the auditory only condition the investigator explained to the participant that this condition involved sounds of the cat, bird, pig and dog, but the blank squares on the display monitor would remain blank throughout testing. The participants' task remained the same: To press the buttons that corresponded to the location of the animal. The participant completed one block of 80 trials in this condition. The start time was

recorded and any other information, i.e. where the participant's focus of attention was, break times, or postural corrections.

3.3.7 Explicit Awareness Test

The explicit awareness test always followed completion of the retention test, transfer test, and auditory only condition. Participants completed the explicit awareness test at different desk than the testing station. This test was completed manually with a pen and paper (figure 6). Prior to the investigator administering the explicit awareness test, the adult participants were specifically asked:

Did you notice anything particular about the button-pressing task?

The children participants were specifically asked:

Did you notice anything about the animals on the screen and pressing buttons?

The participant's response was recorded as a 'No' or 'Yes', and if yes, any other brief descriptors were also recorded. The participants were then debriefed about the purpose of the study, the repeat and random sequences, and the difference between implicit learning and explicit learning. The participants were then given an explicit awareness test sheet (figure 6) and asked to reproduce the sequence as best they could by drawing an 'x' or an asterisk. Each large square represented one item in the sequence.

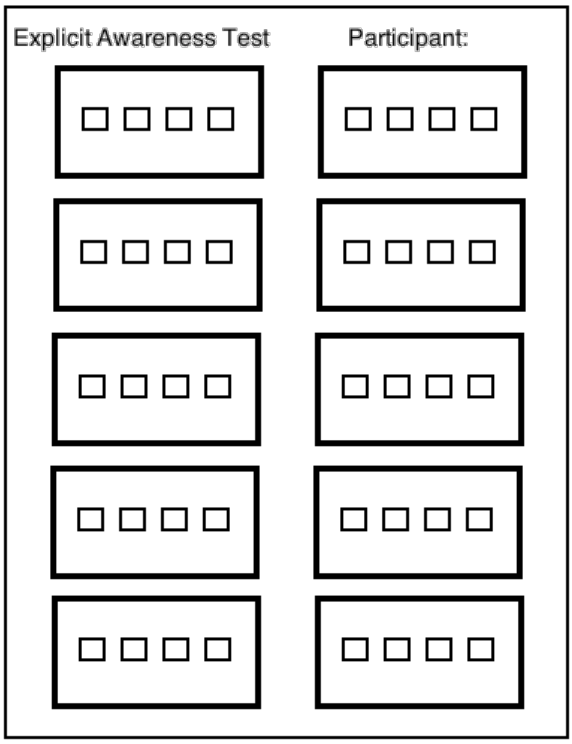


Figure 9: Explicit awareness test sheet
The explicit awareness test sheet is on a standard letter sheet (8.5"x11") involving ten sets of blank testing squares the same as what was seen during testing. The participants were instructed to replicate the sequence of images onto the sheet to their best of their knowledge by simply marking an asterisk or x.

The 'Yes' or 'No' responses were used to cross-reference with the results of the written component on the explicit awareness test and the participants median RTs. The cross-referenced information was used to determine whether knowledge of the repeat sequence and performance yielded shorter reaction times.

3.3.8 Input Response

The stimulus-response interval was determined by the participant for all trials, and only moved onto the next element in the sequence once a response was made. The participant was reminded at the start of each block to respond as quickly and as accurately as possible. The data for each trial was recorded using E-Prime 2.0

(Psychology Software Tools, Inc). Reaction times, response times, and errors were recorded using E-Prime 2.0 (Psychology Software Tools, Inc).

3.4 Dependent Variables

Reaction time and button response inputs were collected through E-Prime 2.0 (Psychology Software Tools, Inc). Reaction time for each button press was recorded. Recording for reaction time began when the animal appeared, and ended when the participant pressed the button. The input of each button response was recorded and response errors were determined by comparing participant input with the button answer key. The median reaction time was analyzed using Statistica (StatSoft), to determine whether any improvement in reaction time occurred as an indicator of learning the ten-item sequence.

3.5 Data Analysis

Prior to analysis of the median reaction times, any errors in responses were removed (Table 4). Analysis measuring accuracy included all input responses both correct and erroneous. The median reaction time was then calculated for each block of testing per participant and were used for each set of analysis respectively: acquisition, perturbation, retention, and motor skill recall. Analysis of acquisition involved analyzing the median RT for blocks 1 – 4, analysis of perturbation involved analyzing the median RT for blocks 4 – 6 (immediate retention), analysis of the retention blocks involved analyzing the median RT for the retention and transfer blocks during day 2 of testing,

and analysis of motor skill recall involved analyzing the median RT for the auditory only block during day 2 of testing.

The analysis used in the current study was a mixed factorial ANOVA using the median reaction time of each block and measuring acquisition, perturbation, and retention; a fourth analysis has been done to look at the effect of motor skill recall through an SRTT involving auditory stimuli only. The analysis on acquisition is a 2 group (Age) x 2 group (Condition) x 4 Blocks (Blocks 1 – 4 during acquisition), used to measure acquisition of the repeat sequence over four blocks of trials. Analysis looking at the effect of the random block is a 2 Age (child, adult) x 2 condition (Vis, AudVis) x 3 Blocks (Blocks 4,5,6 (immediate retention) during acquisition), where blocks 4 and 6 (immediate retention) are the repeat sequence, and block 5 is a random sequence different from the repeat sequence. Block 5 was used to assess for possible impact of fatigue and if the improvement was specific to the repeat sequence task. Retention was tested 24 hours post-acquisition. The retention session tested the participants in the condition they had completed acquisition, and in the other condition: 2 Age (child, adult) x 2 condition (Vis, AudVis) x 3 Blocks (block 6 (immediate retention), retention – audio-visual, retention – visual, transfer – audio-visual, transfer – visual). The auditory only condition, which served as the motor skill recall test, was used in a separate analysis to measure the effect of auditory stimuli on an implicit learning sequence task: 2 Age (child, adult) x 2 condition (Vis, AudVis) x 1 Block (motor skill recall: auditory-only). All significant effects involving more than two means were further analyzed using Tukey's HSD in order to determine where the significant effect(s) occurred.

3.6 Results

3.6.1 Median Reaction Time

The median reaction times (RT) for each block are presented below in Figure 7. An ANOVA was performed on the RTs with group, condition as between-subject variables and blocks as repeated measures. The results of the specific analyses are presented below.

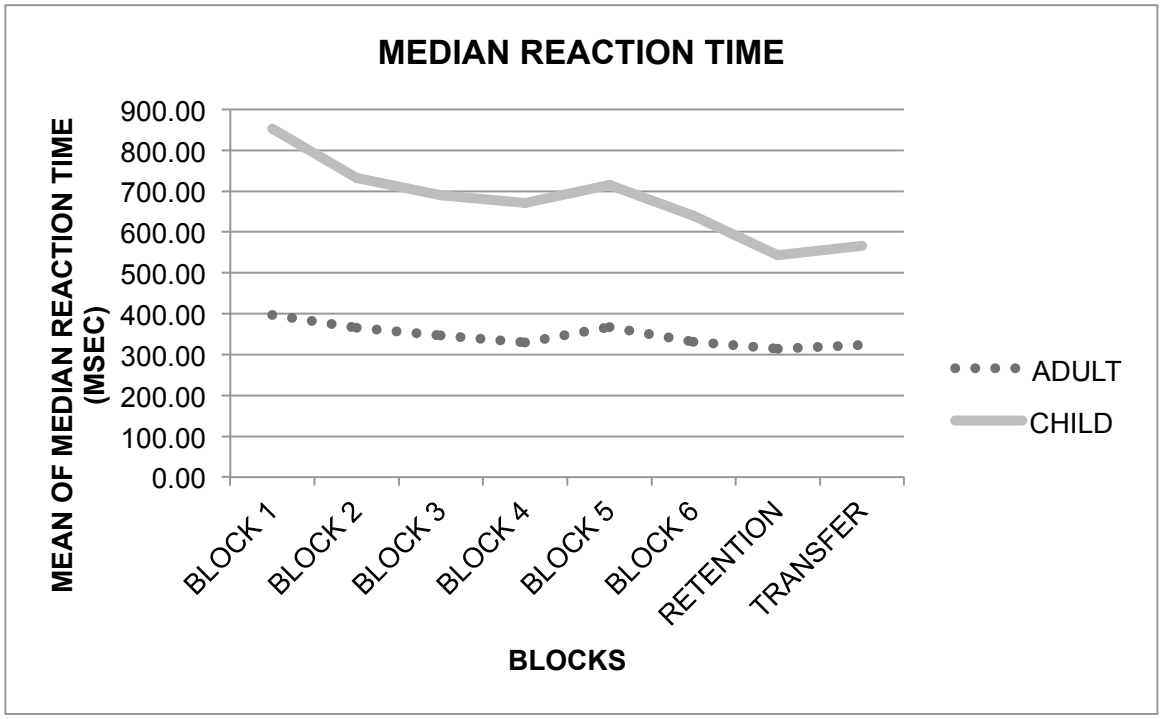


Figure 10: Median reaction times for each group (age) and blocks

3.6.2 Acquisition Analysis

The acquisition blocks occurred on day 1 of testing, where the analysis was a 2 Age (child, adult) x 2 condition (Vis, AudVis) x 4 Block (blocks 1, 2, 3 and 4) analysis. Results showed a significant main effect for Age, $F(1,35)=52.9$, $p<0.0001$, and for Acquisition (blocks 1 – 4), $F(3,105)=12.8$,$p<0.0001$, where the child group showed significant improvement in performance specifically from block 1 to block 2 in the

practice blocks, and following blocks 2 – 4 followed a trend of decreasing median RTs before reaching a plateau. The adult group's median RTs during practice did not change statistically. A small reduction in median RTs can be observed from blocks 1 – 2.

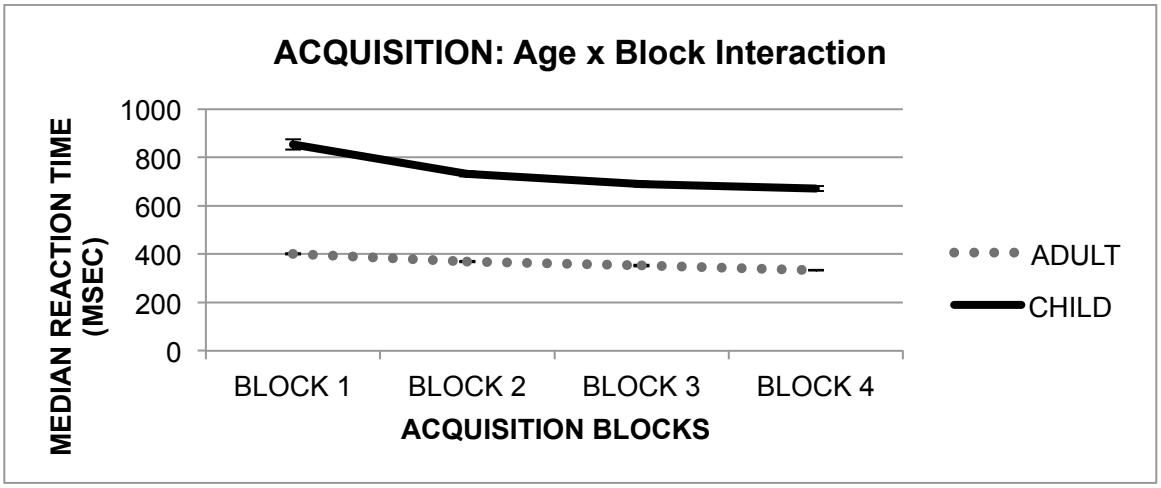


Figure 11: Acquisition analysis: Age by Block Interaction

The interaction with age and acquisition $F(3,105)=3.03, p<0.0001$ was also significant where with the child group showed significant improvement in performance from block 1 to block 2 in practice. The significant effects indicate that age affects performance seen in the acquisition blocks of testing. The child group had significant change in median RTs showing that the group improved significantly as they continued with acquisition, where as the adult group did not show significant effects.

3.6.3 Perturbation Analysis

The perturbation analysis was a 2 Age (child, adult) x 2 condition (Vis, AudVis) x 3 Block (blocks 4, 5 and 6 (immediate retention)) analysis. The blocks included in this analysis were block 4 (repeat sequence), block 5 (random sequence), and block 6:

immediate retention (repeat sequence). The results produced a significant main effect for Age, $F(1,35)=66.2, p<0.0001$, and for the Perturbation blocks (blocks 4 – 6), $F(2,70)=21.3, p<0.0001$. This indicates that age has a significant effect on performance in the perturbation blocks. The child group showed significant results from block 4 to block 5 and significant results from block 5 to block 6: immediate retention, but no significance was found when analyzing blocks 4 and block 6: immediate retention. This finding shows that the effect of the perturbation block (block 5: random sequence) did in fact interfere with implicit learning of the sequence. There were similar findings for the adult group, where the adult group showed significant effects from block 4 to 5 and from block 5 to 6, but no significant findings when analyzing block 4 and block 6: immediate retention. This supports that the child and adult participants were able to implicitly learn the sequence with continued practice. There were no significant interactions between age and the perturbation blocks.

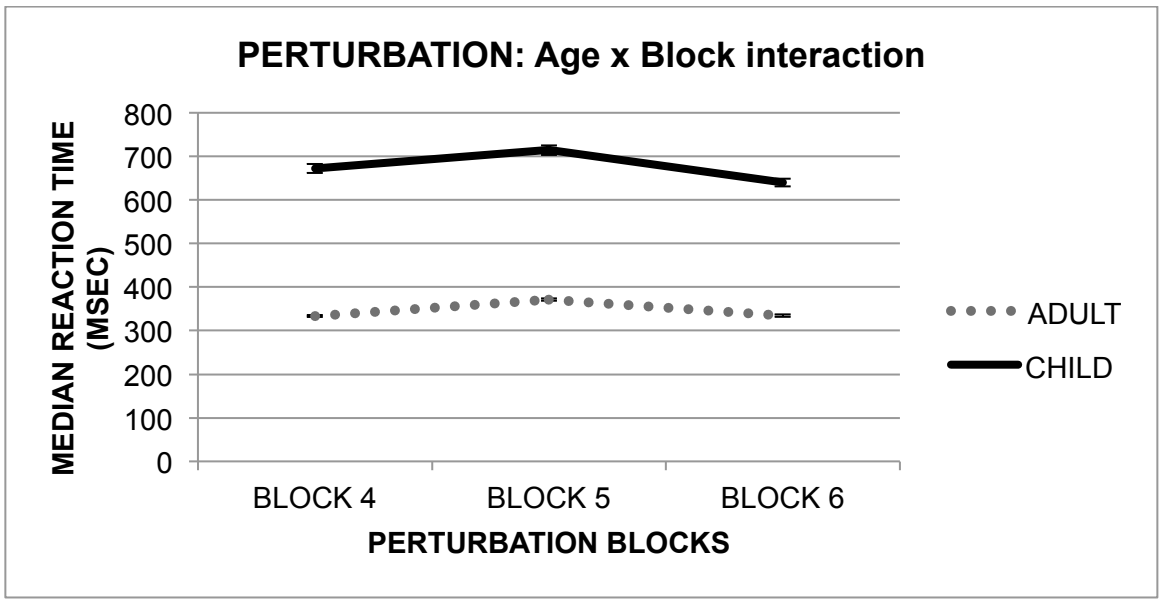


Figure 12: Perturbation Analysis: Age by Block Interaction

3.6.4 Retention and Transfer Analysis

The retention and transfer analysis was a 2 Age (child, adult) x 2 condition (Vis, AudVis) x 3 Block (block 6: immediate retention, retention block, and transfer block) analysis. The blocks measured in this analysis were block 6:immediate retention from day 1 of testing, and the retention and transfer blocks from day 2 of testing. The results showed a significant main effect for Age, $F(1,35)=61.6, p<0.0001$, and for the Retention and Transfer blocks (block 6: immediate retention, retention, transfer), $F(2,70)=19.8, p<0.0001$. There was also a significant interaction for Age and the Retention and Transfer blocks, $F(2,70)=11.0, p<0.0001$. The significant effects indicated that the participants' age affects the reaction time during the retention and transfer blocks of testing.

Further analysis showed that the child group demonstrated significant effects between block 6 and retention, where there was a significant decrease in median RT

between the two blocks of testing. The child group did not produce statistical significance from the retention block to the transfer block. The adult group did not show any statistical significant differences in the retention and transfer analysis.

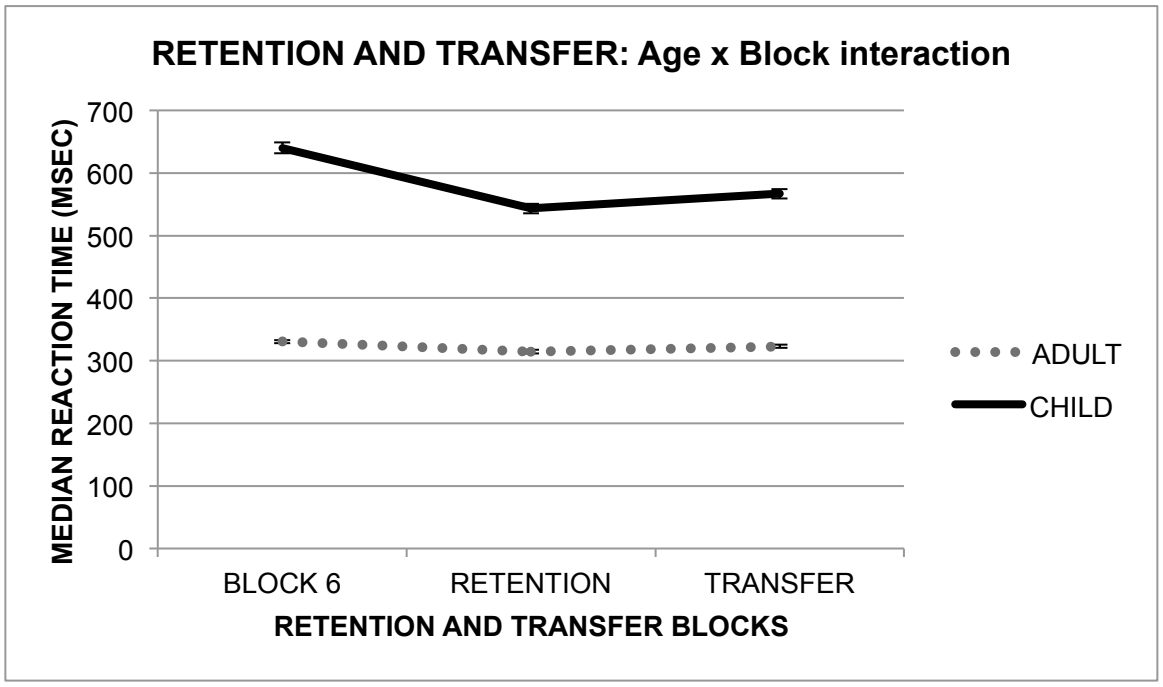


Figure 13: Retention and Transfer Analysis: Age by Block Interaction

3.6.5 Motor Skill Recall Analysis

The analysis of the motor skill recall block (auditory-only) was a 2 Age (child, adult) x 2 condition (Vis, AudVis) x 1 Block (auditory-only) analysis. Analysis of the motor skill recall block (auditory only) showed a significant main effect with age, $F(1,35)=25.4, p<0.00001$, and with condition, $F(1,35)=4.65, p<0.03$. A significant interaction was found for age and condition, $F(1,35)=5.54$; $p<.0247$

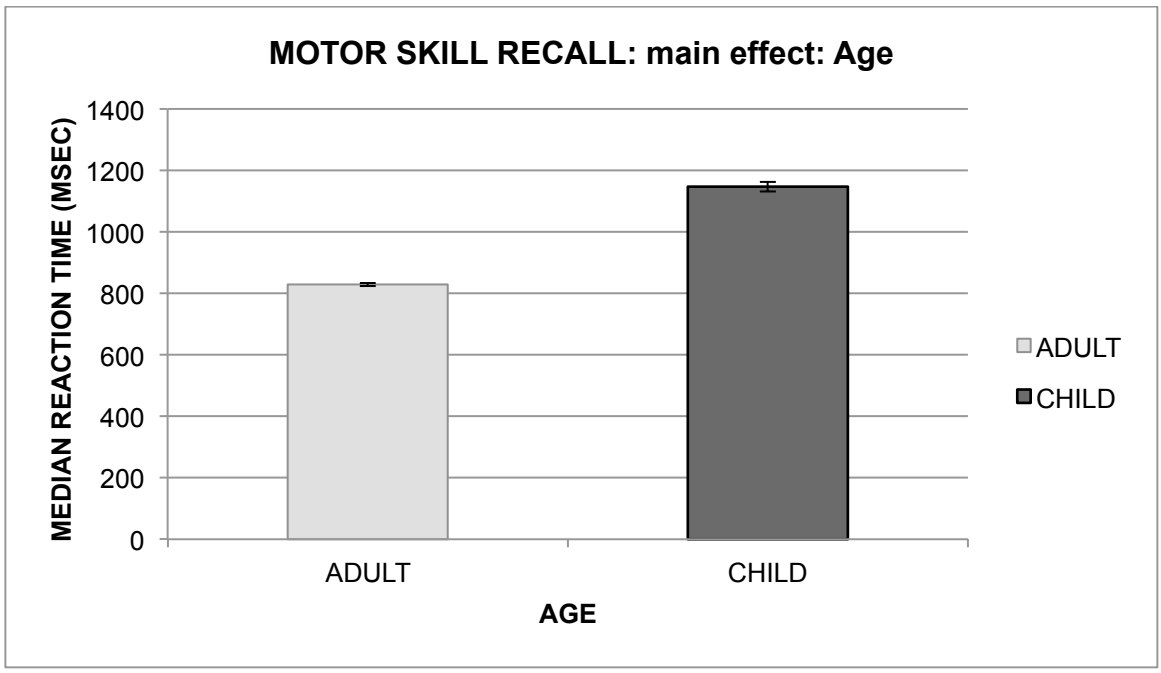


Figure 14: Motor Skill Recall Analysis: significant main effect for age

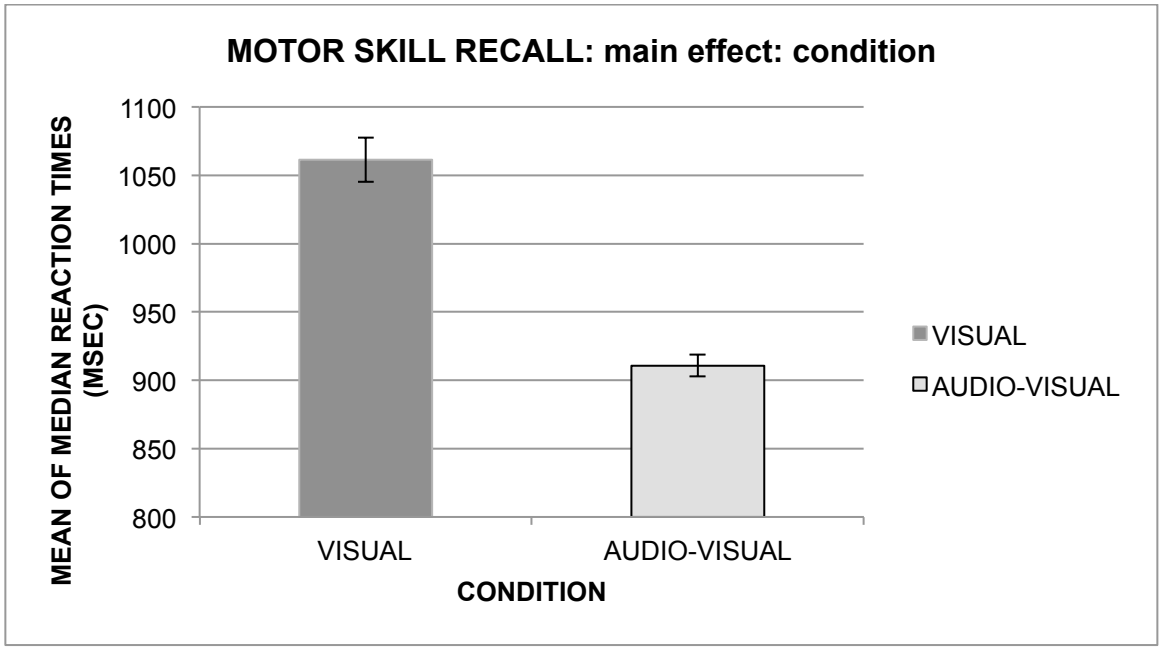


Figure 15: Motor Skill Recall Analysis: significant main effect for condition

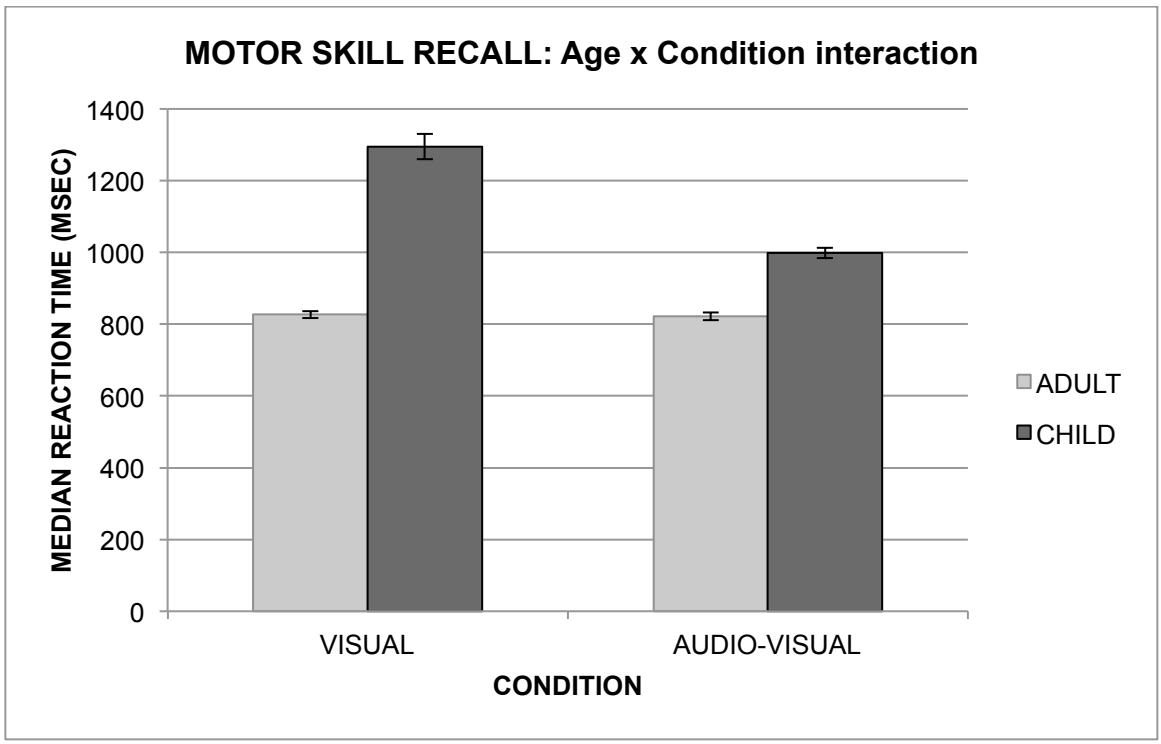


Figure 16: Motor Skill Recall Analysis: Age by Condition Interaction

These results indicate that performance in the motor skill recall block (auditory only) is significantly affected by the age of the participant and the condition they had practiced in. The child group who practiced in the audio-visual condition and the adult groups who practiced in both conditions: visual and audio-visual, did not show statistical significance in the motor skill recall block (auditory only). These results conclude that the child group who practiced with auditory and visual cues were able to transition well to responding with only auditory cues, but the child group exposed to practicing in the visual group only had difficulty crossing modalities to auditory only. Both adult groups of the visual and audio-visual conditions did not produce significant results when tested in the motor skill recall block (auditory only), thus implying that adults are able to cross modalities without difficulty.

3.6.6 Mean accuracy

The mean accuracy was calculated for each block for each participant. Average accuracy scores for the SRT task during practice were very high in both groups, with the adult group demonstrating higher rates of accuracy than the children group in both conditions (Table 4).

	DAY 1		DAY 2			
	ACQUISITION		RETENTION/ TRANSFER		MSR	
	V	AV	V	AV	V	AV
CHILD	95% (SD=3.87)	92.1% (SD=4.83)	96.9% (SD=1.79)	94.7% (SD=2.99)	91.3% (SD=7.84)	82.2% (SD=10.65)
ADULT	98.6% (SD=1.24)	98.3% (SD=1.65)	98.6% (SD=1.29)	98.3% (SD=1.28)	96% (SD=3.31)	88.9% (SD=6.55)

Table 4: Mean number of erroneous inputs

An ANOVA was performed to measure the mean accuracy in the motor skill recall block (auditory only), and a significant effect was found for condition $F(1,35)=6.059, p<0.0189$. In the results the group who completed testing in the audio-visual condition performed better in the motor skill recall block (auditory-only) than the visual-only group (SD = 0.056).

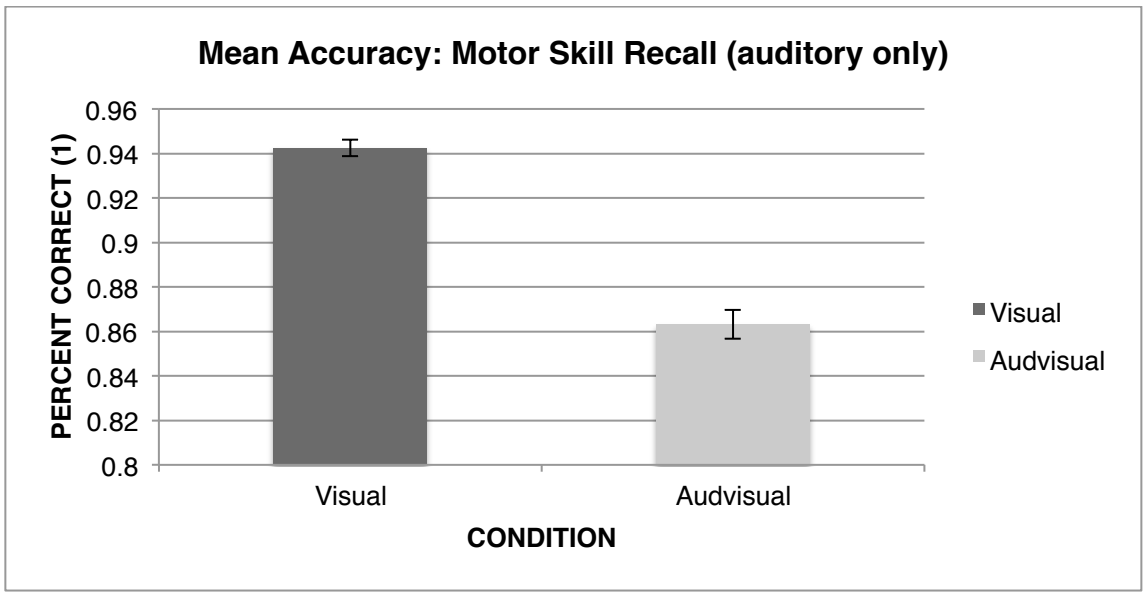


Figure 17: Mean Accuracy: motor skill recall block (auditory only)

3.6.7 Explicit Awareness

To measure the degree of awareness the mean awareness scores were calculated for each age group (Table 5).

	"YES" RESPONSE	MEAN % CORRECT	"NO" RESPONSE	MEAN % CORRECT
ADULT	60%	25 (SD=1.45)	40%	31.25 (SD=1.25)
CHILD	22%	22.5 22.5(SD=0.96)	78%	22.2 (SD=1.56)

Table 5: Explicit awareness mean scores

These findings conclude that the adult group had some awareness of the sequence task, where a smaller percentage of the child group was aware. Though, it is important to note that the degree to which the adult group displayed a sense of awareness of the sequence task is limited, as full awareness of the sequence would have yielded a greater percentage of correct responses on the explicit awareness test.

Chapter 4: Discussion and Conclusions

4.1 Summary and Major Findings

The current study explored how typically developing children 7 – 9 years old and adults 18 – 35 years old performed an implicit learning sequencing task using a uni-modal and bimodal conditions: visual and audio-visual. Implicit learning sequencing tasks have been explored in the literature for an extended period of time dating back to the foundation of SRTT studies: the study by Nissen and Bullemer (1987) that measured implicit learning in a sequencing task across four different experiments. Many of the studies dating back from Nissen & Bullemer (1987) and moving forward to current studies using SRTT have explored how typically developing or healthy adults perform SRTT in different conditions. In order to continue expanding on SRTT research, researchers have looked at increasing the level of complexity in an SRTT with the addition of distractors (Nissen & Bullemer 1987), or different sensory stimuli (Abrahamse et al 2008; Abrahamse et al 2009) to infer the degree of task learning through reductions in reaction time (RT). Studies have also explored SRTT with different uses of stimuli in typically developing and healthy children, and children of special population groups, where the TD and healthy children groups have produced mixed results depending on the type of special population groups (Gheysen et al 2011; Lejeune et al 2013). Comparatively, adult groups have been measured exclusively, and children groups of varying ages have been measured exclusively as well, but to my knowledge, a comparison of typically developing children and adults using uni-modal and bimodal conditions has not been studied. In the literature, the understanding of

how the auditory and visual systems develop in children has stated that both sensory systems are fully developed by the age of 7 (DiSimoni 1957). As the literature states that the level to which a child's auditory and visual system is fully developed by age 7 relative to an adult, could a child's visual and auditory system process information similar to an adult? The literature has reported that both children and adults have successfully learned a sequence task implicitly. However, do children and adults learn a sequence task with varying amounts of visual and auditory stimuli in the same way?

The purpose of the current study was to explore to what extent the auditory and visual systems are developed for sequence learning by measuring how well children and adults are able to implicitly learn a sequencing task, and to measure if the sensory stimuli: visual only or audio-visual influenced learning an implicit learning sequence task. In the literature, many different types of stimuli or distractors have been explored in implicit sequence learning tasks. Among various studies exploring the effect of the use of different stimuli and distractors, the common finding has been that despite interruption or increased difficulty in the task, learning implicitly still occurred. That is, performance became more refined versus when the task was initially performed (Nissen & Bullemer 1987).

The hypothesis of the current study was that the adult and child groups would both learn the sequencing task at a comparable rate. Learning would be inferred through changes in performance, specifically a reduction in RT and an increase in accuracy. In addition, the bimodal condition would be a more effective condition for implicitly learning the sequencing task versus the uni-modal condition due to an

increased of resources available for information processing. Studies by authors Birch (1976) and Haywood and Getchell (2009) reported that the ability for children to process audio and visual information separately are developed by 7 years old and refined by 12 years old to levels comparable to adults. Exploring the use of multisensory versus uni-modal sensory cues for learning in motion detection and discrimination tasks, authors Shams and Seitz (2008) summarized a review of visual and auditory integration and concluded that for each type of task multisensory learning yielded better performance than uni-modal learning.

4.2 Why implicit learning is effective for learning procedural tasks

Implicit knowledge is difficult to verbalize, as it is the acquisition of knowledge that we can then replicate in a procedural manner. Our knowledge of how to complete a motor skill and the environment that surrounds us cannot always be described out loud when a learner observes and replicates a movement (Magill 1998). This statement is evident in serial reaction time tasks that involve a series of patterns where the learner is unaware of the learning that is occurring or the pattern that is present (Nissen & Bullemer 1987). In past studies, participants have completed implicit learning sequence tasks and have acquired implicit knowledge of the sequence, but when tested in an explicit awareness test to determine the ability to declare what was learned, many participants do not score well (Lejeune et al 2013). These findings are similar to what was found in the present study, where the participants were able to learn the sequence effectively, measured by means of decreased reaction times over time, but for all those that reported being aware of a pattern in the study, did not in fact score any better than

those who reported being unaware of a pattern. Of the twenty adult participants only two participants (one participant of the visual condition and one of the audio-visual condition) reached 100% accuracy in the retention and transfer blocks of testing, but both participants reported not having any awareness of the sequence in the task. None of the children participants reached 100% accuracy in the retention and transfer blocks, and none of the children and adult participants reached 100% accuracy in the practice blocks.

4.3 Summary of results

The results of the current study show that age is a significant performance factor in a sequence task despite the use of visual or audio-visual combinations. The adult group performed with shorter reaction times in each one of the sets of blocks tested in comparison to the children group. Interestingly, the change in performance for the adult group did not change statistically from block to block during practice blocks, but did show a trend toward improvement. Thus, concluding that in both the visual and audio-visual conditions, the sequence task was not as challenging for the adult age group versus the child age group based on the difference in accuracy during the practice blocks. The child group did demonstrate larger changes in performance during the practice blocks with significantly shorter reaction times. Therefore the task was challenging enough to generate a change in performance with practice. However, the improvement in RT was significant for the child group only.

The analysis in the perturbation block of testing, blocks 4 – 6, where blocks 4 and 6 were a repeat sequence and block 5 was a random sequence, resulted in a significant

main effect for age and condition. Interestingly, the adult and the child groups demonstrated similar patterns in performance. Thus, demonstrating that transitioning from a repeat sequence to a random sequence and back to a repeat sequence has the same effect on both age groups despite the condition the task is completed in visual or audio-visual.

The results of the retention and transfer blocks showed a significant main effect for age and for retention, and an interaction between age and retention, where by performance for the adult group was not significant from block 6 to retention and transfer, whereas the child group demonstrated a significant improvement in performance from day 1 to day 2 of testing. Thus indicating that the child group could significantly retain and refine the information acquired from the sequence task from day 1 of testing to day 2 of testing. Some possible reasoning for why the adult group did not change significantly could be that the adult group could have reached a ceiling in their performance. The trend of improvement seen in the adult group from block 1 to transfer was not significant, thus reflecting having reach a ceiling. The adult group did improve from block to block, though it was not statistically significant, where significant improvement could have been seen with the addition of more practice blocks. Because the task was not as challenging for the adult group as it was for the child group, a greater amount of practice would be needed to see significant improvement over time.

The motor skill recall (auditory only) blocks demonstrated a significant main effect for age and for condition, and an interaction between age and condition. There was not a significant difference in the adult age group between the visual and audio-visual

condition, nor was there a significant difference between the adult and children groups in the audio-visual condition. But, interestingly there was a significant difference in the child group between the visual and audio-visual condition groups, as well as a significant difference between the adult and child groups in the visual condition. The child participants who completed their practice sessions in the audio-visual condition performed with a median RT lower than the children group who completed their practice sessions in the visual only condition. These results suggest that the adult group was able to cross modalities and adapt better than the children group whether they were of the visual or audio-visual condition. There was a significant difference found with the child groups suggesting that changing modalities is a difficult adaptation. Therefore, these findings suggest that children 7 – 9 years old do not learn sequence task using auditory and visual stimuli in the same way.

Each participant had a 24-hour delay period between the practice blocks on day 1 of testing, and the retention, transfer and motor skill recall (audio-only) blocks on day 2. The adult group did not demonstrate significant improvement from block 6 on day 1 of testing to the retention block on day 2 of testing, however the child group demonstrated a greater improvement from block 6 on day 1 of testing to the retention block on day 2 of testing compared to the adult group. There are two possible reasons for the improvement seen, one of which could be that the child group demonstrated a greater amount of improvement following a delayed retention period because of the greater ability for neuroplasticity. School age children's brains are primed for learning, therefore their ability to gain improvement is more sensitive and sees greater changes

than adults (Galván 2010). Secondly, the improvement seen supports the findings in the literature that performance in a motor skill task can improve, and memory of the task become more refined after a period of overnight sleep at least 11 hours post-acquisition in both children and adults (Fischer, Wilhelm, & Born 2007). The period of sleep between days of testing enhanced the ability to consolidate any procedural memories from the day, therefore assisting in task recall (Diekelmann, Wilhem, & Born 2009). The results from the current study are congruent with what has been reported in the literature regarding sleep consolidation where both groups performed the task with high accuracy and improved in speed by means of reaction time, with the children group demonstrating significant improvement from block 1 to transfer. Though, it is important to note that sleep consolidation was not measured directly as all participants had their initial testing session begin at various times of the day and returned 24 hours for their second testing session.

4.4 Audio and Visual Information in a SRTT

The current study measured the rate of learning through reaction time in both visual and audio-visual conditions for both the adult and child age groups. The results showed that only in the motor skill recall analyses was there a significant main effect for condition and a significant interaction between age and condition. In the motor skill recall, participants who were previously exposed to the audio-visual condition in practice performed with faster reaction times than participants who were only exposed to the visual condition in practice. Though, when comparing the overall median RTs during practice per block of visual versus audio-visual per age group, the audio-visual adult

group had slightly faster reaction times (SD = 34.6 msec), and the audio-visual child group also had slightly faster reaction times (SD = 82.0 msec). The perturbation blocks had similar findings where the adult audio-visual group had faster reaction times (SD = 25.0 msec) and the child audio-visual group also had faster reaction times (SD =37.1 msec) than the visual counterpart. The retention and transfer blocks produced similar findings, where the adult audio-visual group had slightly faster reaction times (SD = 17.6 msec) and the child audio-visual group had even greater reduction in reaction times (SD = 285.6 msec). The literature exploring uni-sensory and multi-sensory integration in a motor task have found that adults performed with shorter reaction times and more accurate responses using multi-sensory information in comparison to uni-sensory information (Teder-Sälejärvi, Di Russo, McDonald, & Hillyard, 2005; Corneil et al 2002; Miller 1982). Though, there was not a significant main effect found when analyzing age and condition in each of the analyses performed, when comparing the median reaction times of each block for age and condition, the trend the participants performing in the audio-visual condition were consistently faster than the visual condition.

4.5 SRTT

The pattern of improvement made by both the adult and child groups when completing the SRTT in the practice blocks is consistent with the literature exploring the use of SRTT with adults and children where the median RTs have a linear decrease over time. These findings are consistent with what has been reported where a SRTT is performed in either a uni-sensory or multi-sensory condition, and is exempt from any distractors, the reaction times over time would decrease, thus indicating an increase in

performance (Nissen and Bullemer 1987; Wilson, Maruff, and Lum 2003; Gheysen et al 2011; Lejeune et al 2013). In the literature there is consistent evidence that as an individual practices a repeat sequence in a SRTT over time the individual implicitly acquires knowledge of the repeat sequence and becomes more efficient at performing the task. The current findings are thus congruent with what has been found in the literature (Nissen and Bullemer 1987; Wilson, Maruff, and Lum 2003; Abrahamse et al 2008; Gheysen et al 2011; Lejeune et al 2013).

4.6 Adult and Child group

The literature suggests that the level where a child's auditory and visual development is similar to that of an adult occurs between the ages of 7 – 10 years old (Birch 1976). In the current study, the child groups consistently had longer reaction times compared to the adult group. Though, the adult and child groups did not have comparable reaction times, the rate of change over each block of testing followed a similar pattern of improvement. Though, the development and ability for a child to input auditory and visual information is similar to an adult at 7 – 10 years old and completely refined by 12 years old (Haywood & Getchell, 2009), the task required for the current study involved processing visual or audio-visual information with the combination of a motor skill input. The complicated series of movements could account for the longer reaction times produced by the child group, where as the adult group demonstrated faster reaction times possibly due to a greater ability to process visual or audio-visual information with a motor skill input as a result of experience with age. The similar rate of change over time when comparing both group supports the notion that though child

and adults cannot process information at the exact same pace, the ability for a child to process information with the same rate of change for improved performance is comparable to an adult (Haywood & Getchell, 2009).

4.7 Limitations

A limitation of the current study was the inability to measure sleep consolidation directly or indirectly due to the varying times of day that participants completed their testing, the lack of a control group, or measurement of sleep directly. Therefore, only an observational statement can be made about the participants' refined learning due to overnight sleep. In the future, directly comparing performance changes following 12 hours with or without sleep would allow for a more direct statement regarding the impact of sleep. Nevertheless, based on the literature (Walker et al 2003), improvement following a period of no practice is likely related to consolidation during sleep.

A second limitation to the current study would be that there was only one age group of children. Adding one or two more age groups, for example, 10 – 12 years old, would help to map out the change in development over time in completing the SRTT, and how these changes compare to adults.

4.8 Future Directions

The current study measured typically developing populations, whereby creating a control group that could expand onto exploring many different elements of the current study. A few examples are outlined below.

4.8.1 Sleep Consolidation

Direct measurement on the effect of sleep consolidation with typically developing children and adults in a SRTT with a delayed retention period. One method would be to control the interval period of wakefulness and sleep to see the effect of sleep on learning using auditory and visual cues. Having one group who would test in the evening, have a strict sleep-interval period, and retention testing first thing the next morning, and a second group who would test first thing in the morning, have a strict wake-interval period of the same duration as the sleep-interval period, and complete retention testing in the evening. Specific factors to measure would ensure both groups are comparable would be to ensure they follow the same typical sleep pattern, and be of the same age groups. It would also be useful to measure whether the participants in the sleep-interval group obtain rapid eye movement (REM) sleep and for what duration, as achieving REM can assist in the plasticity of learning. Also, measuring REM sleep when comparing adults and children group would be a significant factor, as children tend to sleep for longer hours than adults and therefore possibly achieve a greater amount of REM sleep than adults.

4.8.2 Conscious Awareness

Explore how large of a difference conscious awareness has on completing the current task of learning the sequence. By means of measuring typically developing children and adults in groups, one with explicit awareness of the sequence and one completing the task and learning the task implicitly. As the sequence task is a procedural task, it would be interesting to explore if there is a difference and how great the difference would be between conscious and unconscious awareness.

4.8.3 Focus of Attention

One of the limitations to the current study had been added measurement to support that the participants learned the study rather than became more efficient at button pressing in response to the images, exploring where the participant's focus of attention by use of an eye tracker would assist to see whether participant saccades become more efficient and anticipate where the next target will appear. The more predictive their saccades could be interpreted as the participant learning the sequence rather than becoming more efficient at button presses.

4.8.4 Special Population Groups

The current study serves as a baseline for measuring how typically developing children and adults complete a sequence task using auditory and visual cues. It would be of interest to explore how the typically developing groups compare to different special population groups using these same auditory and visual cue combinations. Depending on the type of special population group, this could assist to assess information integration and possibly motor deficits.

4.9 Conclusions

Overall results obtained from the current study using auditory and visual cues in a SRTT, is that it is the effect age and block of practice that has a significant effect on performance and not the condition. The only instance where condition had a significant effect had been during the motor skill recall (auditory only) block, where there was a significant difference between age and condition.

The current study revealed that children and adults do not process visual and auditory information at the exact same rate both ages was able to process the uni-modal and bimodal information efficiently to show learning has occurred. Much of this difference could be the fine motor demand that was required of both groups to complete the task. The adult group has greater experience with manipulating key presses in response to visual and auditory stimulation through exposure to tasks such as typing on a keyboard, where as a child 7 – 9 years old may only be learning how to use a keyboard.

This study can help better understand how children and adults comparatively learn with the use of auditory and visual demands in a sequencing task. The current study concludes that though the literature states that children and adults have similarly developed auditory and visual systems by the age of 7 (Birch 1976), the auditory and visual systems process information at different rates when completing a motor task, but have the same ability to learn a sequence task implicitly.

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Appendices

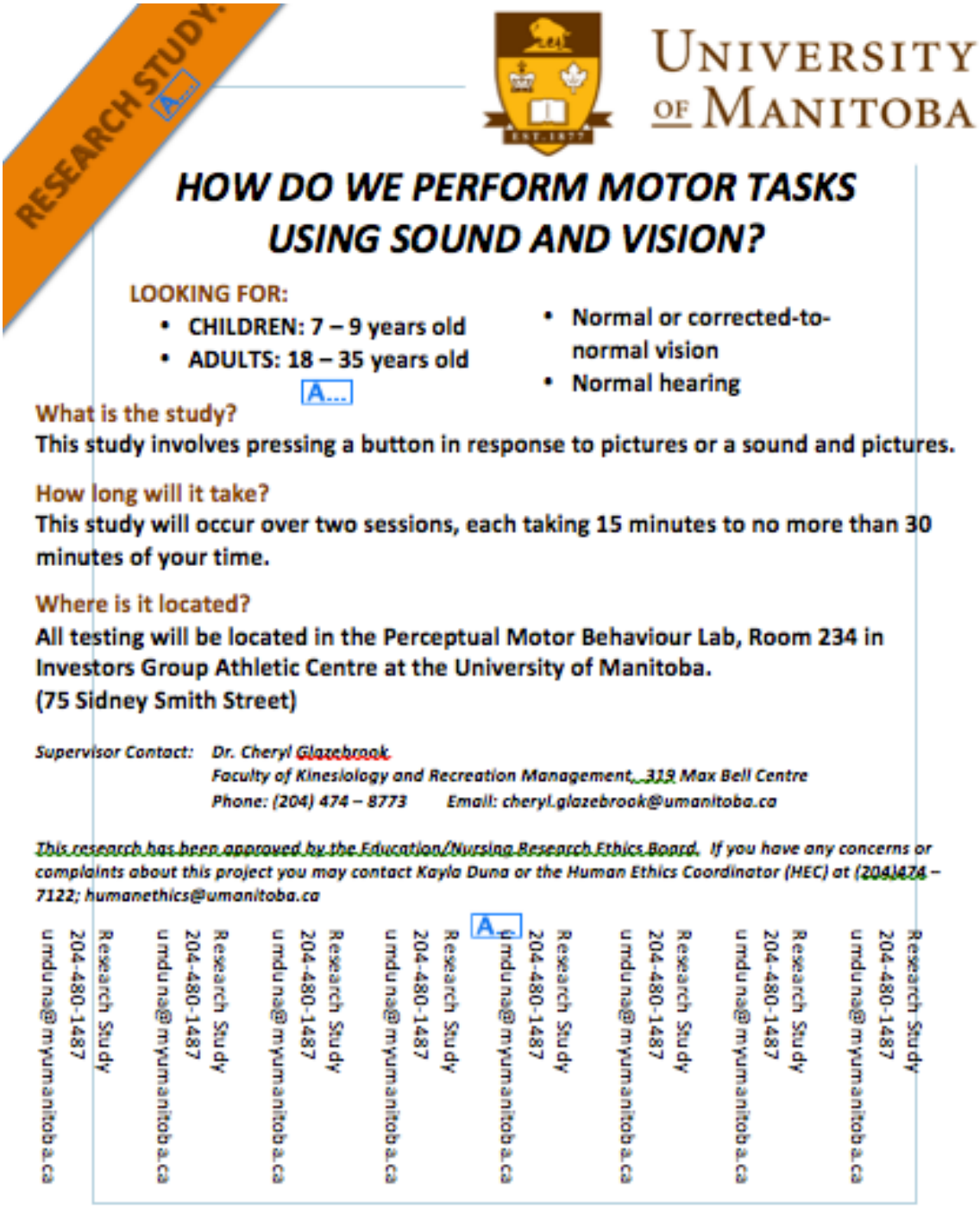
Appendix A: Accuracy per block

AGE	CONDITION	PARTICIPANT	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	BLOCK 6	RETENTION	TRANSFER	MOTOR SKILL RECALL (AUDIO ONLY)
ADULT	VISUAL	P01-1	99%	100%	99%	100%	99%	100%	100%	100%	100%
ADULT	VISUAL	P02-1	99%	99%	99%	99%	98%	99%	100%	99%	96%
ADULT	VISUAL	P03-1	98%	96%	96%	98%	98%	99%	94%	98%	99%
ADULT	VISUAL	P04-1	100%	100%	99%	100%	99%	100%	100%	99%	99%
ADULT	VISUAL	P05-1	100%	99%	100%	100%	98%	99%	98%	100%	86%
ADULT	VISUAL	P06-1	100%	100%	96%	99%	99%	98%	98%	100%	98%
ADULT	VISUAL	P07-1	100%	100%	100%	98%	98%	100%	100%	99%	99%
ADULT	VISUAL	P08-1	100%	100%	100%	100%	99%	100%	99%	100%	94%
ADULT	VISUAL	P09-1	100%	100%	98%	99%	95%	99%	100%	100%	91%
ADULT	VISUAL	P10-1	98%	98%	100%	100%	94%	100%	99%	96%	99%
ADULT	VISUAL	P11-1	96%	96%	99%	98%	94%	100%	98%	98%	96%
ADULT	AUDIO VISUAL	P21-1	99%	99%	100%	96%	99%	100%	100%	98%	93%
ADULT	AUDIO VISUAL	P22-1	96%	94%	100%	95%	98%	98%	96%	96%	89%
ADULT	AUDIO VISUAL	P23-1	99%	99%	99%	99%	94%	100%	98%	98%	85%
ADULT	AUDIO VISUAL	P25-1	100%	99%	99%	100%	96%	100%	98%	98%	89%
ADULT	AUDIO VISUAL	P26-1	100%	100%	100%	100%	98%	100%	100%	100%	93%
ADULT	AUDIO VISUAL	P27-1	100%	100%	96%	100%	99%	93%	100%	99%	89%
ADULT	AUDIO VISUAL	P28-1	100%	99%	100%	100%	98%	99%	99%	100%	93%
ADULT	AUDIO VISUAL	P29-1	100%	100%	100%	100%	100%	99%	100%	100%	100%
ADULT	AUDIO VISUAL	P30-1	96%	98%	94%	96%	98%	94%	93%	98%	70%

AGE	CONDITION	PARTICIPANT	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	BLOCK 6	RETENTION	TRANSFER	MOTOR SKILL RECALL (AUDIO ONLY)
CHILD	VISUAL	P01-2	99%	100%	99%	100%	98%	99%	99%	100%	99%
CHILD	VISUAL	P02-2	88%	91%	0%	89%	99%	96%	98%	94%	98%
CHILD	VISUAL	P03-2	95%	93%	88%	94%	88%	94%	93%	99%	91%
CHILD	VISUAL	P04-2	78%	85%	91%	95%	85%	98%	98%	96%	68%
CHILD	VISUAL	P05-2	98%	96%	95%	95%	98%	98%	93%	96%	89%
CHILD	VISUAL	P06-2	96%	99%	94%	95%	99%	98%	95%	98%	96%
CHILD	VISUAL	P07-2	93%	96%	95%	95%	95%	99%	98%	96%	91%
CHILD	VISUAL	P08-2	89%	99%	100%	100%	100%	100%	98%	99%	98%
CHILD	VISUAL	P09-2	99%	100%	99%	98%	99%	96%	98%	100%	100%
CHILD	AUDIO VISUAL	P21-2	99%	98%	94%	96%	90%	94%	96%	94%	93%
CHILD	AUDIO VISUAL	P22-2	98%	93%	93%	89%	75%	91%	94%	96%	68%
CHILD	AUDIO VISUAL	P23-2	98%	96%	96%	94%	96%	95%	96%	94%	98%
CHILD	AUDIO VISUAL	P24-2	93%	94%	98%	95%	95%	88%	98%	95%	93%
CHILD	AUDIO VISUAL	P25-2	89%	91%	94%	94%	83%	95%	99%	99%	78%
CHILD	AUDIO VISUAL	P26-2	96%	88%	98%	99%	95%	96%	95%	98%	93%
CHILD	AUDIO VISUAL	P27-2	88%	96%	98%	96%	86%	91%	98%	98%	83%
CHILD	AUDIO VISUAL	P28-2	94%	88%	74%	85%	79%	76%	88%	85%	55%
CHILD	AUDIO VISUAL	P29-2	100%	100%	96%	96%	98%	95%	95%	96%	98%

Appendix B: Accuracy per block

Appendix C: Recruitment poster



Appendix D: Informed Consent Form

INFORMED CONSENT

Title of Study: AUDITORY AND VISUAL CUES IN SEQUENCE LEARNING

PRINCIPAL INVESTIGATOR: Kayla Duna (Master's Student)
Faculty of Kinesiology & Recreation Management
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STUDENT RESEARCH ASSISTANTS: Jacqueline Ladwig-Davidson, Kelsey Brown, Brie Page, Tamires Prado
(204) 480 - 1487

This study is funded by a MHRC Grant

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: This study is a Master's thesis project. We are interested in learning how typically developing children and adults perform a sequencing task with vision only or the combination of auditory sound and vision.

DESCRIPTION: During the study, you will be asked to make a series of button presses in response to targets on a computer screen. The software program used will record all of your button-press responses. Prior to this task, you will be asked to fill out a brief demographics questionnaire that inquires about your age, gender, handedness, whether or not your vision and hearing are corrected (glasses, contact lenses, hearing aids). The whole procedure will occur over two separate testing sessions, and each taking 15-30 minutes to complete. At the end of the

second testing session, you will be asked a specific question where your response will be recorded.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks you will perform but some of the tests may become repetitive and you may experience boredom and/or mild muscle fatigue in your hands or arms. You are free to take a break as needed.

Your participation in this study will help us discover ways in which typically developing participants perform with different sensory information: vision or sound and vision.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. You will receive a $10 gift card for Tim Hortons to thank you for donating your time.

CONFIDENTIALITY: Your information will be kept confidential. Once you begin the study your name, information, and results will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your code number. The Principal Investigator and student research assistants, will have exclusive access to identifying information. Your files will only be accessible by the investigators and will be destroyed by Dr. Glazebrook seven years after the completion of the study (approximately June, 2021). All papers containing personal information will be shredded. All electronic files will be deleted. Only Kayla Duna, Dr. Cheryl Glazebrook and the student research assistants listed will have access to any lists that contain identifying information. Dr. Glazebrook will only access the consent forms if audited by ENREB or when it is time to destroy the consent forms.

Results will be presented at academic conferences, invited presentations, and published in the PI's master's thesis, and peer-reviewed academic journals.

DEBRIEFING: Upon completion of the study the experimenter, will ask a specific question where the response will be recorded as part of your data in the study. Following this the experimenter will describe the research questions being considered.

VOLUNTARY CONSENT: Participation in this study is strictly on a voluntary basis, and you can withdraw from the study at any time during the study or by contacting the PI or student research assistants in person, by phone, or email. If you *do not wish to participate* in the study, you are free to withdraw from the research study at any time without consequence and we thank you for your consideration. Upon withdrawal from the study, you will still receive an honorarium of a $10 gift card to Tim Hortons, and your data will be destroyed.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you choose to withdraw from the study you will still receive compensation for

the time you have participated. The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education/Nursing REB If you have any concerns or complaints about this project you may contact Kayla Duna (umduna@myumanitoba.ca, 204-480-1487) or the Human Ethics Coordinator (HEC) at (204)474-7122 or email at humanethics@umanitoba.ca.
A copy of this consent form has been given to you to keep for your records and reference.

Participant's Signature _____ Date _____

(Or)
Parent/Guardian Signature for Participant_____
Relationship _____ Date_____

Researcher/ Delegate's Signature _____Date _____

FINDINGS FROM THE STUDY: I wish to have a summary of the findings of the current study sent to me upon completion of the current study.
(check one) ☐ YES ☐ NO
If "YES", this is my preferred method of contact (please fill one):
Address: _____
_____
Email: _____

Appendix E: Parental/Guardian Consent Form

PARENTAL/GUARDIAN CONSENT

Title of Study: AUDITORY AND VISUAL CUES IN SEQUENCE LEARNING

PRINCIPAL INVESTIGATOR: Kayla Duna (Master's Student)
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STUDENT RESEARCH ASSISTANTS: Jacqueline Ladwig-Davidson, Kelsey Brown, Brie Page, Tamires Prado
(204) 480 - 1487

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PURPOSE: This study is a Master's thesis project. We are interested in learning how typically developing children and adults perform a sequencing task with vision only or the combination of sound and vision.

DESCRIPTION: During the study, the participant will be asked to make a series of button presses in response to targets on a computer screen. The software program used will record all of the participant's button-press responses. Prior to this task, the participant will be asked to fill out a brief demographics questionnaire that inquires about age, gender, handedness, whether or not the participant's vision and hearing are corrected (glasses, contact lenses, hearing aids). The whole procedure will occur over two separate testing sessions, and each taking 15-30 minutes to complete. At the end of the second testing session, a specific question will be asked where the response will be recorded.

RISKS AND BENEFITS: There are no evident risks inherent in the tasks the participant will perform but some of the tests may become repetitive and the participant may experience boredom and/or mild muscle fatigue in their hands or arms. The participant is free to take a break as needed.

Participation in this study will help us discover ways in which typically developing participants perform with different sensory information: vision or sound and vision.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. The participant will receive a $10 gift card for Tim Hortons as a thanks for donating their time.

CONFIDENTIALITY: Participant information will be kept confidential. Once the participant begins the study, their name, information, and results will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with your code number. The Principal Investigator and student research assistants will have exclusive access to identifying information. Participant files will only be accessible by the investigators and will be destroyed by Dr. Glazebrook seven years after the completion of the study (approximately June, 2021). All papers containing personal information will be shredded. All electronic files will be deleted. Only Kayla Duna, Dr. Cheryl Glazebrook and the student research assistants listed will have access to any lists that contain identifying information. Dr. Glazebrook will only access the consent forms if audited by ENREB or when it is time to destroy the consent forms.

Results will be presented at academic conferences, invited presentations, and published in the PI's master's thesis, and peer-reviewed academic journals.

DEBRIEFING: Upon completion of the study the experimenter, will ask a specific question where the response will be recorded as part of the participant's data in the study. Following this the experimenter will describe the research questions being considered.

VOLUNTARY CONSENT: Participation in this study is strictly on a voluntary basis, and the participant can withdraw from the study at any time during the study or by contacting the PI or student research assistants in person, by phone, or email. If the participant *does not wish to participate* in the study, they are free to withdraw from the research study at any time without consequence and we appreciate their consideration. Upon withdrawal from the study, the participant will still receive an honorarium of a $10 gift card to Tim Horntons, and their data will be destroyed.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and as the parent/guardian agree to your child's participation as a subject. In no way does this waive your or your child's legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. The participant is free to withdraw from the study at any time, and /or refrain from answering any questions they prefer to omit, without prejudice or consequence. The participant's continued participation should be as informed as your initial consent, so you should

feel free to ask for clarification or new information throughout your participation. If the participant chooses to withdraw from the study they will still receive compensation for the time they have participated. The University of Manitoba may look at the participant's research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education/Nursing REB If you have any concerns or complaints about this project you may contact Kayla Duna (umduna@myumanitoba.ca, 204-480-1487) or the Human Ethics Coordinator (HEC) at (204)474-7122 or email at humanethics@umanitoba.ca.
A copy of this consent form has been given to you to keep for your records and reference.

Parent/Guardian Signature for Participant_____
Relationship _____ Date_____

Researcher/ Delegate's Signature _____Date _____

FINDINGS FROM THE STUDY: I wish to have a summary of the findings of the current study sent to me upon completion of the current study.
(check one) ☐ YES ☐ NO
If "YES", this is my preferred method of contact (please fill one):
Address: _____
_____
Email: _____

Appendix F: Assent Form

ASSENT
Title of study: AUDITORY AND VISUAL CUES IN SEQUENCE LEARNING

PRINICIPAL INVESTIGATOR: Kayla Duna (Master's Student)
Faculty of Kinesiology & Recreation Management
Health, Leisure, & Human Performance Research Institute
University of Manitoba
(204) 480-1487
umduna@myumanitoba.ca

SUPERVISOR: Dr. Cheryl Glazebrook
Faculty of Kinesiology & Recreation Management
Health, Leisure, & Human Performance Research Institute
University of Manitoba
(204) 474-8773
cheryl.glazebrook@umanitoba.ca

STUDENT RESEARCH ASSISTANTS: Jacqueline Ladwig-Davidson, Kelsey Brown, Brie Page, Tamires Prado
Faculty of Kinesiology & Recreation Management
(204) 480 - 1487

WHY ARE YOU HERE? We are interested in learning how you complete a computer task that is a little bit like a game. You will either see a picture only or you will hear a sound with the picture. This form explains what we will do and your role as a participant. If there is anything you do not understand, please ask your parent, your guardian, or the study staff.

WHY ARE THEY DOING THIS STUDY? We are doing this study to see how you press buttons when you see a picture, or when you also hear a sound. We want to learn about how you perform these tasks so that we can help design new activities and programs. You can choose to do one, more, or none of the activities that we tell you about.

WHAT WILL HAPPEN? If you participate in this study the following will happen:

1. We will ask to sit at a table with a computer screen and have you place the index and middle finger of each hand on a button box.

2. You will have a button box that looks like a game controller, that you will use to 'catch' the pictures on the computer screen. The study will take two separate meetings, and each meeting will take 15 minutes to 30 minutes.

3. At the end of the second meeting, there is a survey with a quick question that you will be asked. The survey is not long or hard. Your parent or guardian can help you with if you need it.

4. **You can take a break at anytime** if you need to. To make sure you have enough breaks during our meetings, we will take a short break every 5-10 minutes.

5. Your parent(s) or guardian(s) can stay during our meetings if you would like.

WHAT IF YOU HAVE ANY QUESTIONS? You can ask questions at any time before, during or after the study.

WHO WILL KNOW WHAT I DID IN THE STUDY? All of the information you give to the study staff will be kept confidential. Only the researchers will be able to look at any of the information you provide to us. After today your personal information will be referred to by a participant number so your information and results will be kept confidential.

DO YOU HAVE TO BE IN THE STUDY? If at any point in time you decide that you do not want to participate in this study please let us know.

Have we answered all of your questions?

Participation Assent for Research Study

I want to take part in this study and understand that I can change my mind at any time.

Name of participant (print): _____ Verbal assent given Yes ☐

_____ _____ _____

Signature of Participant Age Date

Parent/Guardian Signature for Participant_____

Relationship _____ Date_____

_____ _____

Printed name of research staff obtaining assent Signature

_____

Date

FINDINGS FROM THE STUDY:

THE PARTICIPANT: I wish to have a summary of the findings of this study when it is complete. (check one)

☐ YES

☐ NO

If "YES", this is how I want to be contacted (please fill one):

Address: _____

_____

Email: _____

THE PARENT OR GUARDIAN: I wish to have a summary of the findings of the current study upon completion of the current study. (check one)

☐ YES

☐ NO

If "YES", this is my preferred method of contact (please fill one):

Address: _____

_____

Email: _____

Appendix G: Report of Participant Video Gaming and Physical Activity

AGE	CNDTN	PARTCPNT	VIDEO GAMING	FREQUENCY PER WEEK (x/7)	TYPE: ACTION/ PUZZLE	PHYS ACTIVITY	FREQUENCY PER WEEK (x/7)
ADULT	VIS	P01-1	Y	7	ACTION	N	0
ADULT	VIS	P02-1	Y	1	ACTION	Y	7
ADULT	VIS	P03-1	N	0	NA	Y	7
ADULT	VIS	P04-1	Y	7	PUZZLE	Y	3
ADULT	VIS	P05-1	N	0	NA	Y	7
ADULT	VIS	P06-1	N	0	NA	Y	3
ADULT	VIS	P07-1	N	0	NA	Y	5
ADULT	VIS	P08-1	N	0	NA	Y	7
ADULT	VIS	P09-1	N	0	NA	Y	7
ADULT	VIS	P10-1	N	0	NA	Y	3
ADULT	VIS	P11-1	N	0	NA	Y	7
ADULT	AUDVIS	P21-1	Y	7	PUZZLE	Y	2
ADULT	AUDVIS	P22-1	N	0	NA	Y	7
ADULT	AUDVIS	P23-1	Y	2	PUZZLE	Y	7
ADULT	AUDVIS	P25-1	N	0	NA	Y	7
ADULT	AUDVIS	P26-1	Y	1	PUZZLE	Y	2
ADULT	AUDVIS	P27-1	N	0	NA	Y	7
ADULT	AUDVIS	P28-1	Y	6	PUZZLE/ ACTION	Y	6
ADULT	AUDVIS	P29-1	Y	7	ACTION	Y	7
ADULT	AUDVIS	P30-1	N	0	NA	Y	7
CHILD	VIS	P01-2	Y	2	PUZZLE	Y	4
CHILD	VIS	P02-2	Y	7	PUZZLE/ ACTION	Y	5
CHILD	VIS	P03-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	VIS	P04-2	Y	3	ACTION	Y	7
CHILD	VIS	P05-2	Y	1	PUZZLE/ ACTION	Y	7
CHILD	VIS	P06-2	Y	7	ACTION	Y	7
CHILD	VIS	P07-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	VIS	P08-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	VIS	P09-2	N	0	NA	Y	3
CHILD	AUDVIS	P21-2	Y	1	PUZZLE/ ACTION	Y	7
CHILD	AUDVIS	P22-2	Y	2	PUZZLE/ ACTION	Y	7

CHILD	AUDVIS	P23-2	N	0	NA	Y	7
CHILD	AUDVIS	P24-2	Y	4	PUZZLE/ ACTION	Y	7
CHILD	AUDVIS	P25-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	AUDVIS	P26-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	AUDVIS	P27-2	Y	7	PUZZLE/ ACTION	Y	7
CHILD	AUDVIS	P28-2	Y	1	ACTION	Y	5
CHILD	AUDVIS	P29-2	Y	7	ACTION	Y	7

Appendix H: Ethics Approval Certificate

UNIVERSITY OF MANITOBA | Research Ethics and Compliance
Office of the Vice-President (Research and International)

Human Ethics
208-194 Dafoe Road
Winnipeg, MB
Canada R3T 2N2
Phone +204-474-7122
Fax +204-269-7173

APPROVAL CERTIFICATE

March 19, 2015

MHRC

TO: **Kayla Duna** (Advisor C. Glazebrook)
Principal Investigator

FROM: **Lorna Guse, Chair**
Education/Nursing Research Ethics Board (ENREB)

Re: **Protocol #E2015:011**
"Auditory and Visual Cues in Sequence Learning"

Please be advised that your above-referenced protocol has received human ethics approval by the **Education/Nursing Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement (2). **This approval is valid for one year only**.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **If you have funds pending human ethics approval, please mail/e-mail/fax (261-0325) a copy of this Approval (identifying the related UM Project Number) to the Research Grants Officer in ORS in order to initiate fund setup. (How to find your UM Project Number: http://umanitoba.ca/research/ors/mrt-faq.html#pr0)**

- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

The Research Quality Management Office may request to review research documentation from this project to demonstrate compliance with this approved protocol and the University of Manitoba *Ethics of Research Involving Humans*.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/orec/ethics/human_ethics_REB_forms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**