EXAMINING THE EFFICACY OF ATTENTIONAL FOCUS INSTRUCTION ON TYPICALLY AND ATYPICALLY DEVELOPING YOUNG LEARNERS PERFORMING A POSTURAL CONTROL TASK: A FOUR EXPERIMENT RESEARCH PROPOSAL

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ABSTRACT

Within the last decade, the influence of focus of attention (FOA) instruction on postural control has been an increased interest among researchers (Yeh et al., 2016; McNevin et al., 2013). The general agreement when it comes to the role of FOA has been that adopting an external (EXT) FOA enhances the efficiency of motor programming by strengthening the relationship between movement planning and outcome, when compared to an internal (INT) FOA (see Wulf, 2013). However, increasing evidence suggests that the benefits from an EXT FOA can be mitigated by certain factors (e.g., age, skill level, novelty of the task and task complexity; Becker & Smith, 2013; Emanuel et al., 2008). As such, questions remain as to what form of FOA instruction is best suited for young learners, as FOA research has been criticized for being studied almost exclusively among adults (Agar et al., 2016). Research in this area is particularly sparse as it pertains to FOA in combination with postural control among this younger age group. This is particularly problematic as significant changes in postural control, stability and balance occur during one's first decade in life (Haas, et al., 1989; Hay & Redon, 1999; Barela et al., 2003). Moreover, there exists some methodological concerns with regard to the lack of consistency of FOA instructions being used during experimentation. This directly influences where participants are guiding their attention and their interpretation of FOA cues (Davids, 2007; Petranek, et al., 2019). Further, the lack of replicability of traditional FOA studies and the increasing number of non-statistically significant findings in this research, calls into question the overall validity, both internal and external, regarding FOA instruction (Becker & Smith, 2013; Lawrence et al., 2011). Therefore, as a series of four complementary studies, the overall aim of this thesis is to further investigate these theoretical as well as procedural gaps.

The first study examines which type of FOA instruction is best suited for two groups of young learners (typically developing children between 4-6 and 7-10 years of age) performing a postural control task. Participants will be randomized into either an INT, EXT or CTRL condition, where they will perform a postural control task with different respective visual displays. A force platform will be used to assess participants' mediolateral centre of pressure (COP) performance, and electromyography (EMG) will be used to assess muscular activation of the participants' major ankle stabilizers. The primary goal of study one is to investigate the influence of FOA in children by following the most common and traditional of FOA instruction.

The second study serves as an extension for the first study. The aim of this study is to specifically investigate the validity and reliability of using FOA instructions, and whether or not the different attentional cues can drive their intended mental focus states. The method of this study is identical to those is Study 1 with a few major exceptions. In this case, two manipulation checks will be added to the procedure in

order to assess how participants perceived, comprehended, and acted to their assigned FOA instructional condition. The first manipulation check is embedded in the structure of the trial itself: the comparison of postural control performance with and without visual information, modeled after the technique used in Yeh and colleagues (2016). The second manipulation check will be a retrospective verbal interview inspired by Perreault & French (2016).

Finally, the third and fourth studies look to expand the research question from study one and two to different populations of atypically developing young learners who are known to struggle with both attention and postural control. Individuals with ADHD and individuals with DCD have been shown to interpret attentional and postural information differently when compared to age-matched controls. Therefore, the aim of these studies is to compare the differing effects of FOA across neurodiverse populations. Specifically, study three will use a group of young learners (from 4 – 10 years of age) with ADHD and study four will use a group of young learners (from 4 – 10 years of age) with DCD. The only differences in these studies compared to study one will be the lack of an age split and the use of EMG assessment.

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I would like to express sincere gratitude to my thesis supervisor Dr. Jim Lyons for seeing my potential, and for supporting me throughout the many stages of this project. His wisdom, patience, and mentorship during this experience is something that I will always be appreciative for and will pay forward to others. I would like to thank Dr. Jim Burkitt for all his help throughout this process as well. His patience, expertise and encouragement have been invaluable. I would also like to thank my supervisory committee, Dr. Mike Carter, and Dr. Ting-Ting Yeh for their expertise and support throughout this experience.

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LIST OF ALL ABBREVIATIONS

FOA – Focus of Attention
EXT – External
INT – Internal
CTRL – Control
COP – Centre of Pressure
EMG – Electromyography
ADHD – Attention-Deficit / Hyperactivity Disorder
DCD – Developmental Coordination Disorder
PFC – Prefrontal Cortex
SMA – Supplementary Motor Area
Pre-SMA – Presupplementary Motor Area
PMd – Dorsal Premotor Cortex
PMv – Ventral Premotor Cortex
M1 – Primary Motor Cortex
S1 – Primary Somatosensory Cortex
PPC – Posterior Parietal Cortex
KR – Knowledge of Results
KP – Knowledge of Performance
TGMD-2 – Test of Gross Motor Development-2
ACT – Attentional Control Theory
AMY – Amygdala
ACT – Attentional Control Theory
SN – Salience Network
HC – Hippocampus
Ins – Insula
mMTL – Memory-Related Medial Temporal Lobe
N1 – Visual NI
P3 – P300 Wave
DES – Dorsal Executive Neural System
VAS – Ventral Affective Neural System
N170 – N170 Wave
FPN – Fronto-parietal Network
ACC – Anterior Cingulate Cortex
CNS – Central Nervous System
PNS – Peripheral Nervous System
IMD – Internal Modelling Deficit
AP – Anterior Posterior
ML – Mediolateral
ICC – Intraclass Correlation Coefficient
SOL – Soleus
TA – Tibialis Anterior

PL – Peroneus Longus
EDL – Extensor Digitorum Longus
DSM – Diagnostics & Statistical Manual of Mental Disorders
DMN – Disrupted Default-Mode Network
DAMP – Deficits in Attention, Motor Control & Perception Model

DECLARATION OF ACADEMIC ACHIEVEMENT

I, Noah Erskine, declare this thesis to be my own work. I am the sole author of this document. No part of this work has been published or submitted for publication or for a higher degree at another institution. To the best of my knowledge, the content of this document does not infringe on anyone's copyright. My supervisor, Dr. Jim Lyons, Dr. Jim Burkitt and the members of my supervisory committee, Dr. Mike Carter and Dr. Ting-Ting Yeh, have provided guidance and support at all stages of this project. I completed all of the research work.

CHAPTER ONE: INTRODUCTION TO STUDY ONE & METHOD

1.0 INTRODUCTION TO STUDY ONE

1.1 Feedback and its Application in Motor Learning

Humans are born to move, and in order to interact with their environment they must learn how to move skillfully. Whether it be tasks for daily living (e.g., brushing their teeth) to specialized skills (e.g., driving a car) changes related to the performance of these skills are a direct result of practice along with experience (e.g., Wulf et al., 2015). The study of understanding the processes that lead to relatively permanent changes in the capability for skilled movements is formally known as *motor learning.* Specifically, the notion of learning in a motor context is governed by four main principles: 1) Learning is the process of developing the capability to perform skilled movements. 2) Learning is a direct result of practice and experience. 3) Learning can only be inferred through changes in behaviours, as the processes that facilitate learning occur internally. 4) Learning produces relatively permanent changes for skilled movements (Wolpert et al., 2001; Wolpert & Flanagan, 2010; Krakauer et al., 2019).

Learning can be broken down into either explicit or implicit learning. *Explicit learning* is a form of learning that uses deliberate problem-solving techniques to help the individual acquire knowledge that can be consciously recalled (Berry & Dienes, 1993). An example of this type of learning would be an anatomy student making study cue cards to memorize brain regions for an upcoming test. *Implicit learning* on the other hand, is a form of learning where the learner acquires knowledge passively without the use of any analytic strategies and is primarily associated with learning a new physical skill (Berry & Dienes, 1993; Posner & Rothbart, 2014). An example of implicit learning would be an individual knowing the lyrics to their favourite song just from listening to it over time (i.e., without deliberately trying to memorize them). Mainly, implicit learning differs from explicit learning in the sense that acquired knowledge is less accessible and more difficult to articulate consciously in comparison to explicit learning (Liao & Masters, 2001; Hayes & Broadbent, 1988; Reber, 1993; Berry, 1996; Dienes & Berry, 1997; Reed & Johnson, 1998).

While the terms implicit and explicit seem inherently dichotomous, Krakauer and colleagues (2019) argue that even if the end result of a learned skill is implicit and procedural, explicit cognitive processes contribute to learning of that skill. Particularly in the beginning stages of learning a movement, explicit processes may dominate motor learning. Further, explicit learning strategies can be automatized, thus turning the acquired knowledge implicit in nature (Ashby & Crossley, 2012). An example of this can be someone who is unable to consciously recall their ATM pin number but is still able to type it in correctly when placed in front of a keypad (Krakauer et al., 2019).

Implicit and explicit learning are highly related within with the executive functioning network and hippocampus (Posner & Rothbart, 2014; Petersen & Posner, 2012; Posner et al., 2012). The hippocampus particularly plays a major role for acquiring new information, for encoding and indexing new memories, and for recalling information (Squire, 2009; Posner & Rothbart, 2014;

Squire & Wixted, 2011). Specific to motor learning and performance, Krakauer and colleagues (2019) note the contributions from 11 different brain regions for implicit and explicit learning (Figure 1). Briefly: 1) the prefrontal cortex (PFC) is involved with the cognitive control of motor activities and the planning of any future sequences (Mushiake et al., 1991). 2) The supplementary motor area (SMA) plays a significant role in the planning, control, and representation of movement sequences (Gaymard et al., 1990; Jenkins et al., 1994; Lee et al., 2003; Mushiake et al., 1991; Shima et al., 2000; Alexander & Crutcher, 1990; Kurata & Wise, 1988; Tanji et al., 1988). 3) The presupplementary motor area (Pre-SMA) serves as a memory buffer for future action sequences and helps to maintain the proper order of sequenced elements. 4) The dorsal premotor cortex (PMd) is involved in movement planning. 5) The ventral premotor cortex (PMv) plays an important role for communication, particularly with vocabulary, speech production and manual gestures. 6) The primary motor cortex (M1) is involved with the execution of motor behaviours and is the locus of learning for prehension skills. 7) The primary somatosensory cortex (S1) helps with storing and updating an internal model (which will be later discussed in this document) that helps to mediate adaptation (Mathis et al., 2017). 8) The posterior parietal cortex (PPC) aids with maintenance of a stable representation during adaptation. 9) The hippocampus, along with the points noted above, facilitates explicit strategies while learning a new movement (Posner & Rothbart, 2014). 10) Cerebellum helps to recalibrate the motor system during learning to achieve the desired behaviour. 11) The basal ganglia help control the outflow of an action sequence and play a role with carrying out automatized behaviours. These brain areas will be further explored in subsequent sections of this document in the context of research question posed herein.

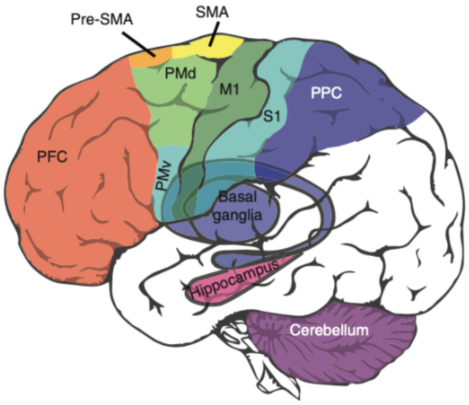

Figure 1: *Brain Regions Contributing to Motor Learning* (Krakauer et al., 2019)

Crucial to motor learning, feedback is argued to be one of the most important factors facilitating the learning process (Wulf et al., 2010; Perreault & French, 2015; Perkins-Ceccato et al., 2003). *Feedback* has been defined as the reception of performance information occurring within a behavioural regulation loop associated with movement error detection and correction needed for motor learning (Potdevin et al., 2018; Mulder & Hulstijm, 1985). In other words, feedback is performance-related information that an individual receives to aid them in rapidly correcting their errors when attempting to achieve desired movement patterns in subsequent attempts (Perreault & French, 2015). More specifically, it helps orient a learner towards nuanced components of a skill, directs attention to the important factors needed for the execution of the skill, and highlights common errors that may potentially arise (Perrault & French, 2013). Thorndike (1927) suggests that feedback is fundamental for strengthening the relationship between a stimulus and the appropriate subsequent response. In addition, feedback reduces the cognitive demand required for processing information while learning a new skill (i.e., explicit learning; Landin, 1994; Perrault & French, 2013).

Furthermore, feedback can be categorized into either inherent or augmented feedback. *Inherent* feedback (or "intrinsic feedback") is the naturally occurring sensory-perceptual information from the exteroceptors (i.e., visual, auditory, and tactile information) and interceptors (e.g., internal muscular tension) available to a learner derived from performing a task (Lauber & Keller, 2014; Sidaway et al., 2005). Inherent feedback enables the individual to evaluate their movements (via sensation of the various sensory mechanisms) in real time such that the individual can correct movement errors during the course of a movement attempt or afterwards before the next attempt. Although some errors may be evident and detected immediately, other errors may require the individual to learn unique sensations in order to make the appropriate adjustments (Cole & Sedgwick, 1992; Lauber & Keller, 2014). An example of this can be an individual learning how to skateboard. A beginner skateboarder may be able to inherently sense when they are off balance on the board. However, they will struggle to interpret advanced level proprioceptive information needed for the necessary biomechanical adjustments to maintain their balance when performing various tricks.

Augmented feedback (or "extrinsic feedback") is an external source of qualitative or quantitative information (e.g., instructor, trainers, or a video) that supplements the already existing sensory information (Lauber & Keller, 2014; Sidaway et al., 2005). It is information that is not available to the learner through internal sources. Moreover, augmented feedback helps galvanize the interpretation and learning of nuanced components of a skill for a learner by explicitly orienting their attention toward them. Perrault & French (2013) argue that the most efficacious forms of augmented feedback are short concise phrases or sentences, which commonly take the form of verbal *cues*. Good verbal cues clarify the necessary informational components needed for the task and match the learner's cognitive and skill level (Rink, 2010). An example of augmented feedback would be cues (e.g., biomechanical tips such as "try to keep your hips over the centre of the board") given to a beginner skateboarder while trying to learn more difficult skills. Both inherent and augmented feedback work in tandem, however, without informational prompts coming from augmented feedback, learning strictly from inherent feedback can be slower and may even stagnate (Perreault & French, 2015). Thus, in many cases, the ability to interpret relatively more advanced biomechanical sensations, direction from a coach is needed. This why even highly skilled athletes such as UFC champions frequently change coaches to gain novel insights and supplementary information to progress their techniques.

For motor learning scientists, augmented feedback paradigms are the predominant focus (Lauber & Keller, 2014). Specifically, the way in which augmented feedback informs the individual regarding their knowledge of results or knowledge of performance is manipulated (Perreault & French, 2015). *Knowledge* *of results* (KR) is performance-based information given to the individual regarding their accuracy of a response outcome relative to the task goal (O'Connor et al., 2008) whereas as *knowledge of performance* (KP), is movement-based information regarding the individual's movement form needed for a particular movement outcome (O'Connor et al., 2008). An example of KP would be a wrestling coach reminding their athlete to bend their knees when picking up their opponent, which contrasts KR, which would be the scores provided to a figure skater from a panel of judges during a routine.

The information-processing model has historically been used as a theoretical framework to explain the influence of augmented feedback on motor learning (Czyż, 2021). The *information-processing model*, a framework used to explain the human decision-making process has several interpretations and iterations, however, the "classical" model holds that there are three distinct stages (figure 2; Czyż, 2021). The first stage, the *stimulus identification stage*, is where a stimulus is first detected and recognized. An identifiable pattern of the stimulus is typically isolated and turned into a meaningful one during this phase. Once properly identified, in the second stage, the *response selection stage*, the learner has to decide an appropriate response from a finite number of appropriate actions to the stimulus. This particular stage is considered to be cognitively taxing, time-consuming, and energy consuming. Lastly, when an appropriate response is selected, the *response execution stage* is where the individual translates the abstract concept of what to do (i.e., response selected in the previous stage) to direct and realistic commands for the motor system (Czyż, 2021). This stage is also referred to as “response programming” or “motor programming” (Czyż, 2021; Pearson, 1993).

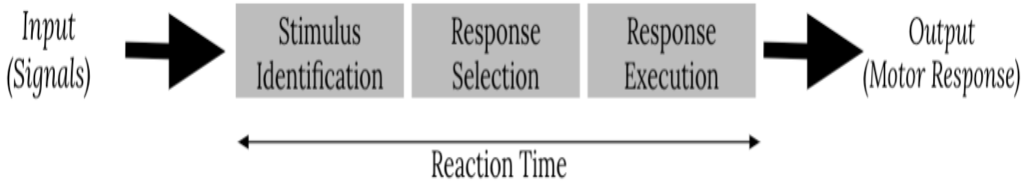

Figure 2: The "classical" *Information-Processing Model*

1.2 Attention & Motor Learning

In the information processing model, augmented feedback plays a major role in enhancing the repetition of the error-identification and error-correction processes (Czyż, 2021; van Dijk et al., 2005). Earlier works, however, explaining the role of augmented feedback can be considered to be overly reductionist as they only consider the influence of this type of feedback on information processing. Consequently, the picture remains incomplete as augmented feedback additionally influences affective phenomena (e.g., motivation) and attention, which are both crucial for the learning process (van Dijk et al., 2005; Davis & Davis, 2016; Hanin, 2007). Particularly, the way in which augmented feedback directs participants’ attention during learning is a major interest for the field of motor learning (see Wulf, 2013), and thus will be the primary focus for this document.

Attention is considered to be a key component affecting behavioural and learning outcomes (Cohen & Maunsell, 2009). The concept of attention, however, has been a major source of debate within the literature (see Anderson, 2011) revolving around the very basic question: what, exactly, *is* attention? Though there are many different theories and descriptions, a lack of experimental consistency and of a universal definition remain absent for the construct (Hommel et al., 2019). Hommel and colleagues (2019) argue that multiple distinct and complex cognitive mechanisms are simply labelled as "attention", resulting in the concept of attention being both the "explanans" (i.e., the cause) and the "explanandum" (i.e., the symptom). The complexity of this problem is further illustrated by Petersen & Posner (2012) who highlight four distinct functions related to the attentional system, along with their different associated brain regions. Briefly: 1) *Alerting*, described as the ability to produce and maintain vigilance for tasks (i.e., alertness), is mainly correlated with the neuromodulator norepinephrine, which is released by the locus coeruleus. 2) *Orienting*, which is the ability to select relevant sensory input (e.g., visual location), is predominately governed by the dorsal attention system (the frontal eye fields and the intraparietal sulcus/superior parietal lobe) and the ventral attention system (the temporoparietal junction and the ventral frontal cortex). 3) *Executive-control*, defined as the control and coordination of higher-order cognitive abilities (e.g., decision making) is regulated by the frontoparietal control system (precunei, the middle cingulate cortex, the dorsolateral prefrontal cortex, the dorsal frontal cortex, the intraparietal sulcus, and the inferior parietal lobe) and the cingulo-opercular system (the dorsal anterior cingulate cortex/medial superior frontal cortex, the thalamus, the anterior prefrontal cortex and the anterior insula/frontal operculum). Lastly, 4) *Self-Regulation* which is the ability to control thoughts, feelings, and behaviours, is mainly related to both the dorsal and ventral portion of the anterior cingulate gyrus. Although these four functions suggested by Petersen & Posner (2012) are distinct in nature, they are commonly referred to simply as “attention”. Nevertheless, the aim of this thesis is not to explicitly solve this conceptual/theoretical problem, but rather to acknowledge the complexities involved with researching attention and to conceptualize the construct of attention in a motor learning context.

As attention remains a difficult concept to both accurately and concisely define, Wells & Matthews (2015) argue that it is best defined practically using a clinical perspective (illustrated by its effect in emotional/affective disorders). Therefore, *attention* is defined by two main ideas: 1) Attention is a process that helps the individual select which stimuli are important and should influence an ensuing response (i.e., attention selectivity). 2) Attention is a process of sustained (“or intensive”) concentration which enhances the efficiency of information processing (i.e., intensive processing). This definition of attention is commonly referred to simply as *selective attention* and maintains that attention aids the information-processing system with selecting relevant stimuli, choosing which stimuli require extensive processing, and dictating which require intervention. Moreover, when a mental activity becomes too demanding, taxing the attentional system, cognitive overload is mitigated through a reduction in intensity of concentration towards peripheral activities. This in turn increases the capacity for processing of the primary task (e.g., an individual turning down the volume of the car stereo to concentrate on parking), but this is a finite function (e.g., a fatigued

Master student distracted by a noisy fan in their room while writing a thesis; Piek & Pitcher, 2004; Summer & Ford, 1995; Schmidt, 1988). For the purpose of this document, selective attention will herein be referred to as attention unless explicitly specified otherwise.

Along with the distinction of attention selectivity and intensity, there are two forms of attentional processing commonly cited: 1) C*ontrolled processing,* which is a form of effortful processing that is slow, attention demanding (i.e., easily interrupted by similar tasks), serial in nature, and voluntary (i.e., can be easily avoided and/or stopped; Schneider & Shiffrin, 1977). 2) *Automatic processing*, which is automatic, fast, non-attention binding, can co-occur with other operations, and is involuntary (Underwood & Everatt, 1996; Schneider et al., 1984; Schneider & Fisk, 1983; Schneider & Shiffrin, 1977). Wells & Matthews (2015) add that these differences in processing can be pictured in dual levels. The lower level reflects *low level processing* of stimuli that is automatic, involuntary, and seldom limited by attentional capacity. In contrast, the upper level supports voluntary *processing of higher order* stimuli requiring cognitive planning; this type of processing is both fatiguing and constrained by attentional capacity. Framed differently, the lower level can be thought as implicit in nature, whereas the higher level can be thought as explicit.

This conceptualization, however, is not without criticism, as the distinction between levels is often blurred (Wells & Mathews, 2015). In a review article by Neumann (1987), it is argued that there is little evidence that an information-processing activity can be free from interference of a secondary task, criticizing whether or not an activity can truly be automatic (i.e., without interference). Summers & Ford (1995) note that the addition of a secondary task and/or an increase in task complexity influences both attentional capacity and the efficiency of processing, potentially causing delayed responses and an increased error potential. Likewise, individuals with maladaptation in disengagement from intensive processing (i.e., deep concentration on task irrelevant aspects) can affect the flow of information processing necessary for fluid and efficient responses (Summers & Ford, 1995; Wilson et al., 1997; Piek & Pitcher, 2004). Correspondingly, it is suggested that this controlled and automatic processing duality be theorized as a continuum rather than a hard dichotomy (MacLeod & Dunbar, 1988; Moors & De Houwer, 2006; Underwood & Everatt, 1996).

Motor behaviour is highly dependent on attentional capabilities. For instance, functional handwriting requires the attentional system to voluntary process inherent higher order information (i.e., planning, and problem-solving of intellectual and grammatical information) as well as being able to intensively concentrate on intricate biomechanical details to accurately carry out the motor output and to selectively attend or filter other stimuli potentially needed for the behaviour (Berninger, 2004). The degree in which behaviour is reliant on attentional capacities is expected to increase along with task complexity. For example, consider how the task of driving a car changes when performed concurrently with operating mobile technologies, especially in unpredictable environments (Stavrinos et al., 2013). Both environmental complexity (Strayer & Johnston, 2001) and an increased level of traffic (Lee et al., 2001; Strayer et al., 2003) elicit a decrease in performance among participants using a cell phone while driving.

Similarly, attention is fundamental for learning, where some researchers argue attention to learning-materials to be the most prominent factor affecting learning (Posner & Rothbart, 2014; Chun & Turk-Browne, 2007; Piek & Pitcher, 2004; Summers & Ford, 1995; Wilson et al., 1997). Consider a pre-schooler learning how to read. Phonological awareness requires the learner to not only selectively attend to different components of the word, but to also produce the correct associative sound. Posner & Rothbart (2014) note that during the early learning steps required for expertise, the individual must be able to effectively direct attention in an efficient and precise manner. More specifically, the authors note that the process to expertise is highly dependent on sustained effortful concentration and the ability to persist through the processing of substantial amounts of information required for a specific skill domain, which are related to the hippocampi. Furthermore, attentional capacities are explained to be a necessary prerequisite for both implicit and explicit learning (Naccache et al., 2002).

Regarding motor learning, Piek & Pitcher (2004) suggest that attention is particularly important while learning a new movement, as it permits the individual to attend to task relevant cues, sequence together biomechanical information, and direct other cognitive processes needed for the movement.

Further, the authors suggest that when a movement is well-learned, components of the movement, or the whole movement itself, can be automatized. Contingent on the degree of movement proficiency, this implies that deliberate practice with sustained attention eventually drives the learner to train their attentional system to process the specific task information more efficiently, decreasing the overall attentional demand (Piek & Pitcher, 2004). This is further evidenced in studies where participants learning familiar motor sequences with minimal new unique components were not as influenced by task distractions compared to learning similar elements of a previously learned task but in different orders (Cohen et al., 1990; Keele & Jennings, 1992). This is potentially due to the task being in a different order requiring more higher-ordering processing, as the rearrangement in movement sequence made it a fundamentally new movement (Cohen et al., 1990; Piek & Pitcher, 2004). Essentially, learning how to improve automatic processing for a given movement can be beneficial as it reduces processing loads, enables processing to become much faster, and allows additional processing to be done simultaneously (e.g., an experienced cook cooking while listening to music; Schneider et al., 1984; Schneider & Fisk, 1983; Schneider & Shiffrin, 1977). When all these factors are taken in account, it is very clear that attention plays a role in motor learning, however, the way in which extrinsic feedback specifically directs and focuses attention is argued to be one of the most important factors concerning attention and its influence on motor learning (Wulf, 2013).

1.3 Focus of Attention (FOA) Instruction

Augmented feedback likely guides *attentional-focus* (or "focus of attention" - FOA) during motor learning and performance in one of two ways: either internally or externally. *Internal focus of attention* (INT) is attention directed towards the mechanics of the movements themselves (e.g., focusing on limb positions and joint angles during a soccer kick). *External focus of attention* (EXT) is attention directed towards the effects (or outcomes) of one's movements (e.g., soccer ball speed or distance; Lawrence et al., 2011; Wulf et al., 2000; Perreault & French, 2015). Perkins-Ceccato and colleagues (2003) note FOA as "consciously attending to specific information during the production of action". Along with this distinction, focus refers to an individual's mental focus and not their visual focus (Yeh et al., 2016). Attention is not often operationally defined in FOA studies (Davids, 2007; Petranek et al., 2019; Perreault & French, 2015) thereby making comparisons between, or accurately assessing the cumulative evidence of these studies very difficult. For the purposes of this thesis, therefore, the construct of attention discussed herein as it relates to the various FOA studies being proposed will imply the specific considerations outlined above by Perkins-Ceccato and colleagues (2003) and Yeh and colleagues (2016).

The modern understanding of FOA originated with Prinz (1990, 1997), who proposed a common coding framework as an alternative to the traditional understanding of perception action coupling, which assumes that there are different and disproportionate coding systems for afferent information (i.e., the transmission of information from the sensory organs to the central nervous system) and efferent information (i.e., the transmission of impulses from the central nervous system to the limbs and organs). Under this perspective, there is no direct interaction between perception and action; requiring additional cognitive processing to convert perceptual representations into actions (e.g., Massaro, 1990; Sanders, 1980; Welford, 1968). The *common coding approach* (figure 3), however, argues that there exists a common representational medium for perception and action. Efferent and afferent codes are generated and maintained in a proportionate way only at a distant level of representation. That is, perception and action planning both refer to distal events, since this is the only format that allows for commensurate coding and, thus, for the planning of actions in a format shared with perception. Therefore, actions should be more effective if they are planned in terms of their intended outcome, rather than in terms of their specific movement patterns (Prinz, 1990, 1997). Consequently, this led Prinz to propose the *action-effect principle*, which postulates there to be a compatible relationship between actions that are planned and controlled in terms of their effects (Prinz, 1997).

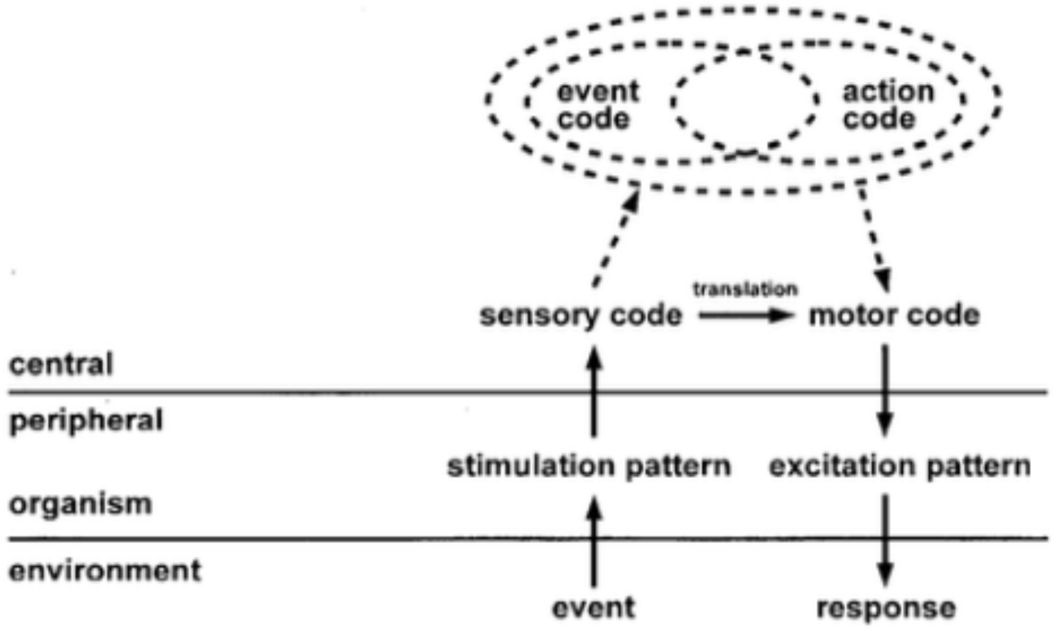

Figure 3: From Prinz (1997) depicting the relationship between perception and action. Lower part (unbroken lines): Separate coding (sensory codes, motor codes and translation between them). Top part (broken lines): Common coding (event codes, actions codes and induction between them).

This theory is somewhat abstract, as it does not take into consideration the differential learning effects of external versus internal attentional foci (Wulf & Prinz, 2001). Wulf and colleagues (1998) further extend the logic from the common coding theory by proposing that if movements are planned with consideration to their outcome, then focusing on movement effects should improve performance by directly enhancing the efficiency of the motor programs responsible for the desired goal actions. Wulf and colleagues (2001) had participants simultaneously perform a dynamic balance task and a probe task where participants were given the objective to balance on a stabilometer and press a button whenever they heard the targeted auditory tone. Participants were divided into either an INT condition where they were instructed to focus on their feet to balance, or an EXT condition where they were told to focus on markers placed on the stabilometer. The researchers discovered that the EXT condition displayed greater balance and lower attentional demands compared to the INT condition. This led Wulf and colleagues (2001) to combine their observations with Prinz's (1997) action-effect principle to propose the *constrained action hypothesis.* This model maintains that EXT FOA enhances the efficiency of motor programming (i.e., a better response outcome) by strengthening the relationship between movement planning and that outcome, thus facilitating a greater level of automaticity. Conversely, under conditions of an INT FOA, organization of motor programming is disrupted by interfering and constraining normal automatic control processes that are presumed to be needed for the efficiency of the movement. Specifically mentioning one's body part or sensations is believed to be enough to activate both self-evaluation and self-regulation processes (self-invoking trigger) which degrades motor performance (Wulf et al., 2001; Perrault, 2013; Lawrence et al., 2011; Wulf & Lethwaite, 2010; Perreault & French, 2016).

Since this early hypothesis, FOA research has gained considerable popularity. FOA research is consistent with Guthrie's (1952) description for skilled performance in that this definition maintains that *skilled performance* can be characterized as both movement effectiveness (i.e., KR) and movement efficiency (KP). Therefore, FOA has been assessed in both KR tasks (e.g., Skiing; Wulf et al., 1998; Soccer; Wulf et al., 2010) and KP tasks (e.g., Gymnastics routine; Lawrence et al., 2014). Moreover, both immediate performance (i.e., during practice when FOA instruction is given) and motor learning (i.e., reflected in permanent changes in performance) are influenced by FOA. Thus FOA, is assessed in acquisition, retention, and transfer tests (Wulf, 2013). The majority of FOA research is, however, conducted strictly using behavioural assessments (Kuhn et al., 2021).

Within the last decade, there has been an increase of studies using neuroimaging assessments to examine the effects of FOA instruction at the cortical level, as the neurophysiological mechanisms are unclear (Kuhn et al., 2021; Zentgraf et al., 2009). For example, by assessing the differences in brain activity of an INT vs. an EXT FOA via fMRI, Zentgraf and colleagues (2009) show increases in activation of the primary motor cortex, the primary somatosensory cortex, and the insular cortices when participants performed a finger sequence task adhering to an EXT FOA. Zimmermann and colleagues (2012), however, show different brain activation patterns via fMRI. Participants were trained with either an INT or an EXT FOA where they had to perform a finger sequence task similar to Zentgraf and colleagues (2009). Participants were then unexpectedly instructed to switch their FOA attention (i.e., from an INT FOA to an EXT FOA and vice-versa) at the halfway mark of the total trials, where they had to adhere to their untrained FOA instructions for the remaining trials. The authors show that the switch from a trained INT FOA state to an untrained EXT FOA state resulted in an increase activation of the lateral premotor cortex, whereas a switch from an EXT FOA state to an untrained INT FOA stated depicted an increase activation of the left primary somatosensory cortex and intraparietal lobule. fMRI studies are, however, limited as their depictions do not differentiate excitatory neural activation from inhibitory neural activation (Kwong et al., 1992; Arthurs & Boniface, 2002). Therefore, other imaging tools such as TMS have been used as well. For example, Kuhn and colleagues (2018) using TMS show that adopting an EXT FOA compared to an INT FOA results in increased inhibitory activity of the interneurons within the primary motor cortex. These data were interpreted by the authors as reflecting more efficient motor planning and a greater level of automaticity, which would reflect Wulf and colleagues constrained action hypothesis.

With respect to the differential effects of FOA instructional sets, Wulf and colleagues have consistently shown superior performance and learning for participants experiencing EXT FOA conditions (see Wulf, 2013) and use these data to strongly forward the idea that an EXT FOA is the gold standard no matter the learning circumstance. The constrained action hypothesis supporting these data is more precisely evidenced in three behavioural areas (Palmer et al., 2017; Perreault, 2013): 1) Attentional capacity (e.g., Wulf et al., 2001), where EXT FOA reduces attentional load as evidenced through an increase in automatic processing, 2) frequency of movement adjustments (e.g., Wulf et al., 2003), where EXT FOA is reflected by relatively efficient frequency adjustments made during the movement in response to perturbations, and 3) efficient motor planning and muscular activity (e.g., Lohse et al., 2010), where EXT FOA has led to less “noise” in the motor system suggesting automatic control. These conclusions are backed by a meta-analysis by Tang and colleagues (2012) showing skill acquisition as benefitting more from an EXT FOA compared to an INT FOA.

An increasing number of researchers have, however, been unsuccessful in replicating findings from Wulf and colleagues (e.g., Shams et al., 2020; Ford et al., 2005; Petranek et al., 2019). For example, Lawrence and colleagues (2011) looked to assess FOA effects through the use of a gymnastic routine. Participants practiced a routine over two days while either focusing on their mechanics (INT FOA), facial muscles and facial expressions (INT FOA irrelevant), the movement pathway and keeping even pressure through their feet (EXT FOA), or no attentional focus (CTRL condition). The researchers concluded that after a one-week retention interval, the groups did not differ in technique scores on a retention and transfer test, which led them to suggest that the learning advantage of EXT FOA may be limited to KR tasks.

Interestingly, a number of studies have in fact shown INT FOA as yielding superior results compared to EXT FOA conditions (e.g., Castaneda & Grey, 2007; Perkins-Ceccato et al., 2003; Black, 2004; Williams, 2009; Gray, 2004). For example, Beilock and colleagues (2002) recruited right-footed soccer novices and right-footed soccer experts and had them complete a series of slalom dribbling trials with either their dominant foot or their non-dominant foot. Participants were either instructed to complete a skilled-focused condition (INT FOA) where they were explicitly instructed to focus on their feet while dribbling, or a dual- task condition (EXT-FOA) where participants had to anticipate the target word "Thorn" and repeat each time they heard it while dribbling. What Beilock and colleagues (2002) discovered is that the self-focus condition resulted in faster dribbling times for the novice group regardless of their dominant foot, and same for the expert group using their non-dominant foot when compared to the dual- task condition. This led the authors to later propose the *deautomization of skill hypothesis*, which suggests that when control is not yet automatic for a task (e.g., a novice learner or an expert using their non-dominant foot) INT FOA instructions are more beneficial for the learner as the conscious control inherent in this attentional set permits the learner to develop a greater overall understanding of the task mechanics, which in turn acts as a necessary base for the eventual development of automaticity. On the other hand, when the performance is already automatic (e.g., experts using their dominant foot), INT FOA instructions can drive the learner to "micro-choke" by focusing on mechanics that are already automatic (deautomization) resulting in a less fluent performance. EXT FOA instruction is believed to amplify the automaticity of the task, which is only beneficial when the task performance is already automatic. Additionally, researchers have expanded this hypothesis beyond novice vs. expert, to other factors such as task novelty and task complexity (Becker & Smith, 2013; Petranek et al., 2019; Agar et al., 2016).

Notably, Wulf and colleagues have evolved their initial constrained action hypothesis to encompass social-cognitive-affective factors (e.g., intrinsic motivation). This is a result of emerging evidence depicting the influence of these factors on skilled performance and learning (e.g., Hagger et al., 2015; Taylor et al., 2014). Wulf and colleagues' new proposal, the *optimizing performance through intrinsic motivation and attention for learning theory* (OPTIMAL; Wulf & Lethwaite, 2016), suggests several new factors to address for practice conditions. These include: 1) Enhancing expectancies for future performances. This is because past performance-based achievements build self-confidence and enable the individual to have positive expectations for future performances (Wulf & Lethwaite, 2016). 2) Supporting learners' autonomy. The authors suggest that this provides the learner with a greater sense of control, which can increase motivation. 3) Promoting an external focus of attention, which is consistent with Wulf and colleagues' earlier hypothesis. Kuhn and collegues (2021) explain, however, that for the last 20 years, the constrained action hypothesis is the most commonly cited hypothesis within the FOA literature and is still widely used to rationalize the benefits of an EXT FOA condition. Therefore, for the purpose of this thesis, the constrained action hypothesis will be used to explain the effects of an EXT FOA herein.

1.4 FOA & Children

FOA research is often criticized for being exclusively studied among adult populations (Agar et al., 2016; Petranek et al., 2019; Emmanuel et al., 2008). Even with the expanding amount of FOA research when considering non-adult populations, the conclusions regarding the relative benefits of INT and EXT FOA remain decidedly mixed. Some studies show a benefit for an EXT FOA over an

INT FOA in children (e.g., Wulf et al., 2010), whereas other studies show no significant differences (e.g., Perreault & French, 2016) or more ambiguous findings in these younger populations (Becker & Smith 2013). For example, Palmer and colleagues (2017) looked to determine the effects of an INT and EXT FOA on children's object control performance. They used the Test of Gross Motor Development-2nd Edition (TGMD-2; Ulrich, 2000. Test of Gross Motor Development-2. Austin: Pro-Ed.), which is a normalized and criteria-referenced assessment frequently used to assess fundamental motor skill competence in children through a subtest of six fundamental motor skills. This test includes striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll. All participants completed the object control subtest of the TGMD-2 under three different attentional focus conditions: baseline (i.e., neutral focus), INT, and EXT FOA. The researchers concluded that there were no significant differences between conditions and suggest there to be a possible age limitation to both the constrained action hypothesis and FOA effects. Palmer and colleagues further suggested that this was perhaps due to a certain level of skill, or a physical, cognitive, or neurological maturity required for participants to be fully susceptible to the effects of altering FOA while performing a motor skill.

Moreover, some studies have shown superior results for an INT FOA over an EXT FOA in younger individuals (e.g., Emanuel et al., 2008). For example, Petranek and colleagues (2019) looked to investigate the type and frequency of FOA instructions best suited for younger children performing an overhand throw.

Participants were provided either an EXT or INT FOA instruction at high- or low-frequency rates resulting in four experimental groups: External-High, External-Low, Internal-High, and Internal-Low. This study showed that the INT FOA groups performed significantly better than the EXT FOA groups during retention and transfer tests. The researchers suggest that the immature cognitive strategies of young learners may mask any benefits of an EXT FOA during motor skill acquisition. Additionally, the EXT FOA cues used in this study (e.g., make a "T") can be considered as being too "abstract" and more difficult to recall, suggesting that INT FOA cues (e.g., arms out wide) may have resonated more with the young performers.

The lack of consistency regarding the best suited FOA condition for this population is particularly concerning, given that children are the most significant population of new movement learners (Perreault, 2013). It is often assumed that children are similar to adult or adolescent novices, due to their lack of experience, unfamiliarity with most tasks, and limited range in motor capabilities. These capabilities and experiences increase along with the development of fundamental motor skills throughout childhood (Clark, 2007; Palmer et al., 2017; Emmanuel et al., 2008; Petranek et al., 2019). Moreover, it is naïve to assume that adult learning strategies are directly transferable to this population, given the breadth of differences in information-processing, memory encoding strategies, emotional regulation, and attentional capacities (Agar et al., 2016; Perreault, 2013).

When compared to adults, it is well documented that children make slower and less accurate decisions during motor learning (Petranek et al., 2019; Lambert & Bard, 2005; Emanuel et al., 2008; Sullivan et al., 2008). Perreault (2013) suggest that as children age, their information processing abilities become more efficient and are able to process information (e.g., KP instruction from a coach) more quickly. One way in which processing speed has been shown to improve with age is evidenced through the ability to process the same or more amounts of information in shorter periods of time. (e.g., Thomas et al., 1979, 1981). Furthermore, cognitive development additionally impacts information processing profoundly. As children age, they develop and learn more mature cognitive strategies which enable them to handle information more efficiently (this will be discussed further; Agar et al., 2016; Yan et al., 2000). One possible reason for this is that many of the executive functions associated with information processing (i.e, prefrontal, and frontal brain regions) are among the last to myelinate and to reach functional maturity (Chugani et al., 1987; Casey et al., 1997; Hooper et al., 2002; Smith & Jonides, 1999; Huttenlocher, 1979; Klingberg et al., 1999).

Children are also different to adults in both memory and encoding strategies (Perreault, 2013). As children mature, they become more efficient at encoding information and develop better memory strategies, rather than just increasing the amounts of memory storage. Winther & Thomas (1981) show that young children seldom use strategies to encode information for later recall. Moreover, the use of spontaneous rehearsal does not typically start until 7 to 8 years of age (Thomas, 1984). The quality of these rehearsal strategies becomes more effective with maturity as well, as young children tend to use more passive memory strategies (e.g., rote memorization) as opposed to adult forms of active strategies (e.g., Feynman technique; Thomas, 1984; Gallagher & Thomas, 1984). Lastly, memory organization is evidenced to increase with maturity (Gallagher & Thomas, 1986; Thomas, 1984).

The influence of emotion is seldom considered in FOA research. Emotion is best conceptualized through the *affective phenomena framework* (Dolcos et al., 2020), which maintains *emotions* are a physiological response, whereas *feelings* are associative psychological states (Iversen et al., 2000; LeDoux & Brown, 2017). Affective phenomena serve as endogenous teaching devices that are intrinsically interrelated with cognitive processes during learning. In other words, affective phenomena help to either reinforce or deter certain behaviours, which further influence the cognitive processing of these behaviours (e.g., an individual who becomes addicted to weightlifting because of an increased self-perception of social desirability and from endorphins contributing to positive emotions and feelings). Therefore, the process of learning is considered to be both emotional and cognitive in nature (Le Doux, 1994; Manzotti et al., 1999; Mayer, 2019; Crick & Dodge, 1994; Derryberry & Tucker, 1994; Izard, 2009; Lewis, 2005). Attentional capabilities are particularly interconnected with affective phenomena (see figure 3; Yamaguchi & Onoda, 2012). The *Attentional Control Theory* (ACT: Eysenck et al., 2007) suggests affective phenomena are processed by a goal-directed attentional system and a stimulus-driven attentional system, which drives information processing efficiency and goal-directed performance. *Emotional regulation* (often seen as “emotional control” or “emotional self-management”) is the extrinsic and intrinsic processes responsible for governing emotional reactions (i.e., the processing of emotional information and the regulation of feelings; Thompson, 1991). Emotional regulation influences both attentional capacity and problem-solving skills for effective learning and cognitive performance (Mischel & Mischel, 1977, 1983). As an individual matures, higher-order cortical functions (i.e., executive control) improve inhibitory control over subcortical emotive processes (Panksepp, 1989). This process is progressively refined during the adolescent and young adult years (Markus, 1977). Consequently, children, adolescents, and even young adults handle emotion differently compared to their adult counterparts. Specifically, children have only shown to start to understand emotion at the age of 4 years (Powell & Dunlap, 2009). Meanwhile, older children and adolescents have been shown to feel more extreme emotions (both positive and negative) and more variable mood states (i.e., feelings) on a daily basis compared to adults (Larson et al., 1980; Larson et al., 2002; Larson & Richards, 1994). Thus, age and maturity level strongly impact emotional regulation which influence other cognitive processes such as attention (Mischel & Mischel, 1977, 1983).

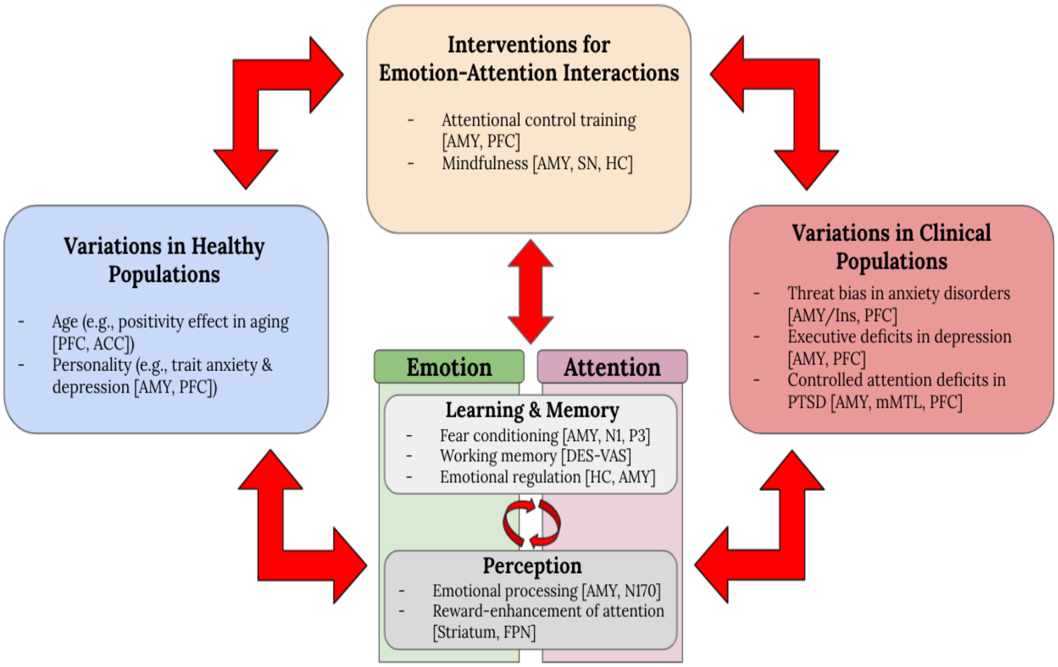

Figure 4: Summary of the *Affect-Attention Interaction* (adapted from Dolcos et al., 2020). Depicts the cyclical relationship between various affect-attentional domains, along with contextual examples and the linked overlapping neural correlates.
Listed neural correlates, events, and neural systems: Amygdala (AMY), Prefrontal Cortex (PFC), Salience Network (SN), Hippocampus (HC), Insula (Ins), Memory-Related Medial Temporal Lobe (mMTL), Visual N1 (N1), P300 Wave (P3), Dorsal Executive Neural System (DES), Ventral Affective Neural System (VAS), N170 Wave (N170), Striatum, Frontoparietal Network (FPN) and Anterior Cingulate Cortex (ACC)

Attentional capacity (Olivier et al., 2008; Perreault & French, 2016) and selectivity (Wickens, 1974; Olivier et al., 2008) are other fundamental components influencing both intrinsic and extrinsic information processing that increase with age. Reduced attentional capacities can be evidenced in lower levels of movement automaticity, additionally reflecting the novice skill level in children (Tse & van Ginneken, 2017; Gallagher & Thomas, 1980, 1986; Pollock & Lee, 1997; Tipper et al., 1989; Olivier et al., 2008; Perreault & French, 2016; Ruitenberg et al., 2013).

Additionally, the mechanisms of attentional selectivity increase with maturity (Wickens, 1974; Olivier et al., 2008). These are important processes given the abundance of sensory information that may deter concentration during motor learning (Perreault, 2013). Emmanuel and colleagues (2008) suggest that a reason as to why their study showed conflicting results to the constrained action hypothesis while assessing differences of FOA in children is because the participants had difficulty directing their attention to relevant information (i.e., distracted by irrelevant cues in their visual field) during their performance. Ross (1978) notes that selective attention strategies progress in stages from over exclusion to over inclusion, and then to selective attention. Children under the ages of 5-6 years typically over *exclude*, meaning that they attend primarily to a single stimulus, resulting in them being unable to recall very little incidental information from the environment. However, children from 5-12 years typically over *include*, meaning they attend to most of the available environmental stimuli, both relevant and irrelevant, resulting in a higher recall of incidental information. It is therefore particularly important that children during this stage have their attention directed to relevant sensory information. These last two stages contrast the final selective attention stage, typically reached during early adolescence (ages 11-12 years and above), where children are able to efficiently attend to relevant stimuli while filtering out the irrelevant.

1.5 Postural Control

Postural control involves tonic muscle contractions acting against gravity to stabilize the body segments in an upright posture and to maintain the center of gravity over the base of support (Ivaneko & Gurfinkel, 2018; Nashner, 1997). Centre of gravity is a point where the mass of the body is concentrated, whereas the base of support is the area where the center of gravity must remain in order to avoid disequilibrium, instability, or a fall. It, therefore, defines the limits of stability and is dependent on its location related to the body at any given time. Typically, this is 12.5 degrees in the anterior-posterior direction and 16 degrees in the mediolateral direction relative to the pelvis (Williams & Ho, 2004).

Postural control can be considered with respect to *static or dynamic balance.* Static balance refers to an individual's ability to maintain their center of gravity over their base of support during quiet sitting and standing (Woollacott & Tang, 1997). *Dynamic balance* is the maintenance of the center gravity over the base of support during movement (e.g., running; Williams & Ho, 2004). Both static and dynamic balance can be reactive, anticipatory, or a combination of both (Cordo & Nashner, 1982; Haas et al., 1989; Inglin & Woollacott, 1988; Nashner, 1977). *Reactive balance control* refers to a response made to an unexpected perturbation or an event that can lead to instability (e.g., a slip, push, or trip), while *anticipatory balance control* is an adjustment for planned instability that is expected or that can be predicted (e.g., stepping on to a patch of ice). Optimal balance function, however, requires an individual to be proficient in both active and anticipatory control (Williams & Ho, 2004).

A systems model is commonly used to describe postural control (Shumway-Cook & Woollacott, 2001; Woollacott & Shumway-Cook, 1990; Williams & Ho, 2004). Through this perspective, the body can be viewed as a mechanical system with mass that is influenced by both external (e.g., gravity and inertia) and internal forces (e.g., muscular contraction; Williams & Ho, 2004). Furthermore, balance is considered a multidimensional process involving the integration and function of many neurological and physiological systems, including but not limited to, the central nervous system (CNS), the peripheral nervous system (PNS), the muscular system (e.g., strength and muscular endurance), the skeletal system (joint range of motion, flexibility, bone strength, etc.), and the visual, proprioceptive, and vestibular systems (Yim-Chiplis & Talbot, 2000; de Sá et al., 2018).

Specifically, the CNS is an integral component for maintaining postural control, as it systematically monitors and integrates information from the three major sensory systems (i.e., the sensory organization of posture/balance) and helps organize the appropriate motor output needed for the activation of corrective responses. The input from the three primary sensory systems is typically redundant information regarding the state of the body's equilibrium, whether or not a corrective response is required, and what the nature of that response should be. Moreover, if one of these three sensory systems is compromised, the other two sensory systems may be able to overcome the issue with appropriate levels of training. The degree of importance of multiple sources of sensory information is both age and context dependent (Woollacott & Shumway-Cook, 1990; Williams & Ho, 2004).

Williams & Ho (2004) define *motor coordination* as the timing and sequencing of activation for motor outputs and consider this to be another crucial aspect of postural control. The authors further explain the efficacy of motor coordination pertaining to postural control to provide useful information surrounding spinal integrity and CNS functioning, along with crucial information for interpreting sensory organizational aspects of balance. More thoroughly, the timing, sequencing, and control of postural responses represents the postural control system's plan of action pertaining to instability (Williams & Ho, 2004). Likewise, postural synergies are an additional component fundamental to postural control. *Postural synergies* are stereotyped muscle responses organized by the CNS to accommodate for instability (Ivaneko et al., 2000). They involve the activation of leg and trunk muscles and are specific to the direction of the induced sway; muscles on the anterior portion of the body address posterior sway and muscles on the posterior side deal with anterior sway. Williams & Ho (2004) further explain the most commonly assessed postural synergies: the "ankle strategy", typically activated by a stretch in the ankle muscles. Humans prefer to maintain postural equilibrium through ankle synergies firstly, this then radiates upward from the base of support in a distal–proximal sequence (Ivaneko et al., 2000). Where in response to a perturbance causing anterior sway, the stretched gastrocnemius muscle is activated followed by the hamstrings and then paraspinal muscles (Williams & Ho, 2004).

As previously noted, the sensory organization of posture is crucial for postural control as it plays an integral role for postural maintenance through its capacity to detect instability (Assaiante & Amblard, 1995). The detection of instability is predominately a function of the visual, proprioceptive, and vestibular systems; where the information provided is integrated and synthesized at higher levels of the nervous system (Williams & Ho, 2004). Furthermore, postural control is most effective when all three sources of sensory input provide accurate information but is still effective when at least two of the three sources of sensory information are available and uncompromised (Shumway-Cook & Woollacott, 2001).

Barela and colleagues (2003) suggest that the development of an internal model of self-orientation is crucial for postural control. When this model of self-orientation develops, children are able to make the transition between postures (e.g., self- supported postures such as sitting to standing), where the continual refinement of this internal model galvanizes these progressions. The authors suggest motor skill development for more complex tasks is dependent on the amplification and improvement of this internal model. An extension from Barela and colleagues (2003) internal model of self-orientation can be extended to the concept of efference copy. *Efference copies*, are described as “copies” of efferent motor command signals sent to CNS structures as a blueprint for its transmission to the neuromuscular system (Bell, 1823; Purkinje, 1825; Crammond, 1997; Von Helmholtz, 1867). In essence, efference copies can be understood as a feedforward model of the visuospatial coordinates needed for upcoming action, often understood kinematically as an "image" of a movement execution. Efferent copies have information pertaining to correct outcome along with the potential consequences associated with certain errors. Individuals who struggle with these types of internal aspects are considered to have an efference copy deficit or an internal modelling deficit (IMD), which is often linked with atypical populations such as DCD (Katschmarsky et al., 2001; Wilson et al., 2001; Wilson et al., 2004).

Postural sway refers to the movement of an individual's centre of gravity relative to their base of support (Cho et al., 2014; Horak, 2006). It is typically measured as the application point of an individual's ground reaction force, commonly known as *centre of pressure* (COP; Yamamoto et al., 2015; Schmid et al., 2005). Yamamoto and colleagues (2015) explain that COP patterns can be either measured through a single inverted pendulum model (Morasso et al., 1999; Lafond et al., 2004), which suggests that sway movements can be interpreted as back and forth oscillations between the destabilizing force of gravity and the stabilizing effect of ankle muscles, or through the double inverted pendulum, which maintains that stabilization happens between the coordination of the ankle and hip joints (Morasso et al., 2019).

A two-dimensional stochastic process for the anterior-posterior (AP) and the mediolateral (ML) directions on the horizontal plane are normally used to model COP complex oscillations (Carroll & Freedman, 1993; Collins & De Luca, 1994; Loughlin et al., 1996; Yamamoto et al., 2015). Several scalar parameters can then be analyzed from these data. Namely, sway size, mean sway velocity and other scaling components (Collins & De Luca, 1993; Prieto et al., 1996; Barratto et al., 2002; Jacono et al., 2004; van der Kooji et al., 2011; Seigle et al., 2009; Raymakers et al., 2005; Milton et al., 2009; Prieto et al., 1996; Laughton et al., 2003). It should be clear, however, that COP oscillations are indirect measures of postural sway (Foudriat et al., 1993).

Force platforms are the apparatus typically used when quantifying data of postural sway. Static force platforms have been shown to have an intraclass correlation coefficient (ICC, standard reliability index Fisher, 1954) of ICC > 0.6 (Levine et al., 1996; Benvenuti et al, 1999) which is in the range of acceptable reliability and are considered the best suited for clinical and scientific settings (Browne and O'Hare, 2001, p. 492).

Yamamoto and colleagues (2015) explain that measuring postural sway is critical for understanding the motor mechanisms underpinning postural control (e.g., Winter et al., 1998; Peterka, 2002; Bottaro et al., 2005; Kim et al., 2008) as well as for better diagnostics regarding the severity of neurological diseases associated with postural instability (e.g., Horak et al., 1992; Rocchi et al., 2002; Maurer et al., 2003; Visser et al., 2008). Moreover, static posturography (i.e., static force platforms) is argued to be less complex compared to dynamic posturography, making it able to better accommodate for children's limited attention span and for a functionally limited clinical population, thus making it best suitable for these populations (Christensen et al., 2018; Barozzi et al., 2014; Micarelli et al., 2020).

With regard to balance and vestibular disorders, the assessment of postural sway is extremely important, as abnormal postures and balance capabilities can indicate impairments in several underlying neurological and physiological systems (Williams & Ho, 2004). This is particularly useful, as the prevalence of balance and vestibular disorders in children is estimated to be around 0.45% to 5.3%, where 90% of diagnosed pediatric disorders are labelled as unspecified dizziness, prompting the need for further investigation (Janky & Rodriguez, 2018; Li et al., 2016; Micarreli et al., 2020). Furthermore, Williams & Ho (2004) highlight six common conditions that can be assessed through postural sway analysis: DCD, cerebral palsy, individuals with lead exposure (lead poisoning), chronic otitis media, Parkinson's disease, and peripheral neuropathy. Yet, more data is needed to create normative standards to both understand typical postural development and to further categorize pediatric balance and vestibular disorders (Micarelli et al., 2020).

What makes studying the development of balance difficult is that the processes governing postural control are not completely understood and the development of postural control is not uniform. For example, most of the vestibular system is structurally developed at birth (Micarelli et al., 2020), however, postural control responses continue to mature throughout childhood (Nandi & Luxon, 2008).

Certain researchers (e.g., Roncesvalles et al., 2001) suggest that by the age of 10 years, typically developing children should demonstrate postural stability capabilities similar to an adult level, whereas other researchers (e.g., Schmid et al., 2005) suggest that mature postural sway patterns, through the speed of COP displacements, continues to develop during puberty (de Sá et al., 2017). This debate is then compounded by the idea that, similar to many other motor milestones, the milestone of being able to stand upright is a sequential process that happens on a continuum (WHO Multicentre Growth Reference Study Group & de Onis, 2006). This milestone can be achieved as early as 6.5 months to as late as 17 months and still be considered within the normative range. This is why researchers argue motor development *level* to be a more accurate predictor in comparison to *chronological age* (Williams & Ho, 2004).

Uncertainty remains however, surrounding the reliance on and the development of each mode of sensory information needed for postural control during child development. Determining a preference of one sensory system is particularly important as it may provide strategical evidence surrounding the development of the CNS (Massion et al., 1996; de Sá et al., 2017). For example, a few studies have shown that before the age of 11 years, visual information does not have the same level of importance for postural control as it does in adults, and the integration of vestibular information is assumed to only happen after the age of 12 years (Peterson et al., 2006; Valente, 2007). Forssberg & Nashner (1982) suggest that in young children, as in adults, somatosensory inputs mediate the temporal and spatial structure of automatic postural adjustments. Contrastingly, Pope (1984) provided infants (2-month-olds) with visual information that was incongruent with the information that they were receiving from their vestibular and somatosensory receptors, in order to observe their muscular responses while sited on a stationary platform. The walls and ceiling of the small room surrounding them would move, providing participants with visual information that made it seem as if their body, and not the room, were moving (i.e., the somatosensory information from the proprioceptors as well as the vestibular and somatosensory receptors indicated that the body was stationary). This study concludes that the infants rely more on the visual information rather than on the somatosensory inputs, as the participants swayed their body more with the visual information compared to the kinesthetic information. Similar conclusions are seen in Butterworth & Hicks (1977).

Moreover, there lacks certainty surrounding the development of postural synergies (Williams & Ho, 2004). Some researchers suggest them to be present as early as 15 months, where they undergo dramatic changes from 4 to 6 years, and typically become adult-like by 7 to 10 years; while specific components such as head control, head–trunk coordination, and the development of anticipatory postural adjustments continue to develop to 8 years and beyond (Nashner, 1977; Shumway-Cook & Woollacott, 2001; Woollacott et al., 1989).

There is, however, general agreement in the literature suggesting that 7 years of age is the critical chronological age point at which children take on more mature postural control patterns similar to those of adults, particularly evidenced through postural sway strategies (See Assaiante & Amblard, 1995; Olivier et al., 2008; Shumway-Cook & Woollacott, 1985; Forssberg & Nashner, 1982; Sundermier et al., 2001; de Sá et al., 2017). More specifically, children at the age of 7 years begin to effectively organize and use postural response synergies (Shumway-Cook & Woollacott, 1985). An example of this is a more effective use of the head stabilization in space strategy (Bronstein, 1988; Pozzo et al., 1991) compared to trunk stabilization, which frees up degrees of freedom of the head relative to the trunk. This in turn enables the individual to use dynamic vestibular cues rather than static vestibular afferents or muscular proprioceptive inputs (Assaiante & Amblard, 1995). This age additionally reflects the finality in the development of the structures responsible for motor control, however, certain children at this age may lack enough motor experiences for a completely adult-like postural control level (Assaiante et al., 2005; de Sá et al., 2017).

Additionally, Barela and colleagues (2003) looked to determine whether the coupling between dynamic somatosensory information and body sway in children is similar to adults. The authors discovered that children under the age of 7 years struggled to produce appropriately-timed responses to balance perturbations. These results were explained through the suggestion that children under 7 years of age may not yet have developed a precise enough internal model that enables them to produce fast postural accommodations, implying attentional processing inefficiencies (i.e., inability to rapidly correct for balance perturbation). The results from this study are consistent with Beilock and colleagues deautomatization of skill hypothesis, which maintains that an individual may benefit from an INT FOA when compared to an EXT FOA, when they lack a certain degree of expertise and automaticity needed for a given task. Therefore, an assumption can be made that an individual without a highly defined internal model of postural control may benefit more from an INT FOA, as the internal nature of this information will be more congruent with their internal model.

1.6 The Role of Attention in Postural Control

Traditionally, postural control was understood to be simply an automatic or reflex controlled task (e.g., Belenkii et al., 1967), but more and more evidence has shown that balance is dependent on attentional resources. This is a function of the complexity of the task and the age and balance capabilities of the performer (Shorer et al., 2012; Wulf, 2013; Woollacott & Shumway-Cook, 2002; Olivier et al., 2008). The involvement of attentional processes can be further evidenced through investigations from relatively simple tasks (i.e., ortho-static) to more complex ones (i.e., unipodal balance; Woollacott & Shumway-Cook, 2002; Vuillerme & Nougier, 2004; Olivier et al., 2008). Olivier and colleagues (2008) explicitly highlight five factors influencing the mobilization of attentional resources associated with postural control:1) Age (Teasdale & Simoneau, 2001; Woollacott & Shumway-Cook, 2002). 2) Availability and quality of sensory information (Shumway-Cook & Woollacott, 2000; Teasdale & Simoneau, 2001). 3) Postural task complexity (Lajoie et al., 1996). 4) Expertise level (Vuillerme & Nougier, 2004). 5) Voluntary attentional focus on body sway (Vuillerme & Nafati, 2007).

In parallel, a few researchers have suggested the degradation in balance performance as a result of voluntary attention focused on movement (Zachry et al., 2005) or body sway (will be discussed further; Vuillerme and Nafati, 2007) relate with an increased level in neuromuscular activity thus implying the recruitment of additional motor units to reflect the role of attention in balance control at a neuromuscular level. This idea is consistent with Wulf and colleagues constrained action hypothesis such that adopting an internal focus leads to less efficient motor planning and muscular activity, which in turn is reflected in a larger degree of "noise" in the motor system (i.e., neuromuscular activity), implying a lack of movement automaticity (Lohse et al., 2010). Similarly, Yeh and colleagues (2016), when investigating differences in adherence to FOA instructions among adults and older adults during a postural control task, found that the older adults performed worse compared to their younger counterparts when subjected to an innocuous visual cue (i.e., incongruent postural visual information). The authors suggest that the older adult's performance was related to age-related declines in non-visual sensory function, which caused them to selectively attend more to visual feedback, making them more susceptible to incompatible sensory information. Yeh and colleagues (2016) show the importance of attentional capabilities during postural control, while further demonstrating limitations to Wulf and colleagues constrained action hypothesis.

1.7 Purpose

The aim of this study is to extend the current research evaluating the most efficacious type of FOA instruction for children by studying their influence on postural control performance. The differential effects of FOA instruction on young learners (i.e., typically developing children) remains unclear. While Wulf and colleagues show robust findings favouring an EXT FOA over an INT FOA for both motor learning and performance among adults, it is conceptually precarious to directly extend these findings to children. Specifically, children vary remarkably from adults with regard to level of expertise, information-processing accuracy and speed, information encoding, memory strategies, emotional regulation and attentional capacities. Postural control, which requires attentional resources, helps depict the relationship between these age differences and the effects FOA instructions may have. Thus, this study will examine the effect of FOA in two groups of young learners (children between 4-6 and 7-10 years of age) performing a postural control task. A force platform will be used to assess static postural sway control. In addition, EMG will be used on the major ankle stabilizers used during the ankle-strategy to measure muscular activity. Moreover, the age groups used will isolate for the critical chronological age point of 7 years which has been identified to be the age in which children make the switch to more mature postural sway patterns (e.g., Assaiante & Amblard, 1995).

There are three research hypotheses driving this study. First, there will be no significant treatment effects across FOA conditions for both postural sway performance and muscular activation. Second, there will be a main effect of age, where the group of older children is predicted to exhibit a significantly lower postural sway and lower muscular activation compared to the group of younger children. Last, there will be a significant interaction of FOA group and age on both postural sway and muscular activation. Specifically, the group of younger children in the INT FOA condition will have a lower postural sway and a lower level of muscular activation compared to the EXT FOA and CTRL condition, which will contrast the group of older children who will show no significant difference in postural sway across FOA conditions. These results will be evidenced throughout acquisition and perturbation tests, which will challenge Wulf and colleagues constrained action hypothesis and will reflect Beliock and colleagues' deautomization of skill hypothesis.

1.8 Impact

The knowledge gained through a better understanding of which type of FOA instruction is best suited for children during postural control hopes to meaningfully extend current research exploring the effects of instructional language used during motor skill learning. Additionally, potential results from this study may provide new fundamental insights on attentional capacities in typically developing children to inform best practices for educational and motor behavioural research.

2.0 METHOD

2.1 Participants

Sample size was determined by an a priori power calculation based on our smallest comparison of interest. For the purpose of this thesis, powering for the sample of Study 1 is based on an interaction of FOA group and type of test. Using an α of 0.05, a power (1 - b) of 80%, a Cohen's f of 0.25, for 3 groups, on 4 measures and with a correlation among repeated measures of 0.5, a sample of 102 participants was calculated. These specific parameters result in 34 participants per group. Given the limitations imposed on participant recruitment as a result of the inclusion criteria (i.e., narrow age range) and the COVID-19 restrictions the study may necessitate a smaller sample size, however, this sample will be consistent with literature and all appropriate cautions pertaining to the interpretation of data collected on a smaller sample than statistically recommended will be observed.

Participants will be recruited from the Literacy and Mathematics Academy private school in Stoney Creek, Ontario. Where participants will be randomized into one of three conditions (INT FOA, EXT FOA and a CTRL). All participants must be between the ages 4-10, present no self-reported neurological disorders, have normal or corrected-to-normal vision, be able to pass the online provincial COVID-19 screening tool (www.covid-19.ontario.ca/self-assessment/), not be students that primary investigator tutors at the academy, and not be a high-risk individual for COVID-19. The latter includes those with weakened immune systems, lung disease, heart disease, hypertension (high blood pressure), diabetes, obesity, kidney disease, liver disease, dementia, and stroke. Other than these characteristics, no other criteria will be enforced on participant recruitment (i.e., no specific sub-groups will be recruited). These inclusion/exclusion criteria are based on previous studies utilizing similar tasks, and or a similar population (see Yeh et al., 2016; Olivier et al., 2008; Petranek et al., 2019; Palmer et al., 2017). To avoid any neuromuscular fatigue, participants will be requested to not perform any intensive training (e.g., a soccer game) for at least 24 hours before the experimental sessions. At the start of the study, all children must provide verbal consent, and their parent/guardians must provide written informed consent. All parking and transportation costs will be covered, and participants will be remunerated with a 10$ Tim Horton’s gift card for participating in the study. This study received approval from the McMaster University Research Ethics Board.

2.2 FOA Instructions

Participants in the INT FOA group will be given the instructions: “focus on maintaining your weight evenly distributed on both legs throughout the trial”, whereas participants in the EXT FOA group will be told to: “focus on keeping the cross in the target square throughout the trial.” To minimize the advantage of an increased feedback frequency and or an increased level of absolute feedback on performance (see Goh et al., 2012), participants will only be reminded of their feedback condition if needed. Note that “attention” for this study is operationally defined as a process that helps the individual select which stimuli are important and should influence an ensuing response, as well as a process of sustained concentration (Wells & Mathews, 2015).

2.3 Protocol

At the start of each session, participants will be outfitted with 8 surface electrodes, 2 of which will be placed parallel to the muscle fibre orientations over the bellies of the soleus (SOL), tibialis anterior (TA), peroneus longus (PL), and extensor digitorum longus (EDL) (figure 5). The interelectrode distance will be 2 cm centre to centre and the SENIAM guidelines (Rose, 2019) will be used as well to direct placement of the electrodes. The area where the sensors will be placed will be shaved with a disposable razor and abraded with an alcohol swab to remove dead skin cells and oils from the surface of the skin. The EMG electrode will be attached with double sided tape (BSN Medical Strappal). A conductive gel will also be used as it inhibits the effects of excessive sweat during long wearing periods. A reference electrode will be placed on the patella of the knee.

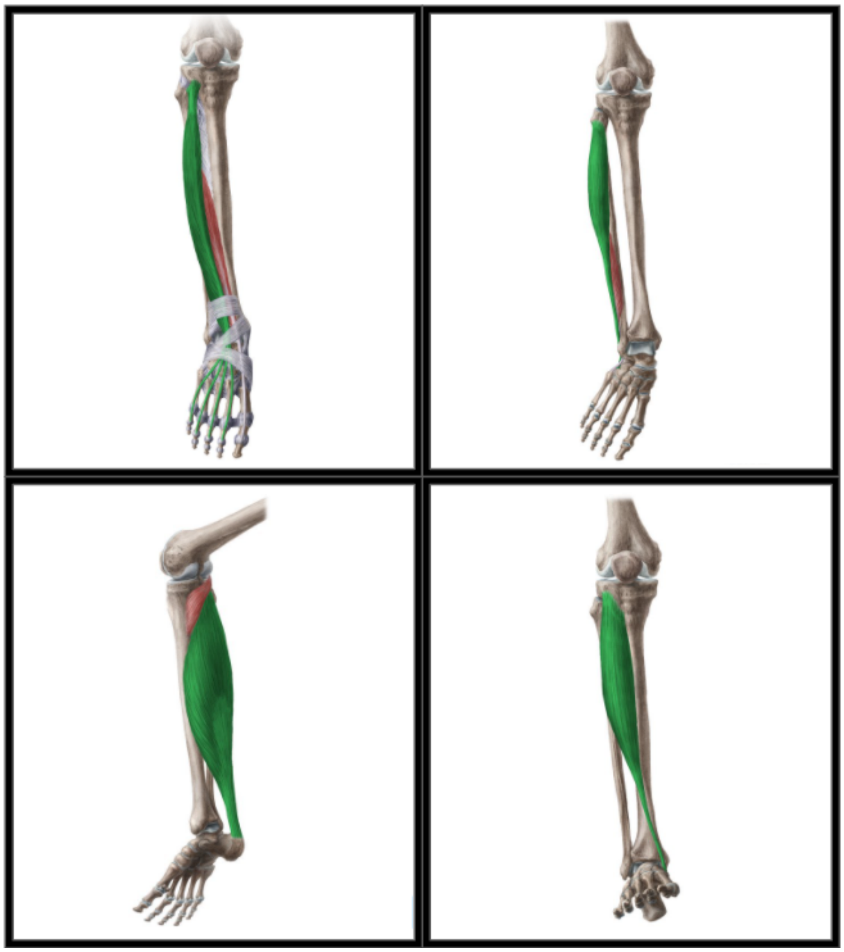

Figure 5: *Ankle Stabilizer Muscles.* Top left corner: EDL, top right corner: PL, bottom left corner: SOL, and bottom right corner: TA (Adapted from Znotina, 2020).

Prior to the commencement of the acquisition and perturbation tests, participants will perform isometric maximal voluntary contractions (10 secs in length) in order to calculate maximal EMG activity, which will then be used to normalise EMG activity during the balance tests. This will consist of four separate maximal contractions: plantarflexion, dorsiflexion, and inversion and eversion with the tibia perpendicular to the sole of the foot (figure 6; Kendall et al., 2005; Cimadoro et al., 2013). Participants will be given a rest period following each maximal contraction for a minimum of 4 mins to however long the participant requires, in order to avoid muscular fatigue. The time needed for lactic acid clearance following high-intensity exercise is suggested to be anywhere between 4–10 mins (e.g., Hultman & Sjoholm, 1986). Given the limitation of this population's attention span, participants will be provided with low-intensity activities such as colouring books and puzzles during the rest periods.

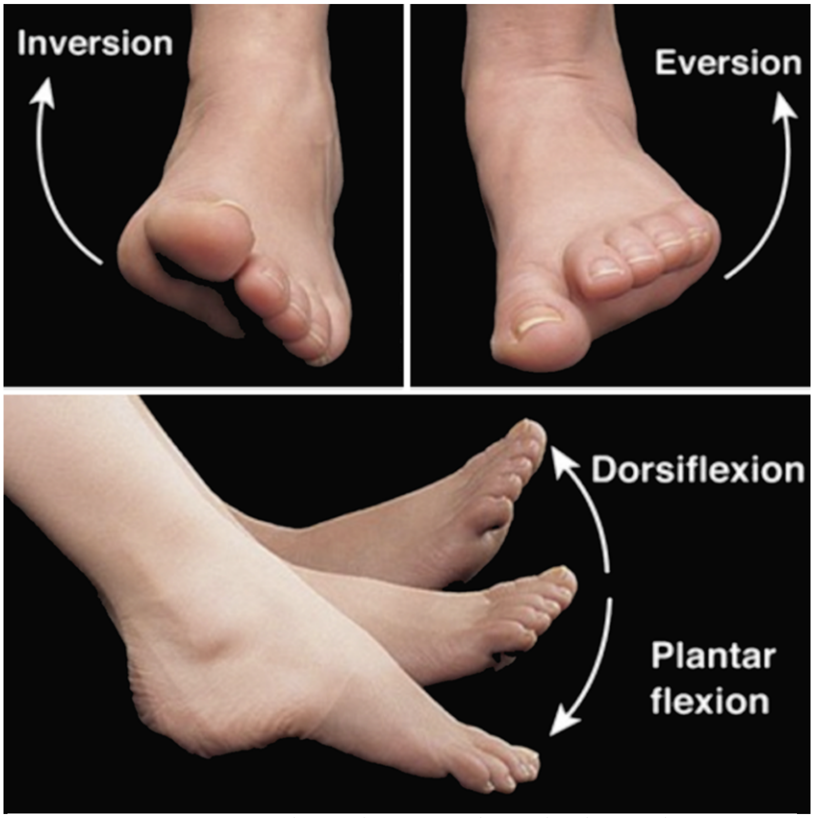

Figure 6: Demonstration of contractions for inversion, eversion, dorsiflexion, and plantar flexion (Moreau, 2016).

For each experimental trial, participants will stand on a force platform (AMTI OR6-2000; Newton, MA, USA) that will output centre of pressure (COP) positions along the anteroposterior (AP) and mediolateral (ML) axes. Participants will face a liquid crystal display (LCD) monitor located at eye level (Viewsonic; 60 Hz refresh rate, 5 ms delay) that will be connected to the force platform. The LCD display will show different augmented feedback information depending on the experimental condition. Test conditions (e.g., room illumination, temperature and noise) will be consistent with the posturographic testing recommendations outlined by Shumway-Cook and colleagues (2000). For the EXT FOA group, a fixed 12x12 mm target will appear on the LCD screen that will represent mean center of pressure for both the ML (i.e., left-right) and AP (i.e., front-back) positions within the first 10 secs of the trial. Following the first 10 secs, the EXT group will see a live 12x12 mm target cross in real-time that will move horizontally and will represent their ML COP, which will be there for the remainder of the trial. This will differ from the INT FOA and CTRL condition who will only see a fixed point on the screen and will be given no real-time visual feedback. The visual display for all three of the conditions can be depicted on figure 7.

For acquisition, participants will be allowed as many practice trials as needed to familiarize themselves with the task and to ensure instructions are understood. Participants will then perform the task a total of 12 times during the acquisition phase and will be given breaks between trials. Trials will be 50 secs in length for each group. Prior to the beginning of each trial, participants will be connected to EMG that will be bilaterally recording signals from the 8 electrodes placed on the SOL, TA, PL and EXD.

Participants will come back 24-48 hours later to perform perturbation tests. Similar to the acquisition phase, participants will be instructed to stand on the force platform. They will be given the new objective of holding their arms straight out in front of them for 2 trials, 2 trials to their left side, and out to their right side for 2 trials, thus totaling 6 trials. The purpose of this manipulation is to create a shift in centre of gravity to assess how participants adapt to a new balance perturbance (i.e., anticipatory postural control) as a function of attentional focus. FOA is believed to influence static postural control, anticipatory postural control, and reactive postural control (Wulf, 2013). No further instruction will be given to the participants. Each trial will last 50 secs, and participants will receive the same respective visual feedback as during acquisition, along with the same EMG and COP measurements.

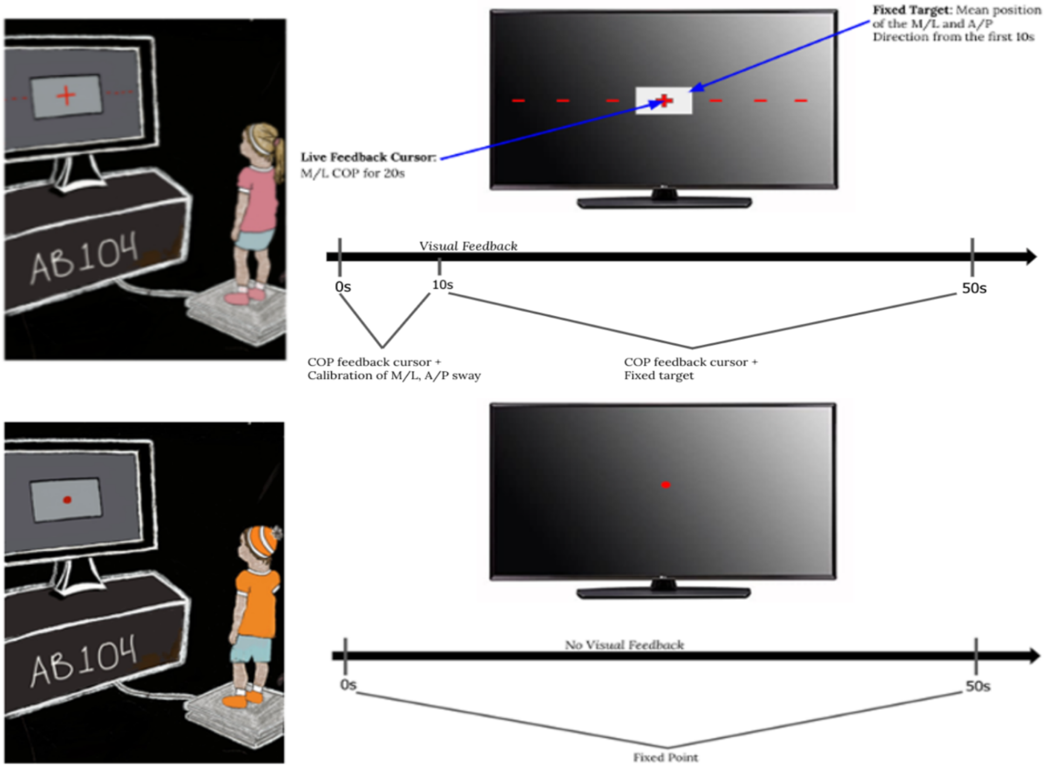

Figure 7: Schematic of the visual display. The top part depicts the visual display for the EXT FOA condition, and the lower part depicts the visual display for the INT FOA and CTRL condition.

2.4 Data Processing

2.4.1 Force Platform Processing

COP data from the AP and ML axes will be recorded from the force platform. The stability of postural control will be determined by the standard deviation (SD; COP position variability) from the mean COP position in both directions. The first 10 secs of data will not be used for all three groups because the fixed target position for the EXT FOA group will be determined by calculating the mean position from the first 10 secs of COP data. Only the last 40 secs of data will be analyzed for each trial at a 40 Hz sampling frequency that will be synchronized with EMG (similar to Cimadoro et al., 2013).

2.4.2 EMG Processing

EMG signals will be recorded via a Biopac system (Biopac, Santa Barbara, CA) and will be collected at a sampling rate of 2500 Hz in accordance with SENIAM surface EMG guidelines (Rose, 2019). The signals will be amplified using a bandwidth frequency ranging from 10 to 2 kHz (gain = 1000). The root mean square (RMS) values will be calculated using 125 ms time windows with 50% overlap, which will then be averaged for the mean RMS for every trial. These values will then be normalised with respect to the maximal values collected during maximal voluntary contractions. Noted earlier, signals from the force platform will be synchronized with EMG. A TTL synchronization signal will be generated from the force platform during the onset and offset of each trial, which will be received and recorded by the Biopac system (see Gebel et al., 2019; Cimadoro et al., 2013).

2.5 Statistical Analysis

2.5.1 Independent & Dependent Variables

There are four independent variables for this study: FOA group (INT, EXT & CTRL), age group (Young: 4 – 6 years of age & Old: 7 – 10 years of age), type of tests (acquisition, perturb left, perturb forward and perturb right) and the number of trials across both the acquisition and the perturbations phases of the study (12 for acquisition and 2 within each of the three perturbation tests). Six dependent variables will be collected: mean standard deviation (SD) of the mediolateral COP in millimetres (mm), mean SD of the anteroposterior COP in mm, and individual root mean square (RMS) measures for the SOL, TA, PL and EXD represented as a percentage (normalized with respect to participants' maximum values obtained during maximal voluntary contractions).

2.5.2 Analyses

There will be two separate analyses conducted for each dependent variable. The first analysis will consider only the acquisition phase of the study and will consist of a mixed analysis of variance (ANOVA) on the three attentional conditions (INT, EXT & CTRL), two age groups (Young & Old) and 12 trial blocks with repeated measures on the last factor. The second analysis will compare the final two trial blocks of acquisition with the three perturbation tests by using a mixed ANOVA on the three attentional conditions, two age groups, four types of tests (acquisition, perturb left, perturb forward, and perturb right) and the two trial blocks within each test condition with repeated measures on the latter two factors. This analysis will compare the last two trials of acquisition to the two trial blocks within each of the three perturbation conditions. For both analyses alpha will be set at 0.05, Greenhouse-Geisser corrections will be employed for sphericity violations (Mauchly's test, $p < .05$) and Tukey's *HSD* post hoc analysis will be used to examine main effects and interactions. Cohen's d will be calculated to report effect sizes. All analyses will be run using RStudio (macOS version 4.0.5).

2.6 Expected Results

The first expected result for this study will agree with the original hypothesis where there will be no significant differences across FOA conditions for neither postural sway performance nor muscular activation. The comprehension level among the participants will likely be variable, and given the overall complexity of the task, it is very plausible that participants may not understand, or may forget, their instructions over the course of their trials. Petranek and colleagues (2019) explain that in order for motor learning to occur, and for motor performance to improve, children must be able to recall the critical elements pertaining to the skill that is being assessed. This is then further compounded by the variability in attentional processing capabilities among the children. As previously mentioned, Ross (1978) explains that attention strategies progress in stages from over exclusion to over inclusion eventually leading to adult-like strategies. Therefore, it may be that participants will be employing different attentional strategies and will vary with regard to their processing abilities. This result would be consistent with the literature (e.g., Perreault & French, 2016).

The second hypothesis is that there will be a main effect of age on postural control performance and muscular activation. The expected result for this hypothesis is that the group of older children will have an overall lower postural sway variability in both the mediolateral and anteroposterior direction, and a lower level of muscle activation for each muscle governing the ankle-strategy response, when compared to their younger counterparts. This result will be consistent with

Agar and colleagues (2016) who used a similar age split. The authors attributed their findings to the natural changes in growth and biomechanical factors, which are factors that can also be extended to this study. Moreover, despite children from 4-6 years of age being able to appropriately accommodate directional postural responses, there still exists evident immaturities in postural synergy use regarding variability between timing and amplitude (Shunway-Cook & Woollacott, 1985). Thus, the group of younger children will not be as skilled and efficient with the task as their older counterparts may be.

The final expected result for this study is that there will be a significant interaction of FOA condition and age, which will be in accordance with the third hypothesis. Specifically, the group of younger children in the INT FOA condition will outperform their age-matched counterparts in the EXT FOA condition and CTRL condition; evidenced through a lower sway variability in the mediolateral direction (side-to-side) and a lower degree of muscle activation among the ankle-stabilizers. This prediction is driven by the idea that children under the age of 7 years do not have a precise enough internal model needed for adult-like posture (Barela et al., 2003). Thus, augmented feedback that is framed internally would most likely add to this internal model (or efferent copy), in comparison to EXT FOA instruction. In parallel, the immature cognitive strategies and cognitive limitations among young children can mitigate the effects of an EXT FOA. Notably, Petranek and colleagues (2019) demonstrate superior benefits for adopting an INT FOA when compared to an EXT FOA among children. These results are suggested to be attributable to the EXT FOA cues used in the study being too abstract for participants to adequately interpret, and thus were not properly encoded. A logical extension can be made to suggest that the EXT FOA cues used by Petranek and colleagues (2019) did not coincide with the information needed to support their participants' internal models, and therefore were not appropriately encoded. Similar results should be seen with this study, given the level of understanding and patience required to understand the complexity behind the live visual feedback cursor in the EXT FOA condition. With regard to the CTRL condition in the younger group, Wulf (2013) suggests that when participants are given no explicit FOA instruction, they will naturally adopt an INT FOA. This does not mean for this study, however, that they will perform similar to the INT FOA condition. The CTRL condition is predicted to have the largest sway variability and muscular activity compared out of all three conditions. This will be a result of the CTRL condition receiving a disproportionately lower amount of feedback compared to the other two conditions, as a greater absolute amount of feedback provides an additional performance advantage (Goh et al., 2012). These results, nevertheless, are unique to the group of younger children, as for the group of older children, there will be no significant differences across conditions. This is because EXT FOA effects are believed to be evidenced when the task is challenging enough for the individual, which would require them to access attentional cues from working memory (Perreault & French, 2016). Working memory is inherently linked to both knowledge and skill acquisition (Alloway et al., 2007). The degree of instability or error caused by this task should be very minimal for the older children and will be further mitigated by the age shift in mature postural patterns occurring at the age of 7 years, where there is more organization and use of postural response synergies (Shumway-Cook & Woollacott, 1985). Moreover, with regards to the perturbation corrections present in the several perturb conditions, FOA is believed to affect the quality and rapidity of error-corrective responses during performance, influencing both anticipatory and reactive movement responses (Wulf, 2013). Therefore, the younger children in the INT condition will additionally exhibit lower postural sway and muscular activity during the perturbation tests compared to the EXT and CTRL condition as a result of having their feedback add to their internal model. This result would be indicative of a more effective (i.e., more rapid, and accurate) postural error-corrective response. Meanwhile for the group of older children, there will be no significant differences across FOA conditions during perturbation tests. Similar to acquisition, the degree of instability caused by these tests will be mitigated by the transition to mature postural patterns and will not require the older children to access attentional cues from the working memory level. These results, in turn, would additionally challenge Wulf and colleagues constrained action hypothesis which maintains an EXT FOA being superior regardless of the circumstance.

CHAPTER TWO: INTRODUCTION TO STUDY TWO & METHOD

3.0 INTRODUCTION TO STUDY TWO

The purpose of Study 1 is to extend the current literature investigating the most efficacious form of FOA instruction for children by studying the influence of FOA instruction on postural control performance. The first expected result for Study 1 is expected to reveal minimal to no effects of FOA condition on both the dependent variables. Our reason for this prediction is driven by the variability in participants' comprehension level and attentional processing capabilities which will affect their understanding and instructional-recall for the task. The second expected result will reveal a main effect of age, where the older participants will have a lower postural sway and lower muscular activation level compared to their younger counterparts. The reasoning for this prediction is attributable to the natural growth and biomechanical factors that occur as children age. The final expected result for Study 1 is expected to depict an interaction of FOA condition and age, where within the group of younger children, the INT FOA condition will exhibit a lower postural sway and ankle-muscular activation compared to their age-matched EXT FOA and CTRL conditions. This result will only be seen in the group of younger children, as the group of older children will illustrate no significant effect across attentional conditions. This prediction is driven by evidence (e.g., Barela et al., 2003) suggesting that children under the age of 7 years require information that adds to their internal model to develop adult-like postural control. Meanwhile, since the group of older children have already made the switch to mature postural control strategies, this transition will mitigate a large amount of instability and or error during performance that the group of younger children will struggle with. While these expected predictions serve to illustrate which form of FOA instruction is best suited for young children utilizing the most traditional FOA study design, questions remain: Are the expected outcomes a result of issues pertaining to the experimental instruction design? Or do they depict a logical inconsistency with the assumption that attentional focus states are dichotomous rather than continuous? Study 2 serves as an extension to Study 1 and aims to address these questions by assessing the reliability and validity of FOA instruction usage with this population through the use of experimental manipulation checks.

3.1 Validity of FOA Research

A fundamental concern in FOA research surrounds the validity and reliability of the methodology used in numerous FOA experiments. There are concerns with regard to the 'purity' of instructions under different conditions (Davids, 2007) along with a lack of consistency in the experimental instruction provided across attentional foci studies (Davids, 2007; Yeh et al., 2016). Peh and colleagues (2011) note the importance of ensuring that participants directly receive either an INT or an EXT FOA; an element that is hardly distinguishable in few studies. Instructions need to be directed to relatively similar aspects of a task, in order to be fairly assessed (Wulf, 2013). For example, Canning (2005) investigated how different FOA instructions affect gait performance in individuals who have Parkinson's disease. For this task, participants had to walk while holding on to a tray with glasses on it, where both greater stride length and faster walking speed were the dependent variables. The INT condition was given the instructions to focus on “maintaining big steps while walking”, whereas the EXT condition was instructed to focus on “balancing the tray and glasses”. Undoubtedly, the INT FOA outperformed the EXT condition, which Wulf (2013) argues to be a result of attention being directed to two fundamentally different aspects of the task, causing a confound. Furthermore, it remains difficult to assess whether or not participants are following their intended FOA instructions (Kee et al., & 2012; Peh et al., 2011). This is described to be a major methodological concern as it directly influences where participants are directing their attention and how they may be interpreting attentional-foci cues during FOA experimentation (Davids, 2007; Petranek et al., 2019; Perreault & French, 2015). Maxwell and Masters (2002) and Poolton and colleagues (2006) argue that participants are likely to switch between attentional foci during a task, and they may not directly adhere to their given FOA instruction. Specifically, in Maxwell and Masters (2002) and Poolton and colleagues (2006) participants indicated using a combination of both an INT and an EXT FOA when completing their respective studies task (i.e., golf putting & dynamic balancing).

3.2 Manipulation Checks

Manipulation checks are a tool used by researchers to check the effectiveness of a manipulation on its intended dependent variable, as well as checking the associated mediational processes (Perreault, 2013; Hauser et al., 2018). Theoretically, manipulation checks provide evidence that an experimental manipulation has been successful, further strengthening the internal validity of the study (Kotzian et al., 2020; Hauser et al., 2018). This is important as it is presumptuous to assume that the intended manipulation will directly yield the expected outcome. Therefore, checking the efficacy of the experimental manipulation is needed (Festinger, 1953, p. 145).

A common usage of manipulation checks is to exclude participants who fail a manipulation check from the statistical analysis (Cheng & Coyte, 2014; Rose et al., 2014; Mastilak et al., 2012). Oppenheimer and colleagues (2009) argue that by eliminating the data of the participants who failed, this will artificially increase the "statistical power" of the study, caused by rises in the signal-to-noise ratio. However, given the inherent assumption that behaviors during the manipulation check are closely related to the behaviours measured by the dependent variables, researchers who remove participants that fail the manipulation checks may also be potentially removing participants who may have been unaffected by the original intended manipulation (Kotzian et al., 2020). This can potentially lead to a treatment group having a more extreme average in the dependent variable (Kotzian et al., 2020). Parrot & Hertel, (1999) argue that manipulation checks may additionally provide participants with relevant information towards the researcher's hypothesis. Specifically, questions about emotions, self-esteem, prejudice or liking for another person in a study may indicate to the participant that the experimenter is interested in those associated factors. Thus, manipulation checks are a useful tool for ensuring experiments produce their intended effects when carefully considered and properly planned (Hauser et al., 2018; Kotzian et al., 2020; Perreault & French, 2015, 2016).

3.3 Manipulation Checks & FOA

As noted earlier, FOA research is limited by questions surrounding the validity of the methodology used in numerous attentional foci studies. Particularly concerning the purity of instructions, the lack of universality of instructions and the efficacy of the instructions directing participants towards their intended focus condition. Researchers (e.g., Yeh et al., 2016) explain that the majority of attentional focus research does not use manipulation checks or any specific experimental. As mentioned prior, Maxwell and Masters (2002) and Poolton and colleagues (2006) discovered a lack of adherence to their participant's attentional focus condition. They were, however, able to uncover this finding by using a post-analysis manipulation. Similarly, along with examining the general efficacy of FOA feedback, manipulation checks are able to investigate individual characteristics (e.g., participants' age) that may influence the effectiveness of FOA instruction. For example, Yeh and colleagues (2016) used a manipulation check to explore the age-related differences in FOA instruction during a static balance task. Participants were either in the younger age group or the older age group and were then further subdivided into either an INT FOA or an EXT FOA condition, thus totalling four different conditions: Young INT FOA, Old INT FOA, Young EXT FOA and Old EXT FOA. For the INT FOA condition they were given the instruction to focus on "keeping weight evenly distributed between both legs", whereas the EXT FOA group were told to focus on "keeping the feedback cursor on the target". The feedback cursor and target refer to the visual display provided to the participants, where the participants in both conditions were presented with a red cross cursor displaying their real-time mediolateral centre of pressure position and a fixed target representing their mean position from the first 5 secs of the centre of pressure data from both the mediolateral and anterior posterior directions. Despite the visual display being the same for both conditions, the key difference was that the EXT FOA condition was explicitly directed to focus on the visual display, hence the external nature of the feedback. The manipulation check in this study was embedded in visual display as a vision no-vision paradigm. The trial duration was 25 secs, where in the first 5 secs only the feedback cursor was displayed, followed by the fixed target for 10 secs. After 15 secs, all visual display disappeared resulting in no visual feedback. The authors argue that FOA instruction refers to an individual's mental focus and not their visual focus, thus, participants should not be influenced by the change in visual display (i.e., the INT FOA should not perform worse when the visual display disappears as their focus was directed internally). The main conclusions from this manipulation check revealed that there was greater adherence to FOA instruction among the younger adults compared to their older counterparts, and that reliance on external visual information skewed more heavily among the older adults specifically in the Old INT FOA condition. The authors interpreted these results to be evidence of age-related decline in ability to allocate attention, and therefore the manipulation check revealing an age-related limitation to FOA instruction.

Moreover, researchers argue that manipulation checks in FOA research are beneficial, particularly for research in children, as it provides researchers with a greater understanding how FOA instructions accommodate for children's limited attention spans (Petranek et al., 2017; Emanuel et al., 2008; Perreault & French, 2015, 2016; Thorn, 2006). For example, in Perreault & French (2015) children were given the objective of learning a free-throw, where participants were divided into either an INT FOA or an EXT FOA condition. Each participant was given verbal cues with respect to their assigned condition (e.g., INT FOA group was told "Line up your hand and eye with the basket" and the EXT FOA group was instructed to "Focus on a spot just above the rim"). As a manipulation check, participants were given a retrospective verbal report where they were asked "What were you thinking about today when you were practicing your free throw?" following each day of practice. The main conclusion from this study was that the EXT FOA group reported better adherence to their respective feedback compared to the INT FOA group, which the authors suggested to be what lead to greater gains in learning rather than just the focus itself. Additionally, the EXT FOA group outperformed the INT FOA on free-throw performance. Utilizing the constrained action hypothesis, which maintains that an INT FOA causes elicit unconscious and conscious self-evaluation and self-regulation processes that disrupt movement automaticity, the authors suggested that the INT FOA group thought less about their instructions because it triggered unfavourable self-evaluation processes at the conscious level.

3.4 Purpose

As noted earlier, Study 2 serves as an extension to Study 1. The purpose of Study 2 is to add to the current research regarding the validity and reliability behind using FOA instruction with children by using experimental manipulation checks to uncover the influence FOA instruction has on attentional capacities during postural control. The lack of universal FOA instructions and the absence of control measures assuring FOA instructions are directing attention towards their intended effects remains an issue in the current published literature findings on attentional focus. This is particularly problematic for young learners given their variability in sustained attention, distractibility, and attentional information-processing. Manipulation checks serve as a useful tool for understanding how FOA instruction both influences attentional foci states in children and how children may be interpreting attentional foci cues. Moreover, manipulation checks enable researchers to examine how well participants were able to adhere to their experimental instructions, preventing attentional switching during tasks; which is particularly useful for controlling for children's limited attention spans (Petranek et al., 2017; Emanuel et al., 2008; Perreault & French, 2015, 2016; Thorn, 2006). Therefore, this study will implement a dual-set of manipulation checks to investigate the efficacy of FOA instruction in two groups of young learners (children between 4-6 and 7-10 years of age) performing a postural control task.

The postural control task will be the same as Study 1, the only difference will be the inclusion of the manipulation checks and the lack of EMG measurements. The first manipulation check will be an embedded vision and no-vision paradigm similar to Yeh and colleagues (2016). This manipulation check serves to determine the adherence to the FOA instruction being used. The second manipulation check will be a retrospective verbal report, similar to Perreault & French (2016), which functions to examine the efficacy and participants' interpretation of the FOA instruction being used. Consistent with Study 1, the two age groups will be used to isolate the chronological age point of 7 years, where children have been shown to make the switch to more mature postural sway patterns, along with better understanding their reliance of external visual feedback during this transitional period. Additionally, the purpose of the CTRL group is to see if the inherent assumption that the CTRL group will naturally adopt an INT FOA holds true.

There are four hypotheses for Study 2. First, there will be a main treatment effect of visual condition, where participants will have a higher sway variability in the non-vision phase compared to visual phase. Second, there will be a significant interaction of FOA group and visual condition on postural control performance, where the participants in the EXT FOA in the non-vision phase will have the highest postural sway. Third, there will be a significant interaction of FOA condition, age and visual condition, where the group of older children in the EXT FOA condition will exhibit an increase in sway when vision is removed (i.e., no vision portion). Meanwhile, for the group of younger children, regardless of their FOA condition, they will experience increases in sway variability when visual information is removed. Last, the verbal manipulation check will reveal that the majority of participants adopted a combination of both the INT and EXT FOA instructions, irrespective to their particular attentional focus condition throughout acquisition and perturbation tests. The group of younger children, however, will provide more task irrelevant information (e.g., emotional content) in their responses.

3.5 Impact

The potential knowledge gained through using manipulation checks to examine the validity and influence of FOA instruction on children during a postural control task hopes to meaningfully extend current research exploring the efficacy of FOA instructions and to see whether or not these types of instructions are a reliable tool for facilitating motor skill learning in younger populations. Additionally, potential results from this study may provide new fundamental insights on attentional capacities in typically developing children to inform best practices for pedagogical and motor behavioural research.

4.0 METHOD

4.1 Participants

Sample size was determined by an a priori power calculation based on our smallest comparison of interest. For the purpose of this thesis, powering for the sample of Study 2 is based on an interaction of FOA group and type of test. Using an α of 0.05, a power (1 - b) of 80%, a Cohen's f of 0.25, for 3 groups, on 4 measures and with a correlation among repeated measures of 0.5, a sample of 102 participants was calculated. These specific parameters result in 34 participants per group. Given the limitations imposed on participant recruitment as a result of the inclusion criteria (i.e., narrow age range) and the COVID-19 restrictions the study may necessitate a smaller sample size, however, this sample will be consistent with literature and all appropriate cautions pertaining to the interpretation of data collected on a smaller sample than statistically recommended will be observed.

Participants will be recruited from the Literacy and Mathematics Academy private school in Stoney Creek, Ontario. Where participants will be randomized into one of three conditions (INT FOA, EXT FOA and CTRL). All participants must be between the ages 4-10, present no self-reported neurological disorders, have normal or corrected-to-normal vision, be able to pass the online provincial COVID-19 screening tool (www.covid-19.ontario.ca/self-assessment/), not be students that primary investigator tutors at the academy, and not be a high-risk individual for COVID-19. The latter includes those with weakened immune systems, lung disease, heart disease, hypertension (high blood pressure), diabetes, obesity, kidney disease, liver disease, dementia, and stroke. Other than these characteristics, no other criteria will be enforced on participant recruitment (i.e., no specific sub-groups will be recruited). These inclusion/exclusion criteria are based on previous studies utilizing similar tasks, and or a similar population (see Yeh et al., 2016; Olivier et al., 2008; Petranek et al., 2019; Palmer et al., 2017). At the start of the study, all children must provide verbal consent, and their parent/guardians must provide written informed consent. All parking and transportation costs will be covered, and participants will be remunerated with a $10 Tim Horton's gift card for participating in the study. This study received approval from the McMaster University Research Ethics Board.

4.2 FOA Instructions

Participants in the INT FOA group will be given the instructions: "focus on maintaining your weight evenly distributed on both legs throughout the trial", where participants in the EXT FOA group will be told to: "focus on keeping the cross in the target square throughout the trial, and when it disappears imagine that it is still there.", and the CTRL condition will be given no instruction apart from the main study objective. To minimize the advantage of an increased feedback frequency on performance (see Goh et al., 2012), participants will only be reminded of their feedback condition if needed. Note that attention for this study is operationally defined as a process that helps the individual select which stimuli are important and should influence an ensuing response, as well as a process of sustained concentration (Wells & Mathews, 2015).

4.3 Manipulation Checks

4.3.1 Visual manipulation check

Participants will be provided with visual feedback for the first half of the trial, which will then disappear for the last half of the trial. The visual paradigm will be the same for all three conditions and will be used in every trial, the only difference between the groups will be FOA instruction given to them. This technique is adapted from the one used in Yeh and colleagues (2016).

4.3.2 Verbal manipulation check

This manipulation check is based on Perreault & French (2016), where following the conclusion of both acquisition and perturbation tests, participants will be asked to verbally respond to an open-ended question to serve as a manipulation check. Specifically, participants will be asked the question: "What were you thinking about today when you were standing on the force plate?". Ericsson & Simon (1993) argue open ended questions to be the most effective tool for retrospective verbal reports to access traces of participants' working memory following task performance. This question will be asked to each participant, and their responses will be recorded via a digital audio recorder.

4.4 Protocol

For each experimental trial, participants will stand on a force platform (AMTI OR6-2000; Newton, MA, USA) that will output centre of pressure (COP) positions along the anteroposterior (AP) and mediolateral (ML) axes. Participants will face a liquid crystal display (LCD) monitor located at eye level (Viewsonic; 60

Hz refresh rate, 5 ms delay) that will be connected to the force platform. The LCD display will show the same augmented feedback information for each experimental condition. Test circumstances (e.g., room illumination, temperature, and noise) will be consistent with the posturographic testing recommendations outlined by Shumway-Cook and colleagues (2000). A fixed 12x12 mm target will appear on the LCD screen that will represent mean center of pressure for both the ML (i.e., left-right) and AP (i.e., front-back) positions within the first 10 secs of the trial. Following the first 10 secs, each group will see a live 12x12 mm target cross in real-time that will move horizontally and represent their ML COP, which will be on the screen for 20 secs, and then will disappear for the remainder of the trial (i.e., last 20 secs). The visual display (depicted on figure 8) will be the same for all conditions, the only difference will be the instructions given to them.

Participants will be allotted as many practice trials as needed to familiarize themselves with the task and to ensure instructions are understood. Participants will perform the task a total of 12 times during the acquisition phase and will be given breaks between trials. Trials will be 50 secs in length for each group.

Participants will come back 24 to 48 hours later to perform perturbation tests. Similar to the acquisition phase, participants will be instructed to stand on the force platform. They will be given the new objective of holding their arms straight out in front of them for 2 trials, 2 trials to their left side, and out to their right side for 2 trials, thus totaling 6 trials. The purpose of this manipulation is to create a shift in centre of gravity to assess how participants adapt to a new balance perturbance as a function of attentional focus. No further instruction will be given to the participants. Each trial will last 50 secs, and they will receive the same visual feedback during acquisition, along with the same COP measurements.

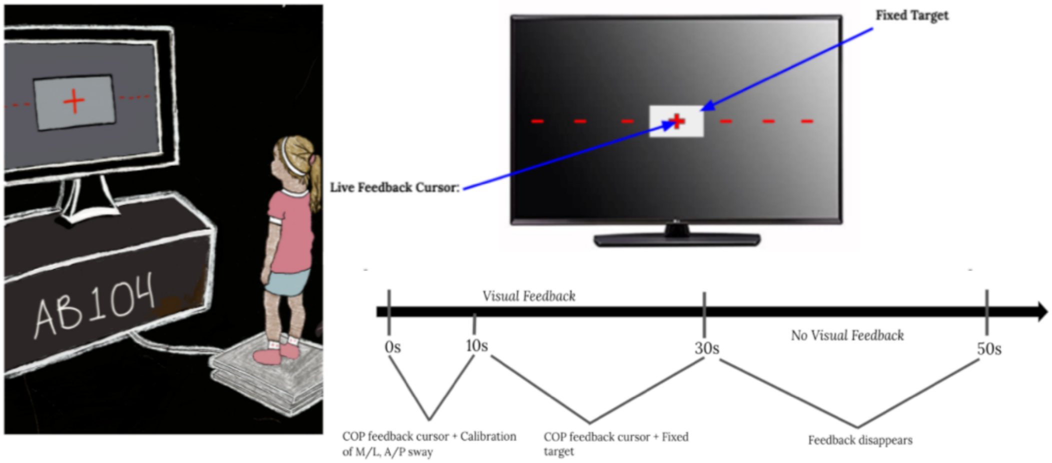

Figure 8: Schematic of the visual display for all three conditions

4.5 Data Processing

4.5.1 Force Platform Processing

COP data from the AP and ML axes will be recorded from the force platform. The stability of postural control will be determined by the standard deviation (SD; COP position variability) from the mean COP position in both directions. The first 10 secs of data will not be used for all three groups because the fixed target position will be determined by calculating the mean position from the first 10 secs of COP data. Only the last 40 secs of data will be analyzed for each trial at a 40 Hz sampling rate.

4.5.2 Verbal Manipulation Check Processing

Responses to the manipulation check will be analyzed using a verbal analysis method similar to that used in Perreault & French (2015, 2016). Each response will be segmented into separate words and/or phrases representing distinct thought patterns during performance (e.g., emotional thoughts, task relevant thoughts and task irrelevant thoughts). For more details on how the thought patterns will be segmented see Chi (1997). After the examination of the verbal responses, the experimenter along with a laboratory assistant will separately develop a coding scheme based on the instructional content presented from the participants, along with other content commonly observed in novice learners' responses (similar to Nielsen & McPherson, 2001).

4.6 Statistical Analysis

4.6.1 Independent & Dependent Variables

There are five independent variables for this study: FOA group (INT, EXT & CTRL), age group (Young: 4 – 6 years of age & Old: 7 – 10 years of age), Visual Condition (Vision vs. No Vision), type of tests (acquisition, perturb left, perturb forward and perturb right) and the number of trials across both the acquisition and perturbation tests of the study (12 for acquisition and 2 within each perturbation). Three dependent variables will be collected: mean standard deviation (SD) of the mediolateral COP in millimetres (mm), mean SD of the anteroposterior COP in mm, and the verbal retrospective analysis responses.

4.6.2 Analysis

As in Study 1, there will be two separate analyses conducted for each dependent variable. The first analysis will only consider the acquisition phase of the study and will consist of a mixed analysis of variance (ANOVA) on the three attentional conditions (INT, EXT & CTRL), two visual conditions (vision and no-vision), two age groups (Young & Old) and 12 trial blocks with repeated measures on the last factor. The second analysis will be a mixed ANOVA on the three attentional conditions, two visual conditions, two age groups, four types of test and the two trial blocks within each test condition with repeated measures on the latter two factors. This analysis will compare the last two trials of acquisition to the two trial blocks within each of the perturbation conditions. For both analyses alpha will be set at 0.05, Greenhouse-Geisser corrections will be employed for sphericity violations (Mauchly's test, $p < .05$) and Tukey's *HSD* post hoc analysis will be used to examine main effects and interactions. Cohen's *d* will be calculated to report effect sizes. All analyses will be run using RStudio (macOS version 4.0.5).

4.6.3 Verbal Manipulation Check Responses

As previously mentioned, responses to the verbal manipulation check will be recorded via a digital audio recorder device. The experimenter along with a laboratory assistant will separately develop a coding scheme based on the informational content provided from the participants. The experimenter will then meet with the laboratory assistant to compare coding schemes in order to determine inter-rater reliability between the experimenters' response coding. Once achieved, separate Kruskal-Wallis tests will be performed for acquisition and perturbation tests to parse out participants' coded responses with group.

4.7 Expected Results

For Study 2, there are four main expected results. The first hypothesis is that there will be a main effect of visual condition on postural control performance. The expected result for this study coincides with this hypothesis, where participants will exhibit a significant increase of postural sway in the mediolateral direction when in the non-vision portion of the trial. This prediction is driven by Ross (1978) who suggests that children do not reach the adult-like stage of being able to selectively attend to relevant stimuli until early adolescence and are therefore susceptible to be influenced by innocuous sensory inputs. This is then compounded by the differences in the participants' comprehension level and propensity to be distracted (both these points will be further elaborated).

The second expected result will reveal a significant interaction of FOA group and vision on postural control performance. Participants in the EXT FOA condition will display a significantly higher postural sway in the mediolateral direction when the visual information is removed in comparison to the other two conditions. The reasoning behind this prediction is attributable to the design of the manipulation check itself. The aim of the visual paradigm is to see how well participants are able to adhere to their given FOA condition. Since the EXT FOA group is directed to focus on the visual stimuli, they are expected to be reliant on that source of constant augmented feedback and therefore should naturally struggle when it is removed.

The third hypothesis is that there will be a significant interaction of FOA group, age, and visual condition. The expected result for this study, will coincide with this hypothesis and will reveal that the EXT FOA group of older children will show a significant increase in mediolateral sway when vision is removed (i.e., no vision portion). The EXT FOA group of older children will only show a difference in the mediolateral direction when in the no visual feedback condition because the visual feedback provided is along the mediolateral direction (side-to-side), and not in the anteroposterior direction (front-to-back). Given that the EXT FOA group is explicitly told to focus externally on the visual feedback, it will make them susceptible to performance decrements when it is removed. Further, the INT FOA group of older children will show no difference for both mediolateral and anteroposterior COP when transitioned from visual feedback to non-visual feedback. This is because the INT FOA group is directed to focus their attention to their own body and will not be significantly impacted by the visual feedback. With regard to the CTRL condition of older children, they will perform similarly to the INT condition given that they are not explicitly directed to rely on the external visual display. These assumptions are predominately driven by the evidence suggesting the chronological age point of 7 years to be when children make the transition to adult-like postural control, and thus they should perform similarly to an adult level. Where, on the other hand, the children in the younger group will show a significant increase in sway variability in the mediolateral direction when visual feedback is removed regardless of their FOA condition. This is prediction is driven by the idea that children under the age of 7 years, as noted earlier, struggle with re-weighting multiple sensory inputs, meaning they struggle with uncoupling irrelevant sensory information for a given task (Oie et al., 2001; Haas et al., 1989; Lee & Aronson, 1974; Barela et al., 2003), therefore, will struggle with the removal of visual information regardless of their respective FOA condition. Although it cannot be extended directly to this population, notably, Yeh and colleagues (2016) saw these results among their older population of adults when comparing younger adults to older adults. The researchers attributed their findings to be a result of an age-related declination in ability to use nonvisual sensory inputs (Eikema et al., 2013; Yeh et al., 2014) and from an inability to suppress unreliable visual cues when exposed to a visual motion stimulus (Jeka et al., 2006), which are similar components to what children under the age of 7 years have been evidenced to struggle with.

The last hypothesis is that the verbal manipulation check will reveal that the majority of participants adopted a combination of both the INT and EXT FOA instructions not withstanding to their particular attentional focus condition. The expected result will reflect this hypothesis. The older children will intuitively switch attentional focus during trials, similarly, seen in Maxwell and Masters (2002) and Poolton and colleagues (2006), in order to accommodate for the differing demands of the task. The group of younger children will additionally use a combination of both FOA types, however, this will be a result of the inherent complexity of the task and the cognitive limitations among this group. Moreover, spontaneous rehearsal strategies for children, as previously mentioned, do not start until around 7 to 8 years of age (Thomas, 1984), coupled by children's immature memory encoding strategies (Petranek et al., 2019); making it plausible to suggest that the younger children may forget their respective attentional focus. Furthermore, since children under 5 to 6 years of age tend to over exclude during attentional information processing (Ross, 1978), and are more susceptible to being distracted (Olivier et al., 2008); it is therefore likely that their responses will contain more task irrelevant information compared to the older children.

CHAPTER THREE: INTRODUCTION TO STUDY THREE & METHOD

5.0 INTRODUCTION TO STUDY THREE

The purpose of Study 1 is to extend the current research pertaining to the best suited FOA instruction type for young learners performing a postural control task. This study was designed in the most traditional way in order to be consistent with the majority of FOA research studies. Briefly, the expected results for Study 1 are that there will be no effects of FOA condition on the dependent variables, there will be a main effect of age on the dependent variables and that there will be an interaction of FOA condition and age on postural sway and ankle-muscular activation. Study 2 is designed as a direct extension to Study 1 in order to further interpret these predictions. Therefore, Study 2 looks to investigate the validity and reliability of using FOA instruction among younger populations. There are four primary expected results of interest for this study. First, there will be a main effect of visual condition on postural control performance. This is driven by evidence by Ross (1978) which suggests that children do not attain adult-level strategies in selective attention until early adolescence and are therefore likely to be influenced by changes in innocuous information during performance. Second, there will be a significant interaction of FOA group and vision. This prediction is directly linked to the nature and intended purpose of the visual paradigm. Given that the EXT FOA condition is directed to focus on the visual stimuli, removing the visual feedback will depict this reliance. Third, there will be a significant interaction of FOA group, age and visual condition on the dependent variable. Specifically, the group of older children in the EXT FOA group will be the only group among the older group of children to show an increased sway variability in the mediolateral direction when in the non-visual feedback portion of the trial. In contrast, the group of younger children, regardless of their attentional focus condition, will struggle with the removal of the visual feedback. This prediction is driven by the idea that children under the age of 7 years struggle with re-weighting multiple sensory inputs and are susceptible to being distracted by inaccurate sensory information, whereas the children above 7 years of age will be able to mitigate the level of error and distractibility derived from the erroneous sensory inputs. Last, the verbal manipulation check will show that the participants will have used a combination of an INT and EXT FOA, regardless of their respective attentional focus condition, throughout acquisition and perturbation phases. This prediction is driven by the idea that the group of older children will switch their attentional focus to meet the specific task demands, while for the group of younger children, the task may be too complex, and they will struggle to adhere to their given FOA instruction. Following Study 2, the next theoretical progression is to extend FOA research into populations with a known attentional deficit. This step serves to evaluate the degree to which compromised abilities in the selection and focus of attention meditates FOA instructional sets. By considering situations in which known deficits in the processing of environmental information requiring attentional resources exist, it is possible that important insights can be gained as to the relative degree of influence those specific systems have on FOA instruction. Further, the results of this approach will offer some applied insight as to whether FOA instruction can be an effective support for non-neurotypical individuals who struggle with attentional control. Thus, Study 3 looks to investigate the influence of FOA instruction in children with attention-deficit/hyperactivity disorder.

5.1 Attention-Deficit Hyperactivity Disorder (ADHD)

Attention-deficit/hyperactivity disorder (ADHD) is a heterogeneous neurodevelopmental disorder, predominately characterized by developmentally compromised levels in concentration and hyperactivity-impulsivity, that first appears in childhood and remains throughout the life span (American Psychiatric Association, 2013; Anastopoulos & Beal, 2020; Dewey & Botos, 2004; Pallanti & Salerno, 2020). ADHD affects approximately 6.5% of the general child population (Polanczyk et al., 2014), and its prevalence is argued to be increasing (Hauck et al., 2017; McMartin et al., 2014). ADHD presents differently depending on the individual, as demonstrated in the severity and frequency of inattentive and hyperactive-impulsive symptoms (Anastopoulos & Beal, 2020; Millichap, 2011; Pallanti & Salerno, 2020). Anastopoulos & Beal (2020) further explain that the same child with ADHD may exhibit inconsistent levels of symptoms, along with the expression of these symptoms changing over time. ADHD is considered be one of the most common referrals among children for both mental health and medical health care evaluation and treatment (Barkley, 2015) and is what many researchers and health care practitioners argue to be the leading health care problem among children of today (Waddell et al., 2002).

Anastopoulos & Beal (2020) note that from the early 1900s until the 1970s, most diagnostic labels applied to ADHD-like behaviours emphasized a presumed etiological basis, such as “post-encephalitic behavior disorder”, “organic drivenness”, “minimal brain damage”, and “minimal brain dysfunction”. A transition during the late 1950s through to the 1960s saw diagnostic labels be more reflective of symptom-based descriptors, such as hyperkinetic-impulse disorder, hyperactive child syndrome, and hyperkinetic reaction of childhood. A major shift in the 1980s occurred with the release of *Diagnostic and Statistical Manual of Mental Disorders 3rd Edition* (DSM-3), where diagnostic labels shifted from symptom-based labels to highlighting inattentive features, which was largely influenced by seminal research of Virginia Douglas (1972; Pallanti & Salerno, 2020; Anastopoulos & Beal, 2020). This is where the terms attention-deficit disorder with hyperactivity, attention deficit disorder without hyperactivity (ADD), and attention-deficit hyperactivity disorder (ADHD) came into use. However, as per the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5), diagnostics are labelled as ADHD despite the term ADD still being used colloquially (Anastopoulos & Beal, 2020).

5.2 The Etiology of ADHD

Pallanti & Salerno (2020) suggest that there are two main ideas surrounding the etiology of ADHD. First, ADHD is a biological condition that is a culmination of compromised genetic and environmental factors affecting the brain, substantiated through molecular genetics and neuroimaging investigations. It is argued that there are many biological pathways that can lead to ADHD that interact with various environmental factors during development (Nigg et al., 2010; Pallanti & Salerno, 2020; Anastopoulos & Beal, 2020). In addition, prenatal and birth complications have been suggested. This perspective infers that most children with ADHD have an inborn biological predisposition affecting both neurochemical and neurophysiological functioning, which requires a treatment intervention (e.g., cognitive behaviour training; Barkley, 2015; Pallanti & Salerno, 2020; Anastopoulos & Beal, 2020).

Second, ADHD can be thought as psychological variant rather than a disorder, where individuals with ADHD require different educational and supportive measures. Problems associated with ADHD through this perspective are associated with social intolerance, which is reflected in the rise of ADHD diagnoses and differences in estimated prevalence rates globally (Taylor, 2011). This debate is then compounded by cultural differences pertaining to the recognition and the acceptance of the ADHD disorder, which is mainly driven by fear of the common stimulant medication treatment (e.g., issues with abuse and dependency), where many are concerned with persons with ADHD being overprescribed by healthcare practitioners and pharmaceuticals companies in the pursuit of economic profit (Pallanti & Salerno, 2020). This idea is argued to be fostered through the recent increase of ADHD diagnoses and subsequent increase of psychostimulant prescriptions (Fulton et al., 2009), even though there is considerable amount of evidence supporting the protective effect of early ADHD pharmacological treatments preventing the development of other psychiatric conditions and associated negative outcomes (Banerjee, 2009; Flapper & Schoemaker, 2008).

5.3 Affected Brain Regions

Shaw and colleagues (2007) compared the cortical thickness patterns of children with ADHD to controls and showed that those with ADHD were characterized by a marked delay in reaching peak thickness in several brain regions (e.g., PFC) rather than a complete deviation from typically developing children. More specifically, children with ADHD reached peak thickness at a median age of 10.5 years compared to the typical age of 7.5 years, along with maturation of the cortical surface area (i.e., the median age by which 50% of right prefrontal cortical vertices attain peak) peaking around 14.6 years compared to 12.7 years of the typically developing controls (Shaw et al., 2012). Additional imaging evidence depicts individuals with ADHD as having approximately 4% smaller volumes of lobes of gray and white matter within each lobe, as well as overall lower cerebral and cerebellar volumes (Castellanos et al., 2002). These differences were mainly reported in the frontal lobes, premotor cortex, posterior cingulate, anterior and medial temporal lobes, cerebellar lobules, and basal ganglia (Vaidya, 2012). Interestingly, the degree and severity of these abnormalities correlated with both clinical outcome and exposure to stimulant medication treatment. That is, children with ADHD whose symptoms persisted into adolescence had a thinner medial PFC at age 8.7 years compared to controls and children with ADHD with symptoms in remission (Shaw et al., 2006), and children who were unmedicated showed a greater degree of cortical thinning than age-matched controls (Shaw & Rabin, 2009). Furthermore, working memory and attention task studies on people with ADHD showed under activation of the frontostriatal and frontoparietal networks that mediate goal-directed executive function, as well as hypoactivation of the ventral attention network that mediates the reorientation of attention toward external stimuli that are salient and behaviorally relevant (Faraone et al., 2015; Cortese, 2012). Resting-state MRI studies have additionally depicted impaired sustained attention abilities in individuals with ADHD to be associated with a disrupted default-mode network (DMN), which is essential for efficient external stimuli processing during task performance (Sonuga-Barke & Castellanos, 2007; Posner et al., 2014).

5.4 ADHD & Comorbidities

What further complicates understanding the expression of ADHD is that the diagnosis is regularly comorbid with other disorders (Daviss, 2018; Millichap, 2011; Sadek, 2019). Specifically, up to 60% of children with ADHD develop at least one co-occurring condition (Pliszka, 2015; Anastopoulos & Beal, 2020). Common comorbidities are epilepsy, borderline personality disorder, anxiety, depression, oppositional defiant disorder, conduct disorder, bipolar disorder, substance abuse disorders, and autism spectrum disorder (Sadek, 2019; Daviss, 2018). Symptoms of ADHD can be intensified by such additional underlying comorbidities that can often reciprocally affect each other (e.g., an individual feeling anxious because they cannot concentrate, and being unable to concentrate because they feel anxious; Willcutt, 2020).

One of the most prominent comorbidities for ADHD is developmental coordination disorder (DCD), which has approximately a 50% co-occurrence rate (Brossard- Racine et al. 2012; Pitcher et al. 2003; Kadesjö & Gillberg, 1999; James et al., 2021). DCD is a disorder characterized by motor skills that are significantly below age-expected levels, despite the individual having adequate opportunities to acquire and develop these skills (American Psychiatric Association, 2013). Similar to ADHD, the expression of DCD is not uniform (Cairney & Dowling, 2016). Lee and colleagues (2021) add that children with the dual diagnosis of ADHD and DCD display fine and gross motor difficulties (Farran et al., 2020; Miyahara et al., 2006; Pitcher et al., 2003) and have significant impairments in academic skills such as handwriting (Racine et al., 2008). Gillberg (2003) provides the *deficits in attention, motor control, and perception model* (DAMP), as alternative perspective and diagnostic tool for individuals who are comorbid with ADHD and DCD. Cairney & Dowling (2016), however, explain that there are challenges for disentangling these disorders. The authors argue that a child who is impulsive can appear as clumsy and a child who has problems with inhibitory control will find it difficult to concentrate on a subjectively boring task. The authors extend this logic to a child with DCD, arguing that they may misbehave due to the frustration of being unable to participate in certain physical activities, or in an attempt to distract others from their motor-based activity problems, which can give the illusion of appearing inattentive, disruptive, or hyperactive.

5.5 ADHD, Motor Impairments & Balance Issues

Despite the high co-occurrence rate between ADHD and DCD, debate remains as whether or not motor deficits are a part of the ADHD phenotype or reflect a compromised motor system attributable to ADHD (Farran et al., 2020; Kaiser et al., 2015; Goulardins et al., 2017). In a study by Tseng and colleagues (2004), they were able to demonstrate metrics of sustained attention and impulse control as viable concurrent predictors of fine and gross motor skills in 6 to 11 year olds with ADHD, which is consistent with other researchers (e.g., Piek et al., 2004) who were able to report strong associations between motor coordination difficulties and ADHD (Shorer et al., 2012; Farran et al., 2020).

Dewey & Bottos (2004) explain that motor deficits attributable to ADHD can be further revealed through neuroimaging, where researchers have shown abnormalities in the frontostriatal circuitry. More precisely, Durston (2003) showed that children with ADHD (6–10 years of age) did not activate frontostriatal regions in the same manner as typical controls. During tasks that required cognitive control (i.e., the ability to suppress thoughts and actions), lower levels of activation were noted in the PFC, the anterior cingulate gyrus, and basal ganglia regions. This frontostriatal dysfunction is argued to illustrate inefficient executive functions in children with ADHD, which translates to difficulties in sustained attention and an impaired ability to plan, organize, and sequence movements (Barkley, 1997; Dewey

& Bottos, 2004). Durston (2003), further suggests that the frontostriatal circuitry may also be implicated in their inability to inhibit certain behaviors which in turn can interfere with motor learning and performance (Dewey & Bottos, 2004). In addition to atypical frontostriatal circuitry, the size of the cerebellum, as previously mentioned, has been found to be significantly smaller in children with ADHD, where Mostofsky and colleagues (1998) suggest that this may contribute to difficulties with timing associated with motor behaviours.

Recent evidence suggests that individuals with ADHD exhibit postural control difficulties (Shorer et al., 2012; Jansen et al., 2017). A study by Hove and colleagues (2015) illustrates that adults with ADHD exhibit larger postural sway deviations when compared to typical controls possibly due to the abnormalities in cerebellar gray matter volume. For children, researchers have been able to find evidence of larger postural sway as well. For example, Feng and colleagues (2007) found greater postural sway velocity in children with ADHD when compared to controls. These differences in postural sway performance may be explained by an impairment of movement coordination (e.g., trunk and head strategies) and balance functions (Iwanga et al., 2006; Buderath et al., 2009; Jansen et al., 2017). Moreover, Jansen and colleagues (2017) conclude that participants with ADHD showed a significantly larger time delay between stimulus and response than control subjects during a postural stability task, where they interpreted the finding as depicting dysfunction of the fronto-striato-cerebellar timing-system in ADHD (Marx et al., 2010).

5.6 ADHD & FOA

The research considering the influence of FOA instruction in children with ADHD is limited (Ghorbani et al., 2020; Saemi et al., 2013). Saemi and colleagues (2013), for example, investigated the influence of FOA instruction on the learning of tennis ball throwing in a group of children with ADHD. The results from this study show that an EXT FOA yielded superior results for accuracy scores in comparison to an INT FOA for both acquisition and retention tests. Similarly, Ghorbani and colleagues (2020) investigated the influence of FOA instructions during a static balance task in children (ages 7 and 11) with ADHD, where participants were measured on how long they could hold a static balance task. The results from this study show that children in the EXT FOA group were able to outperform the children in the INT FOA condition during the static balance task. Both these results are consistent with Wulf and colleagues' constrained action hypothesis.

5.7 Purpose

Study 3 serves as an extension for Study 1 and 2. Theoretically, investigating the influence of FOA instruction in children who are known to have an attentional processing disorder is essential, as it critically examines whether or not the many claims within the FOA literature pertaining to attention hold true. Moreover, the research examining the influence of FOA instruction in children with ADHD is limited. The potential motor learning benefits from directing attention either externally or internally, could be very promising for advancing teaching practices working with individuals who have ADHD. Thus, the purpose of Study 3 is to examine the influence of FOA instruction on children (4-10 years old) with ADHD performing a postural control task. Postural control, as previously mentioned, is dependent on attentional capabilities. Children who have ADHD, along with exhibiting attentional dysfunction, have been shown to struggle with postural control and balance capabilities (Feng et al., 2007). Therefore, assessing postural control is appropriate for this study.

The main hypothesis for this study is that there will be a main effect of FOA condition on postural control performance. Specifically, participants in the EXT FOA group will have a lower postural sway compared to participants in the INT FOA condition. This result will also be seen throughout the acquisition and the perturbation tests. Participants in the EXT FOA condition will be able to accommodate better (i.e., lower postural sway) to the various balance perturbations in comparison to the INT FOA condition. The rationale behind this hypothesis is attributable to evidence within the ADHD literature that suggests individuals with ADHD struggle with the external aspects of attentional processing (which will be discussed later). Provided the claims suggested by FOA researchers (e.g., Wulf, 2013), when implemented correctly, that EXT FOA instruction is able to create a dichotomous external mental focus state for the individual. Therefore, the benefits from this mental state should be evidenced among this population who need to be continuously directed towards relevant external stimuli. This in turn, contrasts the expected results from Study 1, as neuro-typical children are not known to explicitly struggle with the external aspects of attentional processing to same degree as this population, whereas children under the age of 7 years are rather dependent on internal information for the development of their internal models. The hypothesis for Study 3 is then consistent with Wulf and colleagues' constrained action hypothesis.

It is important to note that Studies 3 and 4 serve as a first step in further expanding FOA research into their respective populations. Working with special populations brings a unique set of challenges and limitations. Our approach is to be more conservative with working with these groups and to simplify assessments where necessary, rather than risk to overwhelm or overburden these participants. Therefore, similar to Study 1, Studies 3 and 4 will be assessing the effects of FOA instruction using a traditional FOA research design and will not be implementing any manipulation checks. By doing this, it will enable the researchers to gauge how these participants act in a laboratory setting performing FOA based activities and will help to advise future studies that will have an increased procedural complexity (i.e., the addition of manipulation checks). For similar reasons, EMG will not be collected for these studies as well.

5.8 Impact

The potential knowledge gained through analyzing the influence of FOA instruction in children with ADHD will help extend the understanding surrounding the direct influence that the different types of FOA instruction have on attention. In addition, the potential results from this study surrounding the validity and practicality of using FOA instruction in children with ADHD, may help to inform future teaching and coaching practices for this population.

6.0 METHOD

6.1 Participants

Sample size was determined by an a priori power calculation based on our smallest comparison of interest. For the purpose of this thesis, powering for the sample of Study 3 is based on an interaction of FOA group and type of test. Using an α of 0.05, a power (1 - b) of 80%, a Cohen's f of 0.25, for 2 groups, on 4 measures and with a correlation among repeated measures of 0.5, a sample of 82 participants was calculated. These specific parameters result in 41 participants per group. Given the limitations imposed on participant recruitment as a result of the inclusion criteria (i.e., children with ADHD and a narrow age range) and the COVID-19 restrictions, the study may necessitate a smaller sample size. A smaller sample size would be consistent with literature and all appropriate cautions pertaining to the interpretation of data collected on a smaller sample than statistically recommended will be observed.

Participants will be recruited from the Literacy and Mathematics Academy private school in Stoney Creek, Ontario. Where participants will be randomized into one of two conditions (INT FOA and EXT FOA). All participants must be between the ages 4-10, present no other self-reported neurological disorders than ADHD, not have a history with or currently be taking prescribed medication (e.g., Concerta and Strattera) for their ADHD, have normal or corrected-to-normal vision, be able to pass the online provincial COVID-19 screening tool (www.covid-19.ontario.ca/self-assessment/), not be students that primary investigator tutors at the academy, and not be a high-risk individual for COVID-19. The latter includes those with weakened immune systems, lung disease, heart disease, hypertension (high blood pressure), diabetes, obesity, kidney disease, liver disease, dementia, and stroke. Other than these characteristics, no other criteria will be enforced on participant recruitment (i.e., no specific sub-groups of ADHD will be recruited). These inclusion/exclusion criteria are based on previous studies utilizing similar tasks, and or a similar population (see Yeh et al., 2016; Olivier et al., 2008; Petranek et al., 2019; Palmer et al., 2017). At the start of the study, all children must provide verbal consent, and their parent/guardians must provide written informed consent. All parking and transportation costs will be covered, and participants will be remunerated with a 10$ Tim Horton's gift card for participating in the study.

6.2 FOA Instructions

Participants in the INT FOA group will be given the instructions: "focus on maintaining your weight evenly distributed on both legs throughout the trial", where participants in the EXT FOA group will be told to: "focus on keeping the cross in the target square throughout the trial." To minimize the advantage of an increased feedback frequency on performance (see Goh et al., 2012), participants will only be reminded of their feedback condition if needed. Note that attention for this study is operationally defined as a process that helps the individual select which stimuli are important and should influence an ensuing response, as well as a process of sustained concentration (Wells & Mathews, 2015).

6.3 Protocol

Refer to the protocol seen in Study 1. The only difference will be the exclusion of EMG.

6.4 Data processing

6.4.1 Force Platform processing

COP data from the AP and ML axes will be recorded from the force platform. The stability of postural control will be determined by the standard deviation (SD; COP position variability) from the mean COP position in both directions. The first 10s of data will not be used for all three groups because the fixed target position for the EXT FOA group will be determined by calculating the mean position from the first 10 secs of COP data. Only the last 40 secs of data will be analyzed for each trial at a 40 Hz sampling frequency.

6.5 Statistical Analysis

6.5.1 Independent & Dependent Variables

There are three independent variables for this study: FOA group (INT & EXT), types of tests (acquisition, perturb left, perturb forward and perturb right) and the number of trials across both the acquisition and perturbation phases of the study (12 for acquisition and 2 within each of the three perturbation). There are two dependent variables that will be collected: mean standard deviation (SD) of the mediolateral COP in millimetres (mm), and mean SD of the anteroposterior COP in mm.

6.5.2 Analysis

There will be two separate analyses conducted for each dependent variable. The first analysis will consider only the acquisition phase of the study and will consist of a mixed analysis of variance (ANOVA) on the two attentional conditions (INT & CTRL) and 12 trial blocks with repeated measures on the last factor. The second analysis will be a mixed ANOVA on the two attentional conditions, four types of test and the two trial blocks within each condition with repeated measures on the latter two factors. This analysis will compare the last two trials of acquisition to the two trial blocks within each of the three perturbation conditions. For both analyses, alpha will be set at 0.05, Greenhouse-Geisser corrections will be employed for sphericity violations (Mauchly's test, $p < .05$) and Bonferroni post hoc analysis will be used to examine main effects and interactions. Cohen's d will be calculated to report effect sizes. All these tests will be run using RStudio (macOS version 4.0.5).

6.6 Expected Results

For Study 3, it is hypothesized that there will be a main treatment effect of FOA condition. The expected result for this study is that the children in the EXT FOA group will have a lower mediolateral postural sway compared to the children in the INT FOA group. It should be specified, however, that the difference will only be seen in the mediolateral direction and not in the anteroposterior direction, as the visual feedback is provided along this axis. This result is deduced from the imaging evidence suggesting individuals with ADHD have a frontostriatal dysfunction (e.g., Dewey & Bottos, 2004) and a ventral attention network deficit (e.g., Cortese, 2012). As noted earlier, a frontostriatal dysfunction is linked to impaired executive functioning, which particularly impacts sustained attentional control and behavioural regulation (Barkley, 1997; Dewey & Bottos, 2004). Tseng and colleagues (2004) explain that sustained attentional abilities and impulse control can be considered as viable concurrent predictors of fine and gross motor skills in children with ADHD (6-11 years of age). A ventral attention network deficit negatively affects an individual's ability to reorient their attention towards external stimuli that are behaviorally relevant (Faraone et al., 2015; Cortese, 2012). From these cognitive deficits, one can infer that children with ADHD struggle with the external components of attentional processing. Therefore, the participants in the EXT FOA group will benefit more than the INT FOA group, as they will have their focus continuously directed towards the relevant external information needed for postural control performance. This result is consistent with Wulf and colleagues' constrained action hypothesis.

CHAPTER FOUR: INTRODUCTION TO STUDY FOUR & METHOD

7.0 INTRODUCTION TO STUDY FOUR

Study 1 looks to assess which type of FOA instruction is better suited for children. The expected results for this study are that there will be no main effects of FOA condition, there will be a main effect of age and that there will be an interaction of FOA condition and age on the dependent variables. Study 2 looks to extend these predictions by further investigating the validity and reliability of using FOA instruction with younger populations. The expected results for Study 2 are that there will be a main effect of visual condition, there will be a significant interaction of FOA condition and visual condition, there will be a significant interaction of FOA condition, age and visual condition on the dependent variable, and that the verbal manipulation check will reveal that participants used a combination of an INT and an EXT FOA instruction throughout their trials. Study 3 then serves as a theoretical progression to the two preceding experiments. Specifically, this study looks to examine the degree to which compromised abilities in the selection and focus of attention influences performance under the two FOA instructional sets. Children with ADHD are a population who are known to exhibit deficits in the processing of environmental information requiring attentional resources (Pallanti & Salerno, 2020; Anastopoulos & Beal, 2020). This deficit predominately affects the external components of attentional processing. Thus, gaining insights on the dynamics between this deficit and the role of FOA instruction is important for extending the literature, along with evaluating whether, or to what extent, FOA instruction can be a viable tool for children with ADHD.

The expected result from this study is that there will be a main effect of FOA on the dependent variable. Specifically, participants in the EXT FOA group will have a lower postural sway variability in the mediolateral direction compared to the INT FOA group. This prediction is driven from imaging evidence that shows children with ADHD have a compromised ventral attention network deficit and a frontostriatal dysfunction, which affects their ability to sustain focus on external stimuli and to reorient themselves towards behaviourally relevant external stimuli (Faraone et al., 2015; Cortese, 2012). This final study, Study 4, is theoretically complementary to Study 3 as it looks to examine the influence of FOA instruction now in children who have a known motor performance deficit, children with developmental coordination disorder. Previously noted, ADHD and developmental coordination disorder are closely linked, as they are often comorbid in children. There are, however, subtleties between these disorders which impact how these populations process and attend to environmental stimuli, thereby making it difficult to directly extend conclusions from research with neurotypical individuals and individuals with ADHD to this population. Therefore, it is important to further investigate how these respective differences in children with developmental coordination disorder mediate FOA instruction processing.

7.1 Developmental Coordination Disorder

Developmental coordination disorder (DCD) is a heterogenous neurodevelopmental disorder that affects 5-6 % of children, with approximately 2% of these children being severely impacted (i.e., functionally and/or mentally;

Lingam et al., 2009; Cairney & Dowling, 2016). Missiuna and colleagues (2017) explain that children with DCD typically have difficulties mastering motor skills (e.g., kicking a soccer ball to zipping a backpack) and are unable to perform age-appropriate academic, leisure, and self-care tasks even following adequate learning and practice opportunities. Specifically, children with DCD have a compromised motor coordination abilities that interfere with their ability to function at school, despite being intellectually at an average to above-average intelligence level; these children are often referred to as "clumsy" or "awkward", and they tend to avoid physical activity all together (Cairney et al., 2010). As a result, children with DCD can exhibit decreased strength and endurance over time (Raynor, 2001; Rivilis et al., 2011), along with being at increased risk of becoming overweight (Cairney et al., 2010).

Many different labels have been used to describe children with DCD, the most common ones including developmental dyspraxia, minimal brain dysfunction, sensory integrative dysfunction, perceptuomotor dysfunction, physically awkward, and specific developmental disorder of motor function (Missiuna & Polatajko, 1995). The lack of universality of a consistent label plagued DCD diagnostic criterion until 1994, where researchers and clinical experts made the decision to recognize all "clumsy" children as having *developmental coordination disorder* (DCD; Missiuna et al., 2017). The most recent understanding of the disorder is reflected by the DSM-5 (2013), that added four new criteria for a diagnosis of DCD, summarized as: Criterion A) The acquisition and execution of coordinated motor skills is below those expected given the child's age and opportunities for skill learning and use. Criterion B) The motor difficulties significantly impact age-appropriate performance of activities of daily living (i.e., self-care) and interfere with academic productivity, prevocational and vocational activities, leisure, and play. Criterion C) The onset is in the early developmental period. Criterion D) The motor coordination difficulties are not better explained by intellectual delay, visual impairment, or other neurological conditions that affect movement.

Given the heterogenous nature of DCD, it is difficult to fully depict all associated movement related symptoms. In general, individuals with DCD, when compared to typically developing controls, are slower and have longer reaction times, produce inconsistent and inaccurate motor performances (exacerbated by the complexity of movements), and struggle with postural control and balance (Astill & Utley, 2008; Johnston et al., 2002; Jucaite et al., 2003; Mackenzie et al., 2008; Mak, 2010; Rosengren et al., 2009; Williams, 2002; Missiuna et al., 2017). Children with DCD further have atypical muscular activation, along with irregular muscle sequencing during motor behaviours, where the coordination of multiple joints is particularly difficult (Johnston et al., 2002). Moreover, given the restricted set of movement capabilities, children with DCD struggle to adapt to environmental changes (Astill & Utley, 2006; Kagerer et al., 2004) and have difficulty transferring learned motor skills to novel situations (Bo & Lee, 2013).

7.2 The Etiology of DCD

The etiology of DCD is still relatively unknown (Visser, 2003; Zwicker et al., 2009). Given both the heterogenous and breadth of deficits involved (including postural and gait control, visual-spatial processing, timing and motor planning and execution), DCD research has struggled to identify a single causal explanation (Cairney & Dowling, 2016). The following will discuss some of the major etiological hypotheses for DCD provided over the years. First, *delayed maturation,* this hypothesis suggests DCD to reflect delayed maturation in children, that would eventually catch up to their age-matched peers if allotted enough time and sufficient experiences. However, this hypothesis has been widely disproven via numerous studies, including longitudinal studies (e.g., Losse et al., 1991; Rasmussen & Gillberg, 2000). Missiuna and colleagues (2017) further explain the gap in development between typically developing children and children with DCD to widen with age, particularly for individuals suffering with severe cases of DCD.

Second, *sensory-perceptual dysfunction* is a hypothesis driven by the information-processing framework during the 1980s and 1990s, which considered sensory/perceptual impairment(s) as the possible etiology for DCD. Certain studies from the time were able to illustrate visual, proprioceptive, kinesthetic and cross-modal perception/integration deficits (Wilson & McKenzie, 1998), where more recent work has extended these findings to examine more comprehensively visual difficulties in DCD, such as deficits visual-spatial processing and memory, and a dependency on vision during motor performance (Alloway, 2007; Biancotto et al., 2011; Wilson et al., 2013; Zoia et al., 2005; Rivard et al., 2017; Missiuna et al., 2017).

Third, *deficits in attention, motor control and perception:* previously discussed, the term DAMP recognizes the interplay between cortical structures involved in attention, motor, and perceptual functioning, influencing comorbidities (i.e., ADHD) that children with DCD may experience (Gillberg, 2003; Pereira et al., 2001).

Fourth, *automatization deficit hypothesis* proposes that children with DCD have a difficulty in making motor tasks automatic when the cognitive load increases (Tsai et al., 2009), where children with DCD must direct attentional resources to control the motor movements that are typically performed without conscious thought (Missiuna et al., 2017).

Fifth, *internal modelling deficit,* often referred to as "efference copy deficit", this hypothesis maintains that an internal model is crucial for predictive motor control and motor learning over time, enabling the individual to compare movement estimates with performance to make real-time adjustments (Wilson et al., 2013; Wilson et al., 2004). Children with DCD have consistently shown poor predictive control and an inability to adapt to varying environmental conditions (e.g., changes to vision), implying they lack the ability to update their internal models (Adams et al., 2014; Brookes et al., 2007; Cantin et al., 2007; Kagerer et al., 2006; Missuina et al., 2017).

7.3 Affected Brain Regions

With regard to the associated brain regions affected in individuals with DCD, Biotteau and colleagues (2016) highlight six: 1) The cerebellum, which has been a major target for imaging studies given its importance for movement, balance, coordination, learning, and automatization. Numerous studies (e.g., Zwicker et al., 2011, 2012; Debrabant et al., 2013, 2016) have shown lobule abnormalities in this area among subjects with DCD. 2) The basal ganglia are of interest as they play a primary role in movement initiation, planning, motor control, learning, and automatization. 3) The parietal lobe area is also abnormal in individuals with DCD, as Biotteau and colleagues (2016) explain that studies found differences in the intraparietal cortex (Querne et al., 2008; Kashiwagi et al., 2009; Zwicker et al., 2011, 2012), superior parietal cortex (Kashiwagi et al., 2009, Debrabant et al., 2016), posterior parietal cortex (Kashiwagi et al., 2009), postcentral gyrus (Kashiwagi et al., 2009; Zwicker et al., 2010; McLeod et al., 2014; Licari et al., 2015), supramarginal gyrus (Zwicker et al., 2010), temporoparietal junction (Debrabant et al., 2013), and parietal operculum cortex (McLeod et al., 2014). 4) The limbic lobe area has additionally shown abnormalities, as studies have illustrated differences in the anterior (Querne et al., 2008) and posterior cingulate cortex (Zwicker et al., 2010; Reynolds et al., 2015), the parahippocampal gyrus (Zwicker et al., 2010), the insular cortices and insula (Zwicker et al., 2010; McLeod et al., 2014), and the left amygdala (McLeod et al., 2014; Biotteau et al., 2016). 5) The frontal lobe, as Biotteau and colleagues (2016) cite the dorsolateral prefrontal cortex specifically as a neural correlate of interest for individuals with DCD (Debrabant et al., 2013). 6) The lingual gyrus, imaging studies depicted differences in this area (Zwicker et al., 2010, 2011; McLeod et al., 2014), where this brain region is associated with low-level visual processes (Dien, 2009; Jobard et al., 2003).

7.4 DCD & Balance Issues

Williams & Ho (2004) highlight poor balance/postural control as being a key feature for the diagnosis of DCD, where researchers have argued deficits in postural control as the underlying factor behind the "pervasive" and "diverse incoordination" characterizing the disorder (Williams & Castro, 1997; Williams & Woollacott, 1997). Postural sway patterns of children with DCD substantiate that the integrity of the postural control system may be compromised, where studies (e.g., Wann et al., 1998) illustrate children with DCD having significantly higher sway measures compared to typically developing controls. However, evidence from Williams & Woollacott (1997) examining postural synergies in children with DCD during a postural perturbance task, where subjects stood with eyes open on a force platform that moved to perturb balance in either a forward or a backward direction, showed that children with DCD struggled to sufficiently accommodate for the perturbance. These findings suggest that both inconsistent timing and sequencing of muscle activity to be major factors in the balance and control problems of children with DCD (Williams & Woollacott, 1997).

7.5 DCD & FOA

Studies examining the effects of FOA instruction in children with DCD are limited (Li et al., 2019; Jarus et al., 2015). In a study by Jarus and colleagues (2015) that investigated the influence of FOA instruction on children with DCD and typically developing children during a computer tracking joystick task, results showed non-significant findings for the typically developing children, and no significant differences for the children with DCD. Li and colleagues (2019), however, note a few limitations to the study. One being that the tracking task relied heavily on visual information, which can skew in favour of an EXT FOA, and another being the relatively small sample size, where only 5 typical children and 7 children with children with DCD were assessed. As such, Li and colleagues (2019) examined FOA effects in children with DCD and typically developing children during a dual a pole-holding task and postural stability task and showed better results for both tasks for the EXT FOA in the typically developing children and the children with DCD compared to their respective INT FOA and CTRL groups. Further research, however, is needed to better understand the interaction between FOA instruction and children with DCD.

7.6 Purpose

Study 4 examines the influence of FOA instruction in children with DCD performing a postural control task. Given the close linkage between ADHD and DCD (e.g., DAMP), it is also theoretically important to further investigate the influence of FOA instruction in this population. While DCD can be characterized as predominately a motor disorder, individuals with DCD are additionally thought to have both self-regulatory and attentional control deficits (Missiuna et al., 2017). The motor learning benefits suggested by the FOA literature require further investigation in a population that struggles with motor learning and control (i.e., individuals with DCD) in order to advance claims. Moreover, research that has investigated the influence of FOA instruction in children with DCD is limited. By further investigating the influence of FOA instruction in this population, it will provide additional insights on whether or not FOA instruction can be an efficacious tool in supporting children with DCD. Thus, the aim of Study 4 is to examine the influence of FOA instruction in children (4-10 years of age) with DCD performing a postural control task.

The main hypothesis for Study 4 is that there will be a main effect of FOA condition on postural control performance. Particularly children in the INT FOA group will have a lower postural sway compared to the children in the EXT FOA condition. This result will also be reflected throughout acquisition and perturbation tests, where participants in the INT FOA condition will outperform participants in the EXT FOA and will better accommodate to the postural perturbances. The rationale behind this hypothesis is associated with evidence that suggests individuals with DCD struggle predominately with the internal aspects of attentional processing during motor performance. This processing deficit is comparable to the limitations that children under the age of 7 years have in Study 1 with regard to the development of their internal model. This, however, then contrasts the expected results from Study 3. While Study 3 expects participants in the EXT FOA to benefit more during postural control performance, Study 4 hypothesizes the opposite which is then consistent with Beilock and colleagues' de-automization of skill hypothesis.

7.7 Impact

The potential knowledge gained through analyzing the influence of FOA instruction in children with DCD will help extend the understanding surrounding the direct influence that the different types of FOA instruction have on motor learning and control. Moreover, the potential results from this study pertaining to the validity and practicality of using FOA instruction in children with DCD, may help to inform future teaching and rehabilitative practices for this population.

8.0 METHOD

8.1 Participants

Sample size was determined by an a priori power calculation based on our smallest comparison of interest. For the purpose of this thesis, powering for the sample of Study 3 is based on an interaction of FOA group and type of test. Using an α of 0.05, a power (1 - b) of 80%, a Cohen's f of 0.25, for 2 groups, on 4 measures and with a correlation among repeated measures of 0.5, a sample of 82 participants was calculated. These specific parameters result in 41 participants per group. Given the limitations imposed on participant recruitment as a result of the inclusion criteria (i.e., children with DCD and a narrow age range) and the COVID-19 restrictions, the study may necessitate a smaller sample size. A smaller sample size would be consistent with literature and all appropriate cautions pertaining to the interpretation of data collected on a smaller sample than statistically recommended will be observed.

Participants will be recruited from the Literacy and Mathematics Academy private school in Stoney Creek, Ontario, where participants will be randomized into one of two conditions (INT FOA and EXT FOA). All participants must be between the ages of 4-10, present no other self-reported neurological disorders than DCD, have normal or corrected-to-normal vision, be able to pass the online provincial COVID-19 screening tool (www.covid-19.ontario.ca/self-assessment/), not be students that primary investigator tutors at the academy, and not be a high-risk individual for COVID-19. The latter includes those with a weakened immune systems, lung disease, heart disease, hypertension (high blood pressure), diabetes, obesity, kidney disease, liver disease, dementia, and stroke. Other than these characteristics, no other criteria will be enforced on participant recruitment. These inclusion/exclusion criteria are based on previous studies utilizing similar tasks, and or a similar population (see Yeh et al., 2016; Olivier et al., 2008; Petranek et al., 2019; Palmer et al., 2017). At the start of the study, all children must provide verbal consent, and their parent/guardians must provide written informed consent. All parking and transportation costs will be covered, and participants will be remunerated with a 10$ Tim Horton's gift card for participating in the study.

8.2 FOA Instructions

Participants in the INT FOA group will be given the instructions: "focus on maintaining your weight evenly distributed on both legs throughout the trial", where participants in the EXT FOA group will be told to: "focus on keeping the cross in the target square throughout the trial." To minimize the advantage of an increased feedback frequency on performance (see Goh et al., 2012), participants will only be reminded of their feedback condition if needed. Note that attention for this study is operationally defined as a process that helps the individual select which stimuli are important and should influence an ensuing response, as well as a process of sustained concentration (Wells & Mathews, 2015).

8.3 Protocol

The protocol for this study will be identical to that in Study 3.

8.4 Data processing

8.4.1 Force Platform processing

COP data from the AP and ML axes will be recorded from the force platform. The stability of postural control will be determined by the standard deviation (SD; COP position variability) from the mean COP position in both directions. The first 10 secs of data will not be used for all three groups because the fixed target position for the EXT FOA group will be determined by calculating the mean position from the first 10 secs of COP data. Only the last 40 secs of data will be analyzed for each trial at a 40 Hz sampling frequency.

8.5 Statistical Analysis

8.5.1 Independent & Dependent Variables

There are three independent variables for this study: FOA group (INT & EXT), types of tests and the number of trials across both the acquisition and perturbation phases of the study. There are two dependent variables that will be collected: mean standard deviation (SD) of the mediolateral COP in millimetres (mm), and mean SD of the anteroposterior COP in mm.

8.5.2 Analysis

There will be two separate analyses conducted for each dependent variable. The first analysis will consider only the acquisition phase of the study and will consist of a mixed analysis of variance (ANOVA) on the two attentional conditions (INT & CTRL) and 12 trial blocks with repeated measures on the last factor. The second analysis will be a mixed ANOVA on the two attentional conditions, four types of test and the two trial blocks within each test condition with repeated measures on the latter two factors. This analysis will compare the last two trials of acquisition to the two trial blocks within each of the three perturbation tests. For both analyses, alpha will be set at 0.05, Greenhouse-Geisser corrections will be employed for sphericity violations (Mauchly's test, $p < .05$) and Bonferroni post hoc analysis will be used to examine main effects and interactions. Cohen's d will be calculated to report effect sizes. All these tests will be run using RStudio (macOS version 4.0.5).

8.6 Expected Results

For Study 4, it is hypothesized that there will be a main effect of FOA condition on postural control performance. The expected result for this study is that the children in the INT FOA group will have a lower mediolateral postural sway compared to the children in the EXT FOA group. This result will additionally be seen throughout the acquisition and perturbation tests. Participants in the INT FOA condition will therefore recover quicker (i.e., lower postural sway) to the various postural perturbances in comparison to the EXT FOA. This result is predicted from evidence suggesting individuals with DCD have a dysfunction in internal modelling. DCD can be theorized as an internal attentional processing deficit; this is driven by the automatization deficit hypothesis and the internal model deficit hypothesis. The automatization deficit hypothesis suggests that children with DCD have a difficulty in making motor tasks automatic when cognitive load increases (Tsai et al., 2009). Whereas the internal model deficit hypothesis implies that children with DCD have poor predictive control and an inability to adapt to varying environmental conditions (e.g., changes to vision), inferring they lack the ability to update their internal models (Adams et al., 2014; Brookes et al., 2007; Cantin et al., 2007; Kagerer et al., 2006). This parallels the significant brain abnormalities in children with DCD as evidence through brain imaging research. Notably, abnormalities in the cerebellum, the basal ganglia, and the frontal lobe (Biotteau et al., 2016; Querne et al., 2008; Zwicker et al., 2012), which can be evidenced behaviourally through inconsistent timing and sequencing of muscle activity (i.e., efferent copy dysfunctions; Williams & Woollacott, 1997). Therefore, it is quite plausible that participants in the INT FOA condition will benefit more from the internal nature of the instruction as it will help to address issues in automaticity and will supplement their efferent copies. This result would coincide with Beilock and colleagues' deautomization of skill hypothesis.

CHAPTER FIVE: CONCLUSION

9.0 CONCLUSION

9.1 General Discussion

The influence of FOA instruction on postural control has seen an increased interest among researchers within the last decade (Yeh et al., 2016; McNevin et al., 2013). The motor learning literature examining the effects of FOA instruction on motor skill learning and performance has produced robust findings that suggest that participants who receive an EXT FOA instructional set demonstrate superior results in performance and learning of a motor skill in comparison to participants who are given an INT FOA (e.g., Wulf, 2013). Wulf and colleagues explain the benefits of EXT FOA instruction using the constrained action hypothesis which suggests that an EXT FOA enhances the efficiency of motor programming by strengthening the relationship between movement planning and outcome. This then leads to greater levels of automaticity, which are suggested to be necessary for fluid and precise movements. Conversely, proponents of this position hold that when an individual is provided with INT FOA instructions, the organization of motor programming becomes interrupted due to the interference of conscious thought processes which serve to negatively mediate the developing automaticity required for learning a movement (e.g., Wulf et al., 2001). Although Wulf and colleagues have repeatedly provided evidence for the constrained action hypothesis, an increasing number of researchers have been unsuccessful in revealing similar results or with replicating their findings (e.g., Lawrence et al., 2011; Perkins-Ceccato et al., 2003). For example, Beilock and colleagues (2002) were not able to reproduce results to suggest that an EXT FOA yields superior performance and learning benefits when assessing dribbling performance between novice and experts. Rather, their results depicted instances where adopting an INT FOA may be more beneficial. Beilock and colleagues interpreted their results, showing that INT FOA instruction may be superior to EXT FOA instruction in certain circumstances, through the deautomization of skill hypothesis. This hypothesis suggests that when control is not yet automatic (e.g., a novice learner or an expert using their non-dominant foot in a soccer dribbling task), an INT FOA can drive the learner to develop an overall superior understanding of the intrinsic nature of the motor skill which in turn facilitates the development of automaticity for that skill. This hypothesis has been expanded to suggest that an INT FOA may be more beneficial for a learner when the individual is at a novice level, the task is novel and/or if the task is complex (Becker & Smith, 2013; Agar et al., 2016).

Although FOA studies are now fairly abundant in the motor learning literature, it is often criticized for being exclusively researched in adult populations. As such, there is a substantial information gap regarding FOA effects in children (Agar et al., 2016; Petranek et al., 2019; Emmanuel et al., 2008; Perreault, 2013). This paucity of research in this age range is problematic as extending findings directly from adult populations to children can be both theoretically and practically problematic given the numerous differences between these populations, such as differences in general motor skill expertise level, differences information-processing, memory encoding strategies, emotional regulation, and attentional capacities (Agar et al., 2016; Perreault, 2013). When considering research that examines the effects of FOA instruction on postural control performance among children, the research is particularly limited. This presents an additional problem given all of the transitional cognitive and growth changes that occur during childhood. Moreover, the lack of replicability of traditional FOA studies and an increasing reporting of non-significant findings raises questions surrounding the validity and reliability of FOA instruction in general.

This research proposal explores these limitations. Study 1 explores the effect of FOA instruction on postural control performance in children. This study compares the different types of FOA instruction in order to determine which will be more beneficial in yielding greater performance and learning results for postural sway and ankle-strategy muscular activation, specifically under the constraints of a traditional FOA study design. There are three main expected results of interest for Study 1. First, Study 1 is expected to reveal minimal to no effects of FOA condition on the dependent variables. This prediction is driven by the limitations children have with regard to comprehension level and attentional processing, which will constraint their understanding and instructional-recall for the task. Second, this study will reveal a main effect of age on the dependent variables, where the group of older children will have an overall lower postural sway and muscular activation level in comparison to the group of younger children. This will be a result of the natural growth and biomechanical factors that occur during the transitional stages throughout childhood. Last, this study will reveal an interaction of FOA condition and age, where the children in the younger group, specifically in the INT FOA condition, will exhibit a lower postural sway (in the mediolateral direction) and lower muscular activation when compared to their age-matched EXT FOA and CTRL conditions. This result will occur due the participants in the INT FOA condition being provided with internal information, which will coincide with the development of their internal model of self-orientation. The children in the older group, however, will not differ in performance as the group of older children will have already made the switch to mature postural control strategies, and therefore this transition will mitigate a great deal of instability and or error during performance that the group of younger children will struggle with, and will not require the older children to access their FOA instructional sets on the level of working memory. The main takeaway from this study is the expected interaction of FOA and age. If the expected result of greater performance on the dependent variables of interest for the INT FOA group in the younger condition is found, it will support Beilock and colleagues deautomization of skill hypothesis and will directly challenge Wulf and colleagues constrained action hypothesis.

As noted earlier, important questions still remain following Study 1. Particularly, those surrounding the experimental instruction design and the logic behind the assumption that FOA states are dichotomous. Study 2 aims to address these questions by assessing the reliability and validity of FOA instruction usage with children via the implementation of experimental manipulation checks. The first manipulation check is a vision non-vision paradigm that is embedded in the trial (modelled after Yeh et al., 2016). This serves to evaluate participants' adherence to their respective FOA instructions. The second manipulation check is a retrospective verbal report, which functions as tool to assess what participants are focusing on during their trials. Study 2 has four main expected results of interests. First, there will be a main treatment effect of visual condition, where participants will exhibit a higher sway variability in the non-vision phase compared to the visual phase. This prediction is formed based on Ross (1978) who show that children still lack the ability to maturely and efficiently (i.e., relative to an adult level) selectively attend to relevant stimuli during motor skill performance. Therefore, the children are susceptible to be distracted by the sudden visual feedback switch during the trial, leading to decrements in postural sway performance. Second, Study 2 will show a significant interaction of FOA and visual condition on postural control performance. The participants in the EXT FOA condition will show a significant increase in postural sway when the visual feedback is removed, compared to the participants in the INT and CTRL conditions. This is a result of the participants being explicitly directed to focus and rely on the external visual feedback during the trial. Third, there will be a significant interaction of FOA group, age and visual condition. Specifically, the older group of children in the EXT FOA condition will show a significant increase in postural sway when in the non-vision phase of the trial in comparison to their age-matched peers in the other conditions. The group of younger children will exhibit a significant increase in postural sway regardless of their attentional condition when in the non-visual portion of the trail. This prediction is driven once again by evidence suggesting that children under the age of 7 years struggle with re-weighting multiple sensory inputs and are vulnerable to being distracted by innocuous sensory information, whereas children 7 years and older will be able to handle the level of error and distractibility derived from the erroneous sensory inputs better than their younger counterparts. Last, the verbal manipulation check will reveal that the participants will have used a combination of an INT and EXT FOA, regardless of their respective attentional focus condition, throughout acquisition and perturbation tests. This prediction is motivated by the indication that the group of older children will switch their attentional focus to meet the specific task demands, while for the group of younger children, the task may be too complex, and thus they will struggle to adhere to their given FOA instruction. Both the verbal and visual manipulation checks will provide a better understanding on how well the experimental instructions worked, along with challenging the supposed dichotomous nature of FOA instruction types.

Study 3 serves as theoretical progression to the preceding studies. Although Study 2 provides better insight on FOA instruction adherence in children and their interpretation to their respective conditions, the direct relation between FOA and specific attentional mechanism remains unclear. To address this issue, Study 3 examines FOA instruction in a population with a known attentional deficit. The aim of this study is to evaluate the degree to which compromised abilities in the selection and focus of attention meditates FOA instructional sets. In addition, the results of this study may offer some applied insight as to whether FOA instruction can be an effective support for non-neurotypical individuals who struggle with attentional control. Thus, Study 3 investigates the influence of FOA instruction in children with ADHD. The main expected result for this study is that there will be a main effect for FOA condition on the dependent variable. The participants who are in the EXT FOA condition will have a lower postural sway variability in the mediolateral direction compared to the INT FOA group. This prediction is driven from imaging evidence that show children with ADHD to have a compromised ventral attention network deficit and a frontostriatal dysfunction which affects their ability to reorient themselves towards behaviourally relevant external stimuli and sustain focus on external stimuli (Faraone et al., 2015; Cortese, 2012). One can infer from this then that children with ADHD struggle with the external aspects of attentional processing. If the assumption that EXT FOA instruction is able to adequately create an external mental focus state, then children with ADHD should benefit from this type of FOA instruction. This would therefore reflect Wulf and colleagues constrained action hypothesis for this group.

The final study, Study 4, is theoretically complementary to Study 3 as it looks to examine the influence of FOA instruction in children who have a known motor performance deficit, specifically children with DCD. ADHD and DCD are believed to be closely linked, as they are often comorbid in children (Brossard-Racine et al. 2012; Pitcher et al. 2003; Kadesjö & Gillberg, 1999; James et al., 2021). It is, however, inappropriate to extend findings from typical and ADHD populations to children with DCD given the subtleties in how these individuals process and attend to environmental stimuli. Therefore, as an additional step, it is also imperative to further investigate how these respective differences in children with DCD mediate FOA instruction processing. Thus, the aim of Study 4 is to examine how FOA instruction influences postural control performance in children with DCD. The expected result for this study is that there will be a main effect of FOA condition on postural control performance, where the children in the INT FOA group will have a lower mediolateral postural sway compared to the children in the EXT FOA group. This prediction is made as a result of the theoretical evidence suggesting individuals with DCD have a dysfunction in internal modelling and automaticity, and thus struggle with internal components of attention, which contrasts the ADHD population. If the assumption that an INT FOA condition can adequately create an internal mental focus state, then children with DCD should benefit when provided information that is framed internally, similar to what is expected with the group of younger children in Study 1. If this expected result is found during testing, this would then provide further evidence for Beilock and colleagues deautomization of skill hypothesis.

9.2 Limitations

While this proposal has the potential to provide the motor learning community with important insights that extend the FOA literature, it is also important to consider the experimental and theoretical limitations that this proposal may have. A potential limitation for this proposal may be the lack of consideration for differences in skill level across the age groups in each study. Participants who are at a more advanced skill level, such as individuals who have a longer history playing sports (e.g., a participant who has been training gymnastics for a couple of years), will have an additive performance advantage with the postural control task. Similarly, a limitation surrounds the age split used in Study 1 and Study 2. Although there has been considerable evidence suggesting 7 years of age to be when children make the switch to more mature postural control patterns, throughout childhood and adolescence children vary considerably with regard to their maturational timing (Williams & Ho, 2004). This affects their size, strength, cognitive capacities, and coordination. Therefore, a split in maturational stage may be more appropriate when studying this population. With regard to Study 2, there are also concerns surrounding the validity of the retrospective verbal report. In general, qualitative assessments are limited by human emotions and perspectives of both the researchers and participants, which cause biases that can confound these data (Leung, 2015). Given the age of the participants and the nature of them being in an unfamiliar environment (i.e., the laboratory), participants may be susceptible with providing more socially desirable answers, rather than be truthful and risk a level of self-embarrassment or unfavorable reactions from the examiners and or accompanying guardians. Thus, it is crucial for the researchers to communicate to the participants that there are no right or wrong answers and that their answers do not directly impact how they are socially perceived, but rather help the researchers find out how to improve instructions for working with children around their age. There is, however, still the issue of the researchers' biases when it comes to interpreting and coding participants' responses. A potential way to mitigate some of this bias is by keeping one of the examiners who are coding the retrospective verbal responses naïve to the overall purpose of the experiment. Moreover, there is a limitation surrounding the nature of the types of FOA feedback provided to participants. One can infer that the FOA feedback among conditions cannot be directly comparable; the INT FOA condition is directed to focus on the internal nature of their movements, meanwhile, the EXT FOA condition is provided with supplementary augmented feedback from a visual stimulus. The comparison can then be thought of as a difference in somatosensory informational feedback (INT condition) vs. visual informational feedback (EXT condition) and can be confounded by external factors such as the quality of the respective feedback (e.g., screen latency time for the visual feedback). It is suggested that FOA feedback should focus on similar components of a skill and should only vary slightly with regard to the phraseology of where to direct attention for the task (see Wulf, 2013), yet there is also a fine line with making these instructions distinguishable enough (Davids, 2007). Lastly, with regard to Study 3, a potential limitation is a lack of control for the different subtypes of ADHD. ADHD can be further broken down into three subtypes that each affect attentional processing differently: ADHD primarily inattentive, ADHD primarily hyperactive and a combination of ADHD inattentive and hyperactive. The brain regions and mechanisms that distinguish these behavioural subtypes, are seldom parsed out within the literature.

9.3 Future Directions

Future research is still required to better understand the influence of FOA instruction in children. Future research should control for participants' level of expertise, along with comparing performance across maturational stages and motor capabilities opposed to chronological age. With respect to the manipulation checks, future FOA research should continue to use these tools in order to better gauge the efficacy of the experimental instructions and participants' interpretations of these instructions. An extension for Studies 3 and 4 should be the implementation of manipulation checks to better understand how these populations interpret FOA instruction, as their respective differences in information processing, sustained attention and motor learning differ immensely from typically developing children. Moreover, future research should look to utilize a more direct comparison between FOA instructions, where the feedback is provided in a more similar way but is still distinguishable. This will help to mitigate task confounds such as differences in the quality of feedback being provided. Lastly, future attentional focus research studying the effects of FOA in children with ADHD should further divide participants into their respective behavioural subtypes, in order to better understand how these subtypes, mediate the effects of FOA instruction.

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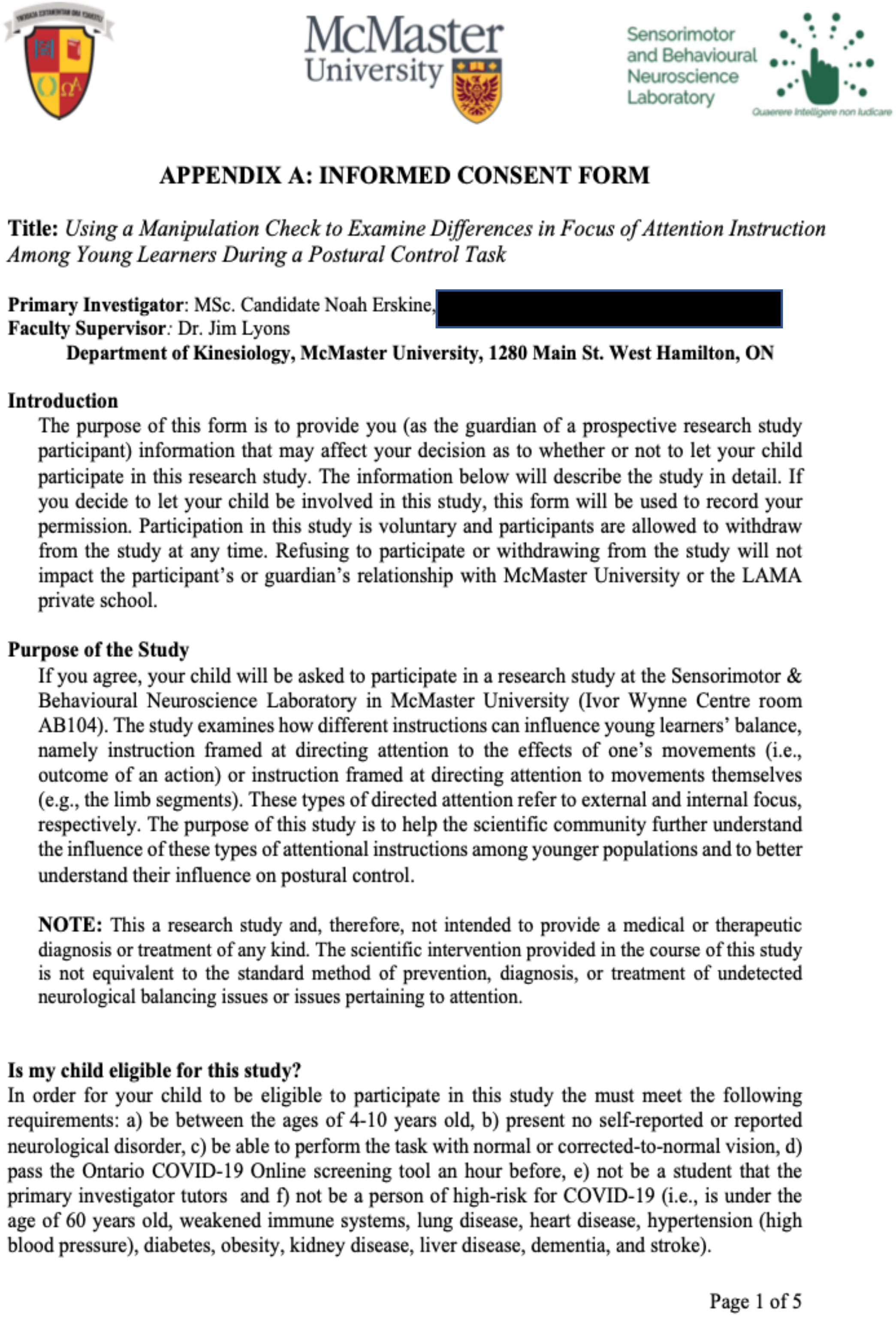
APPENDIX A: INFORMED CONSENT FORM



APPENDIX A: INFORMED CONSENT FORM

Title: *Using a Manipulation Check to Examine Differences in Focus of Attention Instruction Among Young Learners During a Postural Control Task*

Primary Investigator: MSc. Candidate Noah Erskine, [redacted]
Faculty Supervisor: Dr. Jim Lyons
Department of Kinesiology, McMaster University, 1280 Main St. West Hamilton, ON

Introduction

The purpose of this form is to provide you (as the guardian of a prospective research study participant) information that may affect your decision as to whether or not to let your child participate in this research study. The information below will describe the study in detail. If you decide to let your child be involved in this study, this form will be used to record your permission. Participation in this study is voluntary and participants are allowed to withdraw from the study at any time. Refusing to participate or withdrawing from the study will not impact the participant's or guardian's relationship with McMaster University or the LAMA private school.

Purpose of the Study

If you agree, your child will be asked to participate in a research study at the Sensorimotor & Behavioural Neuroscience Laboratory in McMaster University (Ivor Wynne Centre room AB104). The study examines how different instructions can influence young learners' balance, namely instruction framed at directing attention to the effects of one's movements (i.e., outcome of an action) or instruction framed at directing attention to movements themselves (e.g., the limb segments). These types of directed attention refer to external and internal focus, respectively. The purpose of this study is to help the scientific community further understand the influence of these types of attentional instructions among younger populations and to better understand their influence on postural control.

NOTE: This a research study and, therefore, not intended to provide a medical or therapeutic diagnosis or treatment of any kind. The scientific intervention provided in the course of this study is not equivalent to the standard method of prevention, diagnosis, or treatment of undetected neurological balancing issues or issues pertaining to attention.

Is my child eligible for this study?

In order for your child to be eligible to participate in this study the must meet the following requirements: a) be between the ages of 4-10 years old, b) present no self-reported or reported neurological disorder, c) be able to perform the task with normal or corrected-to-normal vision, d) pass the Ontario COVID-19 Online screening tool an hour before, e) not be a student that the primary investigator tutors and f) not be a person of high-risk for COVID-19 (i.e., is under the age of 60 years old, weakened immune systems, lung disease, heart disease, hypertension (high blood pressure), diabetes, obesity, kidney disease, liver disease, dementia, and stroke).

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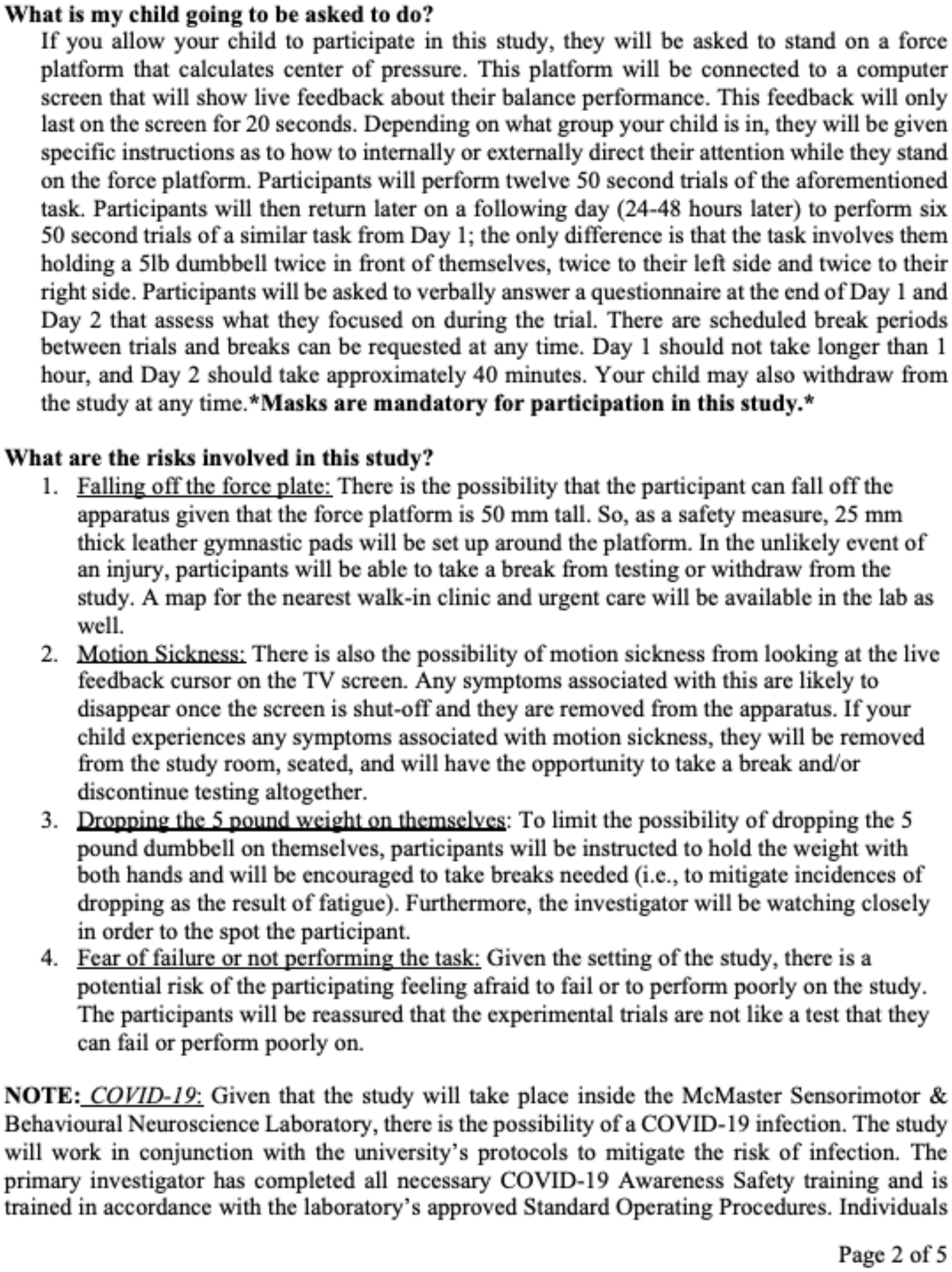


What is my child going to be asked to do?

If you allow your child to participate in this study, they will be asked to stand on a force platform that calculates center of pressure. This platform will be connected to a computer screen that will show live feedback about their balance performance. This feedback will only last on the screen for 20 seconds. Depending on what group your child is in, they will be given specific instructions as to how to internally or externally direct their attention while they stand on the force platform. Participants will perform twelve 50 second trials of the aforementioned task. Participants will then return later on a following day (24-48 hours later) to perform six 50 second trials of a similar task from Day 1; the only difference is that the task involves them holding a 5lb dumbbell twice in front of themselves, twice to their left side and twice to their right side. Participants will be asked to verbally answer a questionnaire at the end of Day 1 and Day 2 that assess what they focused on during the trial. There are scheduled break periods between trials and breaks can be requested at any time. Day 1 should not take longer than 1 hour, and Day 2 should take approximately 40 minutes. Your child may also withdraw from the study at any time.***Masks are mandatory for participation in this study.***

What are the risks involved in this study?

1. Falling off the force plate: There is the possibility that the participant can fall off the apparatus given that the force platform is 50 mm tall. So, as a safety measure, 25 mm thick leather gymnastic pads will be set up around the platform. In the unlikely event of an injury, participants will be able to take a break from testing or withdraw from the study. A map for the nearest walk-in clinic and urgent care will be available in the lab as well.
2. Motion Sickness: There is also the possibility of motion sickness from looking at the live feedback cursor on the TV screen. Any symptoms associated with this are likely to disappear once the screen is shut-off and they are removed from the apparatus. If your child experiences any symptoms associated with motion sickness, they will be removed from the study room, seated, and will have the opportunity to take a break and/or discontinue testing altogether.
3. Dropping the 5 pound weight on themselves: To limit the possibility of dropping the 5 pound dumbbell on themselves, participants will be instructed to hold the weight with both hands and will be encouraged to take breaks needed (i.e., to mitigate incidences of dropping as the result of fatigue). Furthermore, the investigator will be watching closely in order to the spot the participant.
4. Fear of failure or not performing the task: Given the setting of the study, there is a potential risk of the participating feeling afraid to fail or to perform poorly on the study. The participants will be reassured that the experimental trials are not like a test that they can fail or perform poorly on.

NOTE: *COVID-19*: Given that the study will take place inside the McMaster Sensorimotor & Behavioural Neuroscience Laboratory, there is the possibility of a COVID-19 infection. The study will work in conjunction with the university's protocols to mitigate the risk of infection. The primary investigator has completed all necessary COVID-19 Awareness Safety training and is trained in accordance with the laboratory's approved Standard Operating Procedures. Individuals who fail the COVID-19 screening tool will be denied access into the university, this includes all research personnel. There will be a specific route to access the laboratory and all of the laboratory equipment used for this study will be sanitized before and after all experimental sessions. There will also be a sanitize-station set up at the entry of the room where the experiment takes place. Participants, legal guardians and the investigator will be asked to thoroughly wash their hands before entering the room and upon leaving the room. Along with this, there will be signs depicting proper hand sanitizing techniques to act as a prompt and to educate participants on healthy hand washing techniques. Masks will be mandatory for the investigator, accompanying parents/guardians and participants. Participants under the age of 5 must wear masks with the supervision of their parent/guardian. There will be extra personal protective equipment (i.e., masks and gloves) that will be offered if needed. Only 3 individuals are allowed in the Sensorimotor and Behavioural Neuroscience Laboratory at a time, so the participant is allowed to be accompanied by 1 parent/guardian. Moreover, the investigator, Noah Erskine, is also a tutor at the LAMA, so he is already a part of the school's social bubble and will be the only researcher in the lab. The investigator will remain 2 meters apart from the participant and parent/guardians throughout the process.

In the case of infection, testing for the study will be stopped immediately and indefinitely, and all parents/guardians from the study will be contacted directly

What are the possible benefits of this study?

Your child will receive no direct benefit from participating in this study. However, the potential insights from this study will help further the scientific community's understanding of attentional instruction among younger populations and its influence on postural control. Knowledge from this type of research can be transferable to fields such as rehabilitation, motor development and developmental psychology.

Does my child have to participate?

Your child's participation in this study is voluntary. Your child may decline to participate or withdraw from participation at any time. Withdrawal or refusing to participate will not affect their relationship with McMaster University, the McMaster Sensorimotor & Behavioural Neuroscience Lab, and the Literacy & Mathematics Academy School in anyway. You can agree to allow your child to be in the study now and change your mind later without any penalty. If your child decides to withdraw from the study, any collected data will be destroyed unless otherwise indicated by the parent or guardian.

What if my child does not want to participate?

In addition to your permission, your child must agree to participate in the study. If your child does not want to participate, they will not be included in the study and there will be no penalty. If your child initially agrees to be in the study, they can change their mind later without any penalty.

Will there be any compensation?

Participants will be awarded a $10 Tim Horton's gift card for participating in the study. Participants will still be compensated in the event they withdraw while performing the experiment.

How will your child's privacy and confidentiality be protected if they participate in this research study?

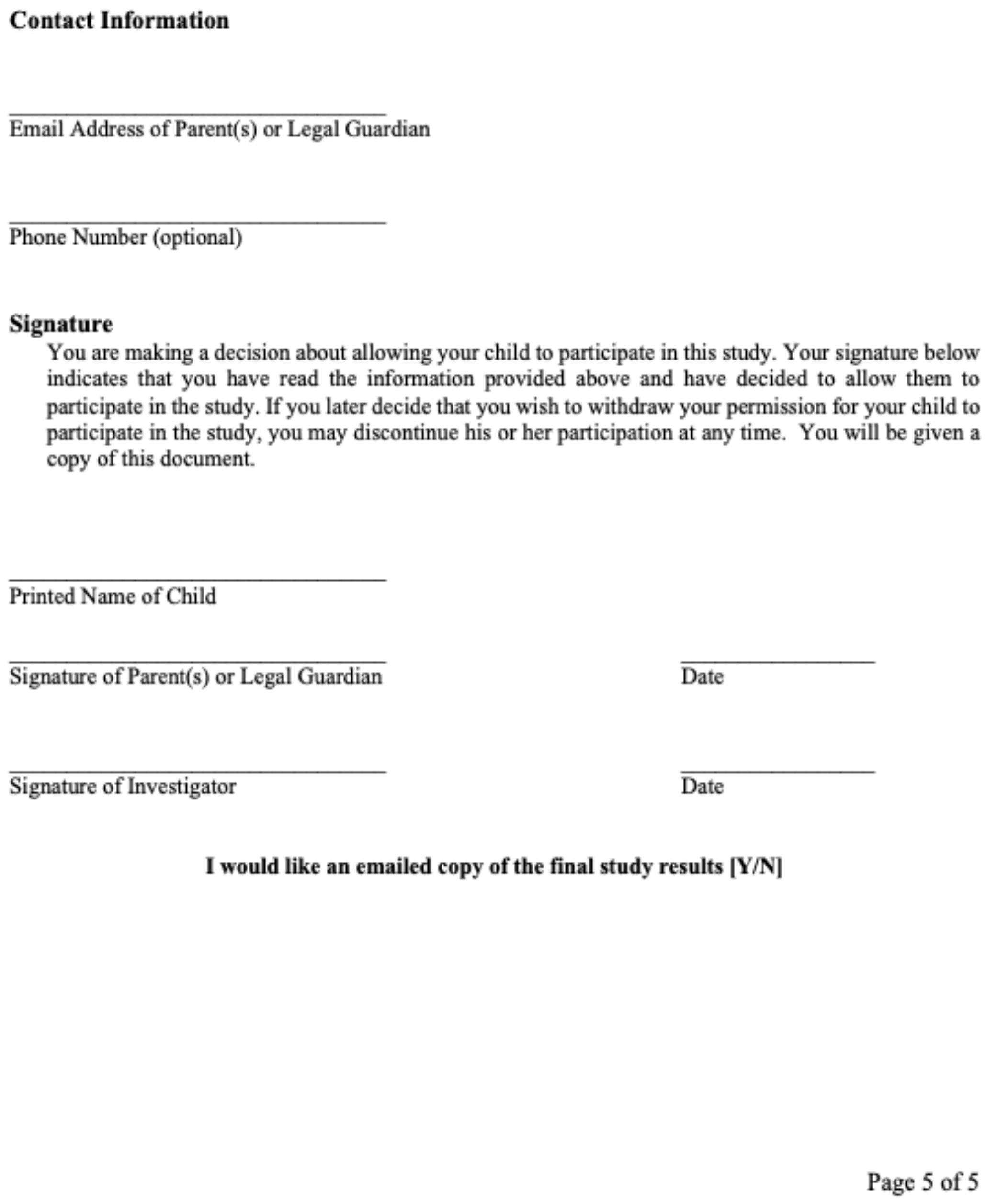
Your child's privacy and the confidentiality of their data will be protected. The data collected in these studies (center of pressure measurements and questionnaire responses) will be stored under numerical indicators and no attempts will be made to associate your child's name with the indicators. The collected center of pressure data are numerical sequences from which personal identification cannot be made. All electronic information will be initially saved on a password protected file in the Sensorimotor & Behavioural Neuroscience lab at McMaster University. Any back-up files containing study related information will be saved on hardware and stored in a locked desk that only the lead investigator has access to. All paper information will be stored in a locked desk in a lab space that only the lab team members have access to. Only the investigator will have access to the personal information provided by the participants. Only group means and standard deviations will be released as findings. In conjunction with the tri-council policy on data archiving, the data collected from this research study will be securely stored and maintained until 2030 at which point it will be electronically deleted and all written records destroyed.

Whom to contact with questions about the study?

Prior to, during, or after your participation you can contact the researcher Noah Erskine, H.BSc, MSc. (Candidate) at [redacted] or send an email to [redacted] for any questions.

This study has been reviewed and approved by The McMaster Research Ethics Board and the study number is [redacted]

If you have concerns or questions about your rights as a participant or about the way the study is conducted, please contact:
McMaster Research Ethics Secretariat
Telephone: (905) 525-9140 ext. 23142
E-mail: ethicsoffice@mcmaster.ca



Contact Information

____
Email Address of Parent(s) or Legal Guardian

____
Phone Number (optional)

Signature

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your permission for your child to participate in the study, you may discontinue his or her participation at any time. You will be given a copy of this document.

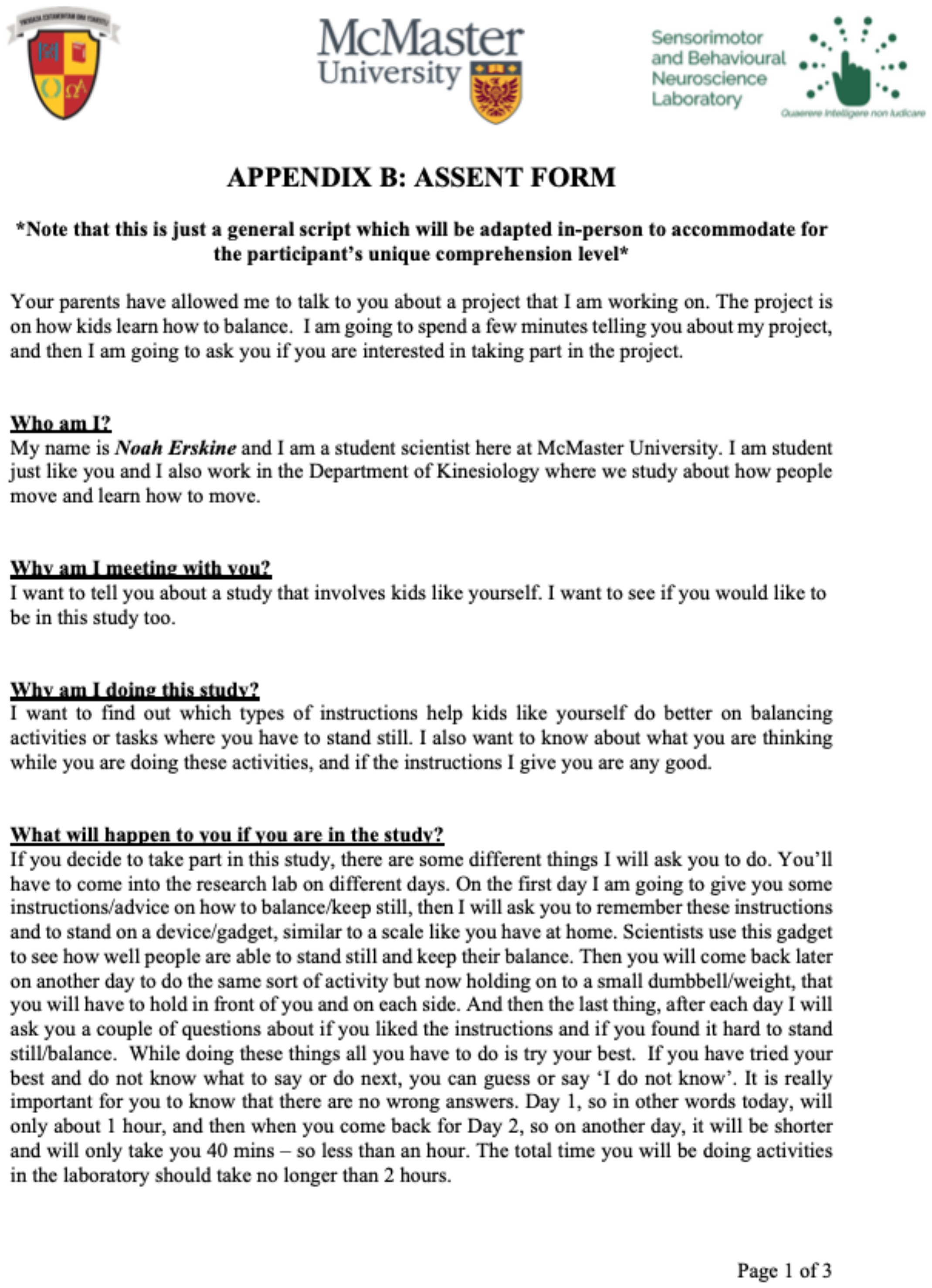
____
Printed Name of Child

________________________________ ________________
Signature of Parent(s) or Legal Guardian Date

________________________________ ________________
Signature of Investigator Date

I would like an emailed copy of the final study results [Y/N]

APPENDIX B: ASSENT FORM



McMaster University

Sensorimotor and Behavioural Neuroscience Laboratory

Quaerere intelligere non iudicare

APPENDIX B: ASSENT FORM

Note that this is just a general script which will be adapted in-person to accommodate for the participant's unique comprehension level

Your parents have allowed me to talk to you about a project that I am working on. The project is on how kids learn how to balance. I am going to spend a few minutes telling you about my project, and then I am going to ask you if you are interested in taking part in the project.

Who am I?

My name is ***Noah Erskine*** and I am a student scientist here at McMaster University. I am student just like you and I also work in the Department of Kinesiology where we study about how people move and learn how to move.

Why am I meeting with you?

I want to tell you about a study that involves kids like yourself. I want to see if you would like to be in this study too.

Why am I doing this study?

I want to find out which types of instructions help kids like yourself do better on balancing activities or tasks where you have to stand still. I also want to know about what you are thinking while you are doing these activities, and if the instructions I give you are any good.

What will happen to you if you are in the study?

If you decide to take part in this study, there are some different things I will ask you to do. You'll have to come into the research lab on different days. On the first day I am going to give you some instructions/advice on how to balance/keep still, then I will ask you to remember these instructions and to stand on a device/gadget, similar to a scale like you have at home. Scientists use this gadget to see how well people are able to stand still and keep their balance. Then you will come back later on another day to do the same sort of activity but now holding on to a small dumbbell/weight, that you will have to hold in front of you and on each side. And then the last thing, after each day I will ask you a couple of questions about if you liked the instructions and if you found it hard to stand still/balance. While doing these things all you have to do is try your best. If you have tried your best and do not know what to say or do next, you can guess or say 'I do not know'. It is really important for you to know that there are no wrong answers. Day 1, so in other words today, will only about 1 hour, and then when you come back for Day 2, so on another day, it will be shorter and will only take you 40 mins – so less than an hour. The total time you will be doing activities in the laboratory should take no longer than 2 hours.

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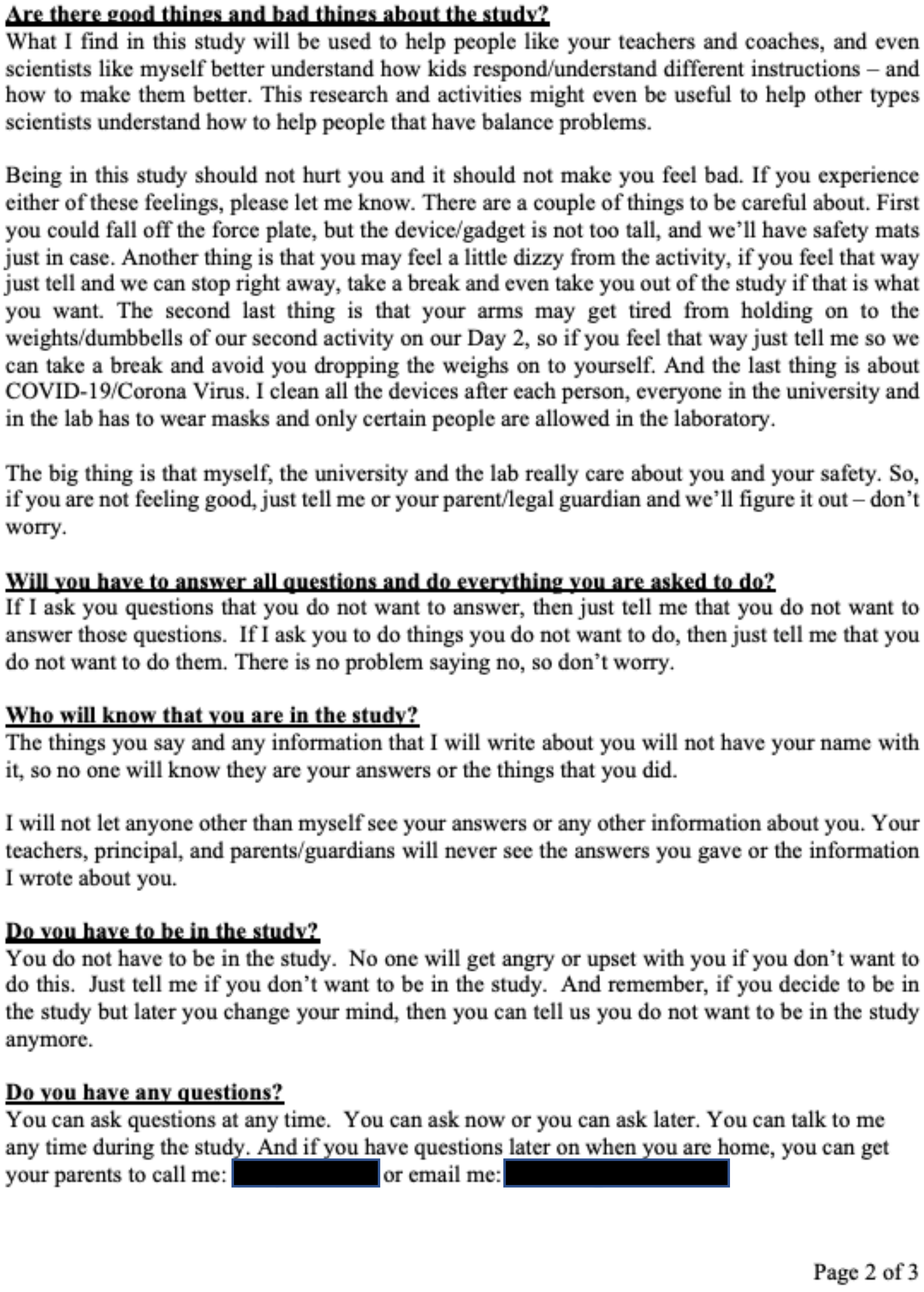


Are there good things and bad things about the study?

What I find in this study will be used to help people like your teachers and coaches, and even scientists like myself better understand how kids respond/understand different instructions – and how to make them better. This research and activities might even be useful to help other types scientists understand how to help people that have balance problems.

Being in this study should not hurt you and it should not make you feel bad. If you experience either of these feelings, please let me know. There are a couple of things to be careful about. First you could fall off the force plate, but the device/gadget is not too tall, and we'll have safety mats just in case. Another thing is that you may feel a little dizzy from the activity, if you feel that way just tell and we can stop right away, take a break and even take you out of the study if that is what you want. The second last thing is that your arms may get tired from holding on to the weights/dumbbells of our second activity on our Day 2, so if you feel that way just tell me so we can take a break and avoid you dropping the weighs on to yourself. And the last thing is about COVID-19/Corona Virus. I clean all the devices after each person, everyone in the university and in the lab has to wear masks and only certain people are allowed in the laboratory.

The big thing is that myself, the university and the lab really care about you and your safety. So, if you are not feeling good, just tell me or your parent/legal guardian and we'll figure it out – don't worry.

Will you have to answer all questions and do everything you are asked to do?

If I ask you questions that you do not want to answer, then just tell me that you do not want to answer those questions. If I ask you to do things you do not want to do, then just tell me that you do not want to do them. There is no problem saying no, so don't worry.

Who will know that you are in the study?

The things you say and any information that I will write about you will not have your name with it, so no one will know they are your answers or the things that you did.

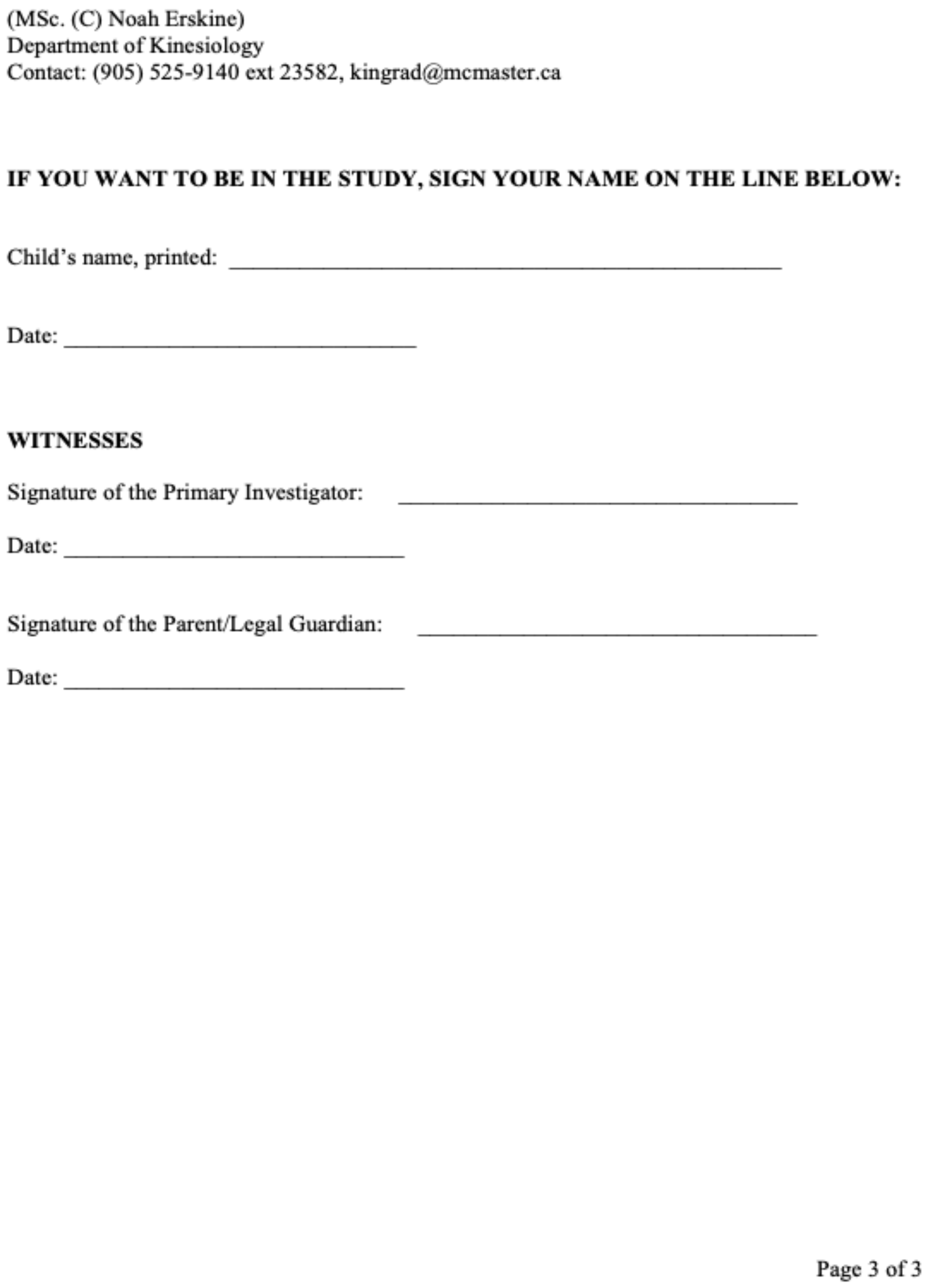
I will not let anyone other than myself see your answers or any other information about you. Your teachers, principal, and parents/guardians will never see the answers you gave or the information I wrote about you.

Do you have to be in the study?

You do not have to be in the study. No one will get angry or upset with you if you don't want to do this. Just tell me if you don't want to be in the study. And remember, if you decide to be in the study but later you change your mind, then you can tell us you do not want to be in the study anymore.

Do you have any questions?

You can ask questions at any time. You can ask now or you can ask later. You can talk to me any time during the study. And if you have questions later on when you are home, you can get your parents to call me: [redacted] or email me: [redacted]



(MSc. (C) Noah Erskine)
Department of Kinesiology
Contact: (905) 525-9140 ext 23582, kingrad@mcmaster.ca

IF YOU WANT TO BE IN THE STUDY, SIGN YOUR NAME ON THE LINE BELOW:

Child's name, printed: ____

Date: _____________________________

WITNESSES

Signature of the Primary Investigator: ________________________________

Date: ____________________________

Signature of the Parent/Legal Guardian: ________________________________

Date: ____________________________

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APPENDIX C: MREB APPROVAL FORM

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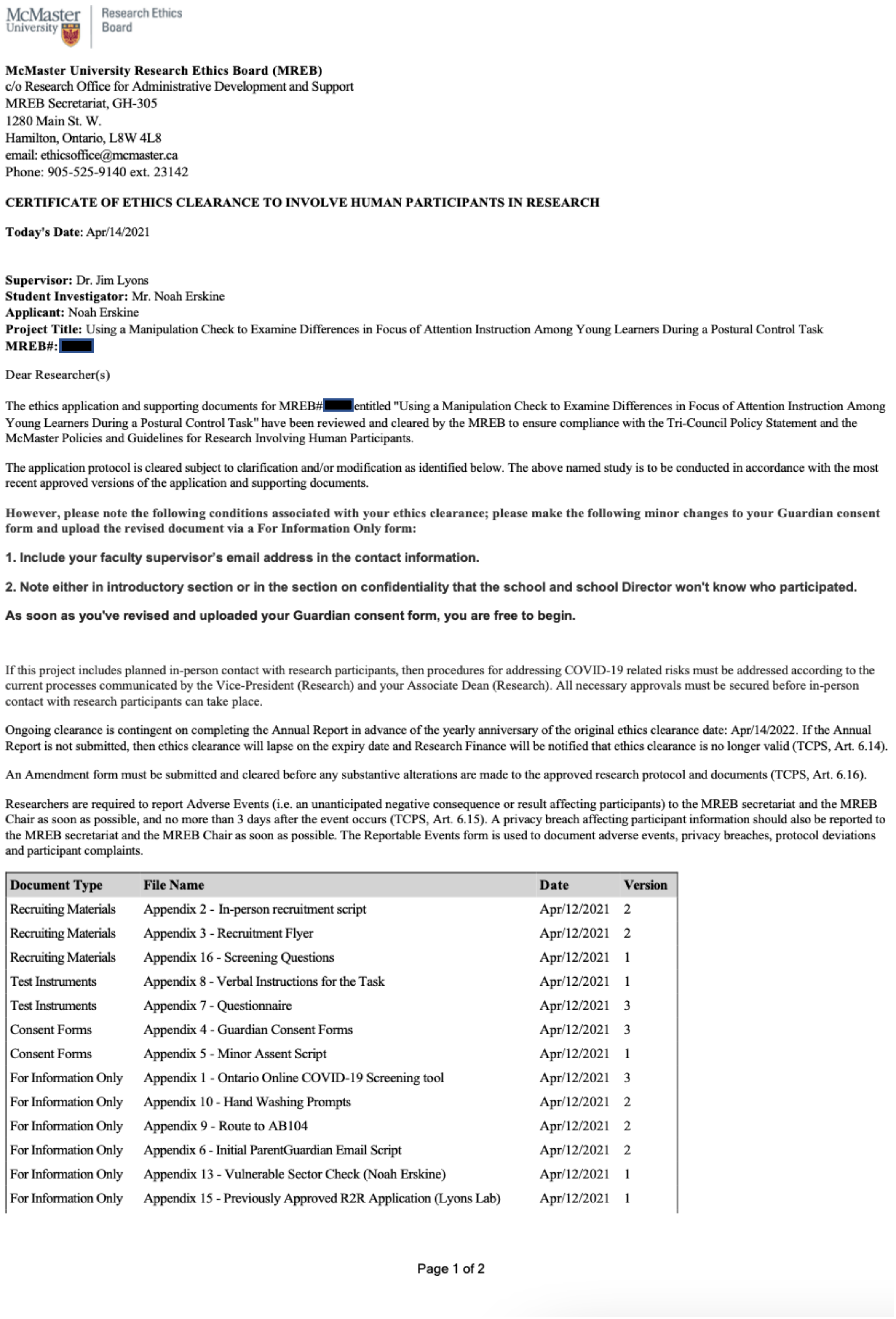

McMaster University | Research Ethics Board

McMaster University Research Ethics Board (MREB)
c/o Research Office for Administrative Development and Support
MREB Secretariat, GH-305
1280 Main St. W.
Hamilton, Ontario, L8W 4L8
email: ethicsoffice@mcmaster.ca
Phone: 905-525-9140 ext. 23142

CERTIFICATE OF ETHICS CLEARANCE TO INVOLVE HUMAN PARTICIPANTS IN RESEARCH

Today's Date: Apr/14/2021

Supervisor: Dr. Jim Lyons
Student Investigator: Mr. Noah Erskine
Applicant: Noah Erskine
Project Title: Using a Manipulation Check to Examine Differences in Focus of Attention Instruction Among Young Learners During a Postural Control Task
MREB#: [redacted]

Dear Researcher(s)

The ethics application and supporting documents for MREB#[redacted] entitled "Using a Manipulation Check to Examine Differences in Focus of Attention Instruction Among Young Learners During a Postural Control Task" have been reviewed and cleared by the MREB to ensure compliance with the Tri-Council Policy Statement and the McMaster Policies and Guidelines for Research Involving Human Participants.

The application protocol is cleared subject to clarification and/or modification as identified below. The above named study is to be conducted in accordance with the most recent approved versions of the application and supporting documents.

However, please note the following conditions associated with your ethics clearance; please make the following minor changes to your Guardian consent form and upload the revised document via a For Information Only form:

1. Include your faculty supervisor's email address in the contact information.

2. Note either in introductory section or in the section on confidentiality that the school and school Director won't know who participated.

As soon as you've revised and uploaded your Guardian consent form, you are free to begin.

If this project includes planned in-person contact with research participants, then procedures for addressing COVID-19 related risks must be addressed according to the current processes communicated by the Vice-President (Research) and your Associate Dean (Research). All necessary approvals must be secured before in-person contact with research participants can take place.

Ongoing clearance is contingent on completing the Annual Report in advance of the yearly anniversary of the original ethics clearance date: Apr/14/2022. If the Annual Report is not submitted, then ethics clearance will lapse on the expiry date and Research Finance will be notified that ethics clearance is no longer valid (TCPS, Art. 6.14).

An Amendment form must be submitted and cleared before any substantive alterations are made to the approved research protocol and documents (TCPS, Art. 6.16).

Researchers are required to report Adverse Events (i.e. an unanticipated negative consequence or result affecting participants) to the MREB secretariat and the MREB Chair as soon as possible, and no more than 3 days after the event occurs (TCPS, Art. 6.15). A privacy breach affecting participant information should also be reported to the MREB secretariat and the MREB Chair as soon as possible. The Reportable Events form is used to document adverse events, privacy breaches, protocol deviations and participant complaints.

Document Type	File Name	Date	Version
Recruiting Materials	Appendix 2 - In-person recruitment script	Apr/12/2021	2
Recruiting Materials	Appendix 3 - Recruitment Flyer	Apr/12/2021	2
Recruiting Materials	Appendix 16 - Screening Questions	Apr/12/2021	1
Test Instruments	Appendix 8 - Verbal Instructions for the Task	Apr/12/2021	1
Test Instruments	Appendix 7 - Questionnaire	Apr/12/2021	3
Consent Forms	Appendix 4 - Guardian Consent Forms	Apr/12/2021	3
Consent Forms	Appendix 5 - Minor Assent Script	Apr/12/2021	1
For Information Only	Appendix 1 - Ontario Online COVID-19 Screening tool	Apr/12/2021	3
For Information Only	Appendix 10 - Hand Washing Prompts	Apr/12/2021	2
For Information Only	Appendix 9 - Route to AB104	Apr/12/2021	2
For Information Only	Appendix 6 - Initial ParentGuardian Email Script	Apr/12/2021	2
For Information Only	Appendix 13 - Vulnerable Sector Check (Noah Erskine)	Apr/12/2021	1
For Information Only	Appendix 15 - Previously Approved R2R Application (Lyons Lab)	Apr/12/2021	1

Page 1 of 2

For Information Only	Appendix 11 - Nearset Medical Centres	Apr/12/2021	1
Response Documents	Appendix 14 - Summary of Revisions for MREB	Apr/12/2021	1
Consent Forms	Appendix 12 - COVID-19 LOI	Apr/12/2021	2

Dr. Violetta Igneski

V Igneski

Dr. Violetta Igneski, MREB Chair,
Associate Professor,
Department of Philosophy, UH-308,
905-525-9140 ext. 23462,
igneski@mcmaster.ca

Dr. Sue Becker, MREB Vice-Chair,
Professor,
Department of Psychology, Neuroscience and Behaviour, PC-312,
905-525-9140 ext. 23020,
beckers@mcmaster.ca

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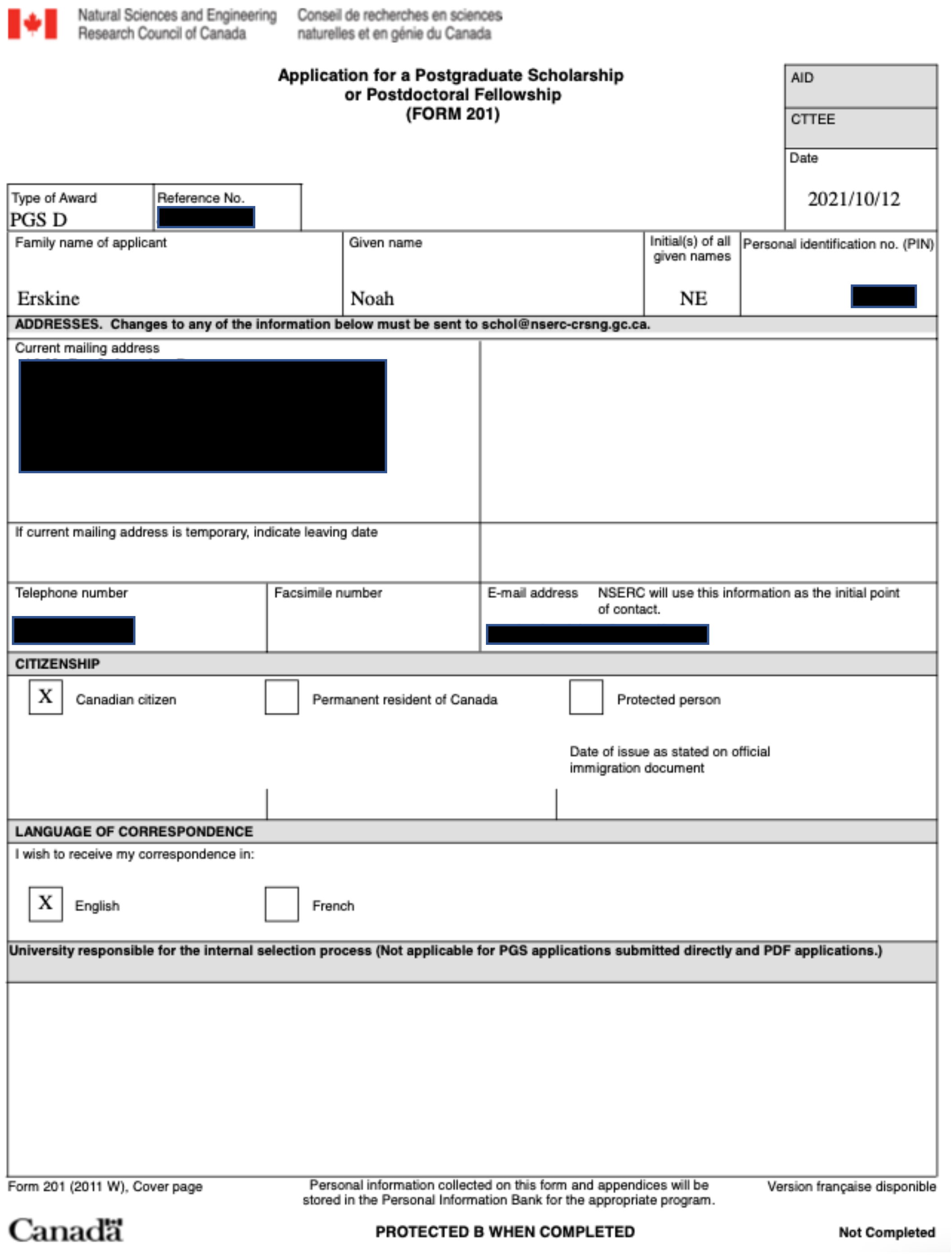
APPENDIX D: NSERC POSTGRADUATE SCHOLARSHIP – PGS D



Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Application for a Postgraduate Scholarship or Postdoctoral Fellowship (FORM 201)

AID	
CTTEE	
Date	2021/10/12

Type of Award	PGS D
Reference No.	[redacted]

Family name of applicant	Erskine
Given name	Noah
Initial(s) of all given names	NE
Personal identification no. (PIN)	[redacted]

ADDRESSES. Changes to any of the information below must be sent to schol@nserc-crsng.gc.ca.

Current mailing address
[redacted]

If current mailing address is temporary, indicate leaving date

Telephone number	[redacted]
Facsimile number	
E-mail address NSERC will use this information as the initial point of contact.	[redacted]

CITIZENSHIP

☒ Canadian citizen ☐ Permanent resident of Canada ☐ Protected person

Date of issue as stated on official immigration document

LANGUAGE OF CORRESPONDENCE

I wish to receive my correspondence in:

☒ English ☐ French

University responsible for the internal selection process (Not applicable for PGS applications submitted directly and PDF applications.)

Form 201 (2011 W), Cover page

Personal information collected on this form and appendices will be stored in the Personal Information Bank for the appropriate program.

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Canada

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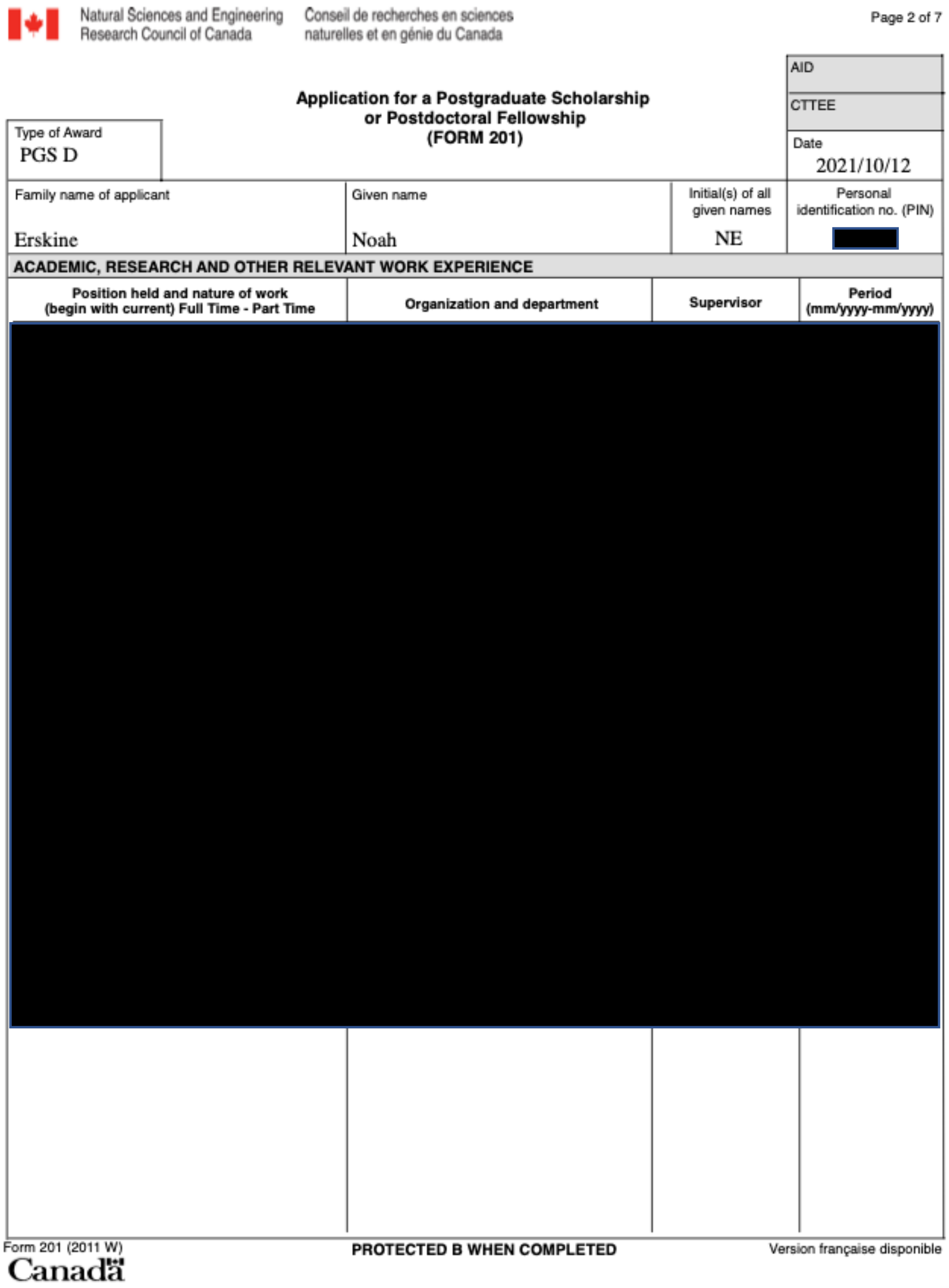

Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Page 2 of 7

AID
CTTEE

Application for a Postgraduate Scholarship or Postdoctoral Fellowship (FORM 201)

Type of Award: PGS D

Date: 2021/10/12

Family name of applicant Erskine	Given name Noah	Initial(s) of all given names NE	Personal identification no. (PIN) [redacted]

ACADEMIC, RESEARCH AND OTHER RELEVANT WORK EXPERIENCE

Position held and nature of work (begin with current) Full Time - Part Time	Organization and department	Supervisor	Period (mm/yyyy-mm/yyyy)
[redacted]			

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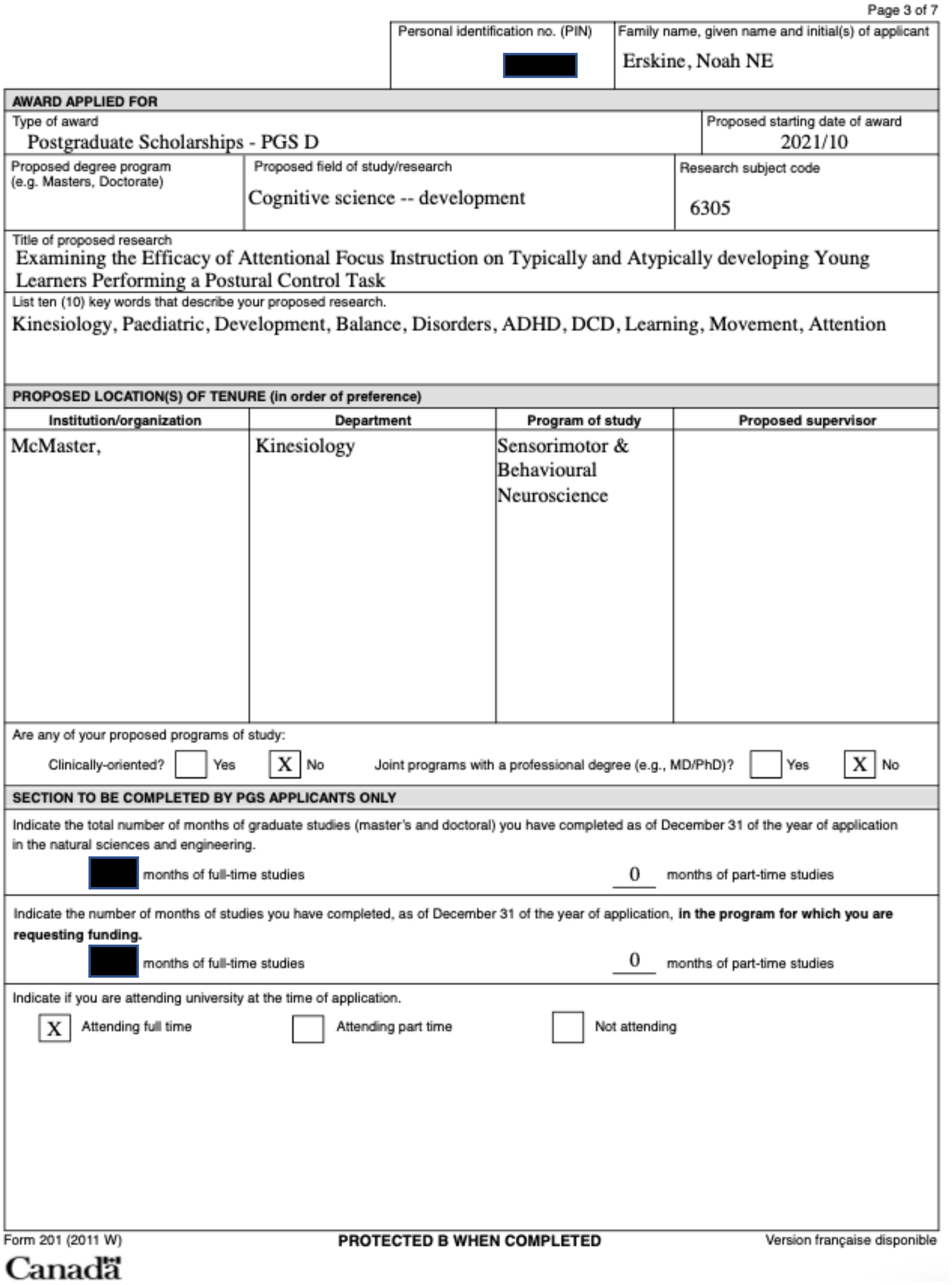

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Personal identification no. (PIN)	Family name, given name and initial(s) of applicant
[redacted]	Erskine, Noah NE

AWARD APPLIED FOR

Type of award	Proposed starting date of award
Postgraduate Scholarships - PGS D	2021/10

Proposed degree program (e.g. Masters, Doctorate)	Proposed field of study/research	Research subject code
	Cognitive science -- development	6305

Title of proposed research
Examining the Efficacy of Attentional Focus Instruction on Typically and Atypically developing Young Learners Performing a Postural Control Task

List ten (10) key words that describe your proposed research.
Kinesiology, Paediatric, Development, Balance, Disorders, ADHD, DCD, Learning, Movement, Attention

PROPOSED LOCATION(S) OF TENURE (in order of preference)

Institution/organization	Department	Program of study	Proposed supervisor
McMaster,	Kinesiology	Sensorimotor & Behavioural Neuroscience	

Are any of your proposed programs of study:

Clinically-oriented? ☐ Yes ☒ No Joint programs with a professional degree (e.g., MD/PhD)? ☐ Yes ☒ No

SECTION TO BE COMPLETED BY PGS APPLICANTS ONLY

Indicate the total number of months of graduate studies (master's and doctoral) you have completed as of December 31 of the year of application in the natural sciences and engineering.

[redacted] months of full-time studies 0 months of part-time studies

Indicate the number of months of studies you have completed, as of December 31 of the year of application, **in the program for which you are requesting funding.**

[redacted] months of full-time studies 0 months of part-time studies

Indicate if you are attending university at the time of application.

☒ Attending full time ☐ Attending part time ☐ Not attending

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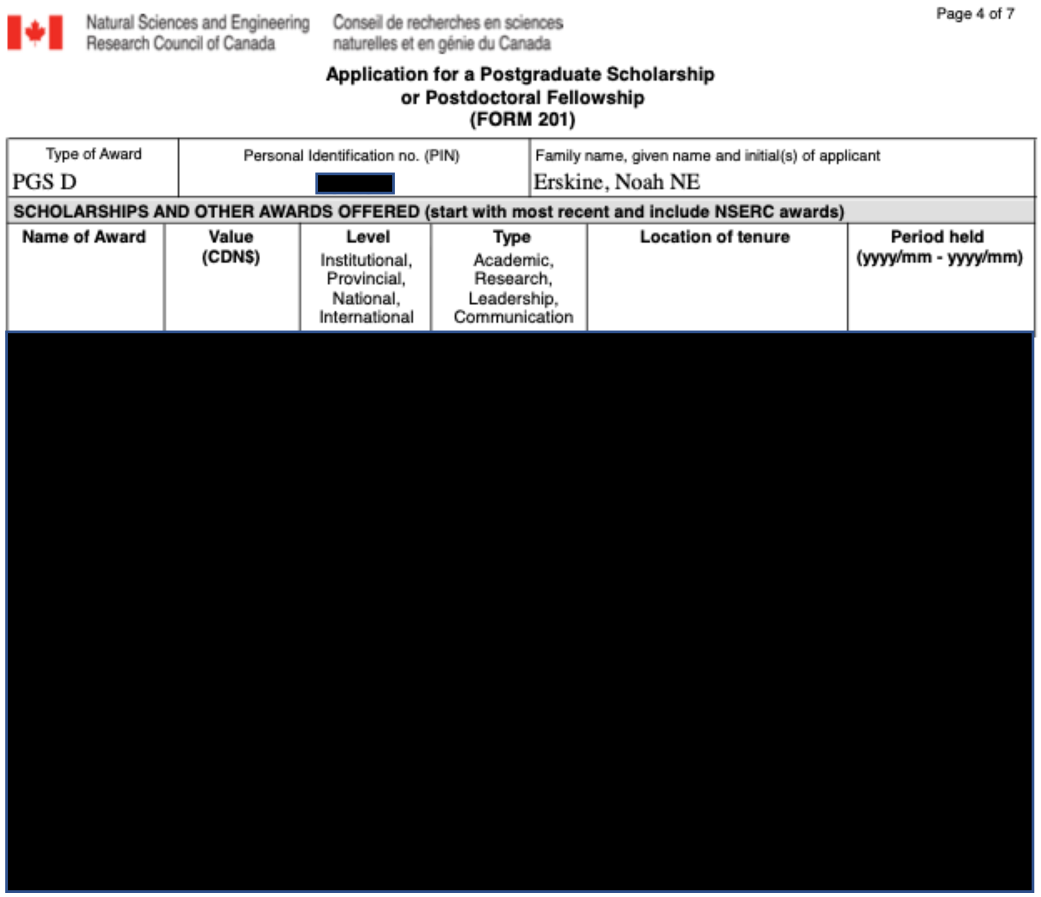

Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

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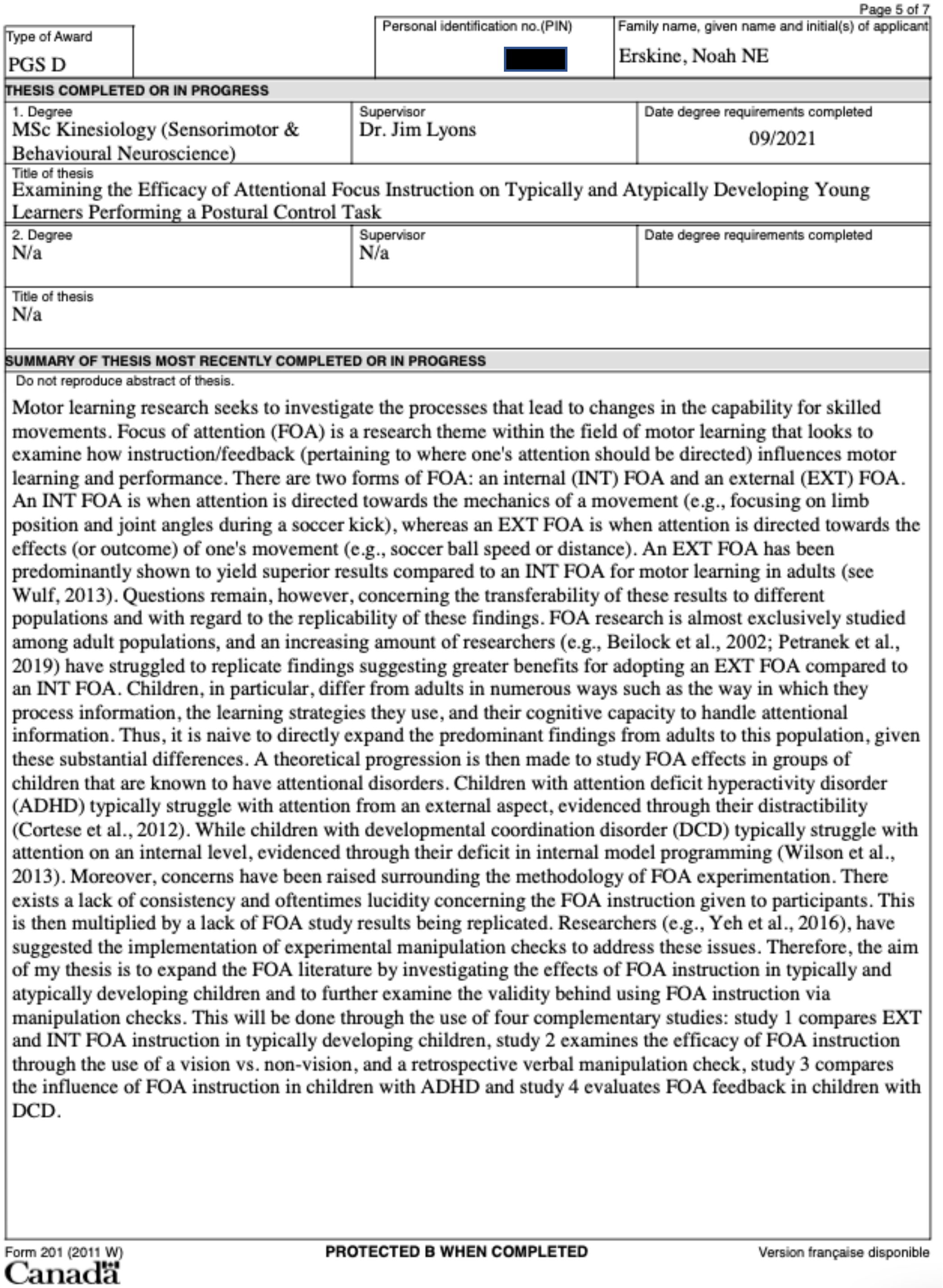
Application for a Postgraduate Scholarship or Postdoctoral Fellowship (FORM 201)

Type of Award	Personal Identification no. (PIN)	Family name, given name and initial(s) of applicant
PGS D	[redacted]	Erskine, Noah NE

SCHOLARSHIPS AND OTHER AWARDS OFFERED (start with most recent and include NSERC awards)

Name of Award	**Value (CDN$)**	**Level** Institutional, Provincial, National, International	**Type** Academic, Research, Leadership, Communication	**Location of tenure**	**Period held (yyyy/mm - yyyy/mm)**

[redacted]



Page 5 of 7

Type of Award PGS D	Personal identification no.(PIN) [redacted]	Family name, given name and initial(s) of applicant Erskine, Noah NE

THESIS COMPLETED OR IN PROGRESS

1. Degree MSc Kinesiology (Sensorimotor & Behavioural Neuroscience)	Supervisor Dr. Jim Lyons	Date degree requirements completed 09/2021
Title of thesis Examining the Efficacy of Attentional Focus Instruction on Typically and Atypically Developing Young Learners Performing a Postural Control Task		
2. Degree N/a	Supervisor N/a	Date degree requirements completed
Title of thesis N/a		

SUMMARY OF THESIS MOST RECENTLY COMPLETED OR IN PROGRESS

Do not reproduce abstract of thesis.

Motor learning research seeks to investigate the processes that lead to changes in the capability for skilled movements. Focus of attention (FOA) is a research theme within the field of motor learning that looks to examine how instruction/feedback (pertaining to where one's attention should be directed) influences motor learning and performance. There are two forms of FOA: an internal (INT) FOA and an external (EXT) FOA. An INT FOA is when attention is directed towards the mechanics of a movement (e.g., focusing on limb position and joint angles during a soccer kick), whereas an EXT FOA is when attention is directed towards the effects (or outcome) of one's movement (e.g., soccer ball speed or distance). An EXT FOA has been predominantly shown to yield superior results compared to an INT FOA for motor learning in adults (see Wulf, 2013). Questions remain, however, concerning the transferability of these results to different populations and with regard to the replicability of these findings. FOA research is almost exclusively studied among adult populations, and an increasing amount of researchers (e.g., Beilock et al., 2002; Petranek et al., 2019) have struggled to replicate findings suggesting greater benefits for adopting an EXT FOA compared to an INT FOA. Children, in particular, differ from adults in numerous ways such as the way in which they process information, the learning strategies they use, and their cognitive capacity to handle attentional information. Thus, it is naive to directly expand the predominant findings from adults to this population, given these substantial differences. A theoretical progression is then made to study FOA effects in groups of children that are known to have attentional disorders. Children with attention deficit hyperactivity disorder (ADHD) typically struggle with attention from an external aspect, evidenced through their distractibility (Cortese et al., 2012). While children with developmental coordination disorder (DCD) typically struggle with attention on an internal level, evidenced through their deficit in internal model programming (Wilson et al., 2013). Moreover, concerns have been raised surrounding the methodology of FOA experimentation. There exists a lack of consistency and oftentimes lucidity concerning the FOA instruction given to participants. This is then multiplied by a lack of FOA study results being replicated. Researchers (e.g., Yeh et al., 2016), have suggested the implementation of experimental manipulation checks to address these issues. Therefore, the aim of my thesis is to expand the FOA literature by investigating the effects of FOA instruction in typically and atypically developing children and to further examine the validity behind using FOA instruction via manipulation checks. This will be done through the use of four complementary studies: study 1 compares EXT and INT FOA instruction in typically developing children, study 2 examines the efficacy of FOA instruction through the use of a vision vs. non-vision, and a retrospective verbal manipulation check, study 3 compares the influence of FOA instruction in children with ADHD and study 4 evaluates FOA feedback in children with DCD.

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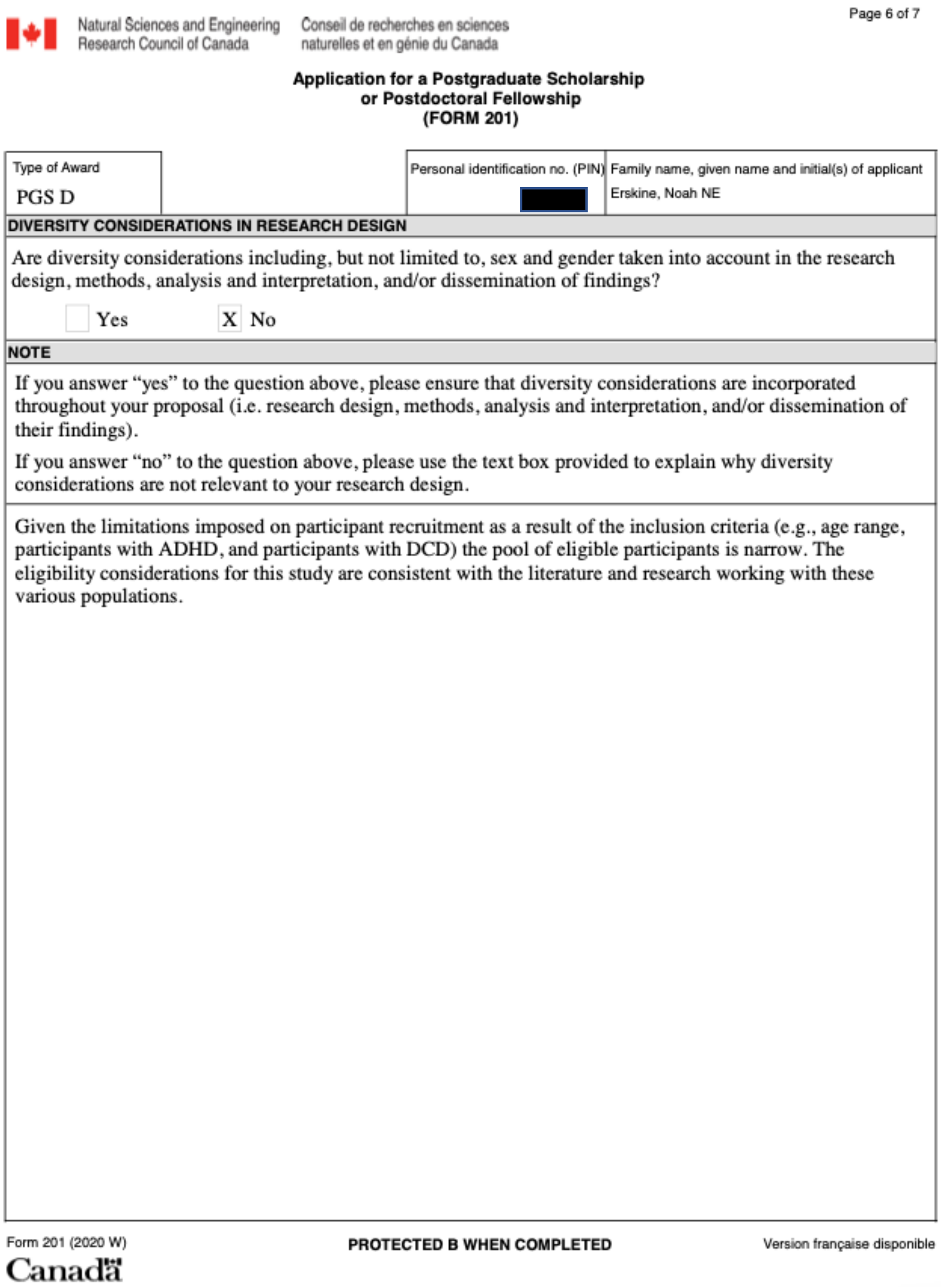

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Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Application for a Postgraduate Scholarship
or Postdoctoral Fellowship
(FORM 201)

Type of Award PGS D	Personal identification no. (PIN) [redacted]	Family name, given name and initial(s) of applicant Erskine, Noah NE

DIVERSITY CONSIDERATIONS IN RESEARCH DESIGN

Are diversity considerations including, but not limited to, sex and gender taken into account in the research design, methods, analysis and interpretation, and/or dissemination of findings?

☐ Yes ☒ No

NOTE

If you answer “yes” to the question above, please ensure that diversity considerations are incorporated throughout your proposal (i.e. research design, methods, analysis and interpretation, and/or dissemination of their findings).

If you answer “no” to the question above, please use the text box provided to explain why diversity considerations are not relevant to your research design.

Given the limitations imposed on participant recruitment as a result of the inclusion criteria (e.g., age range, participants with ADHD, and participants with DCD) the pool of eligible participants is narrow. The eligibility considerations for this study are consistent with the literature and research working with these various populations.

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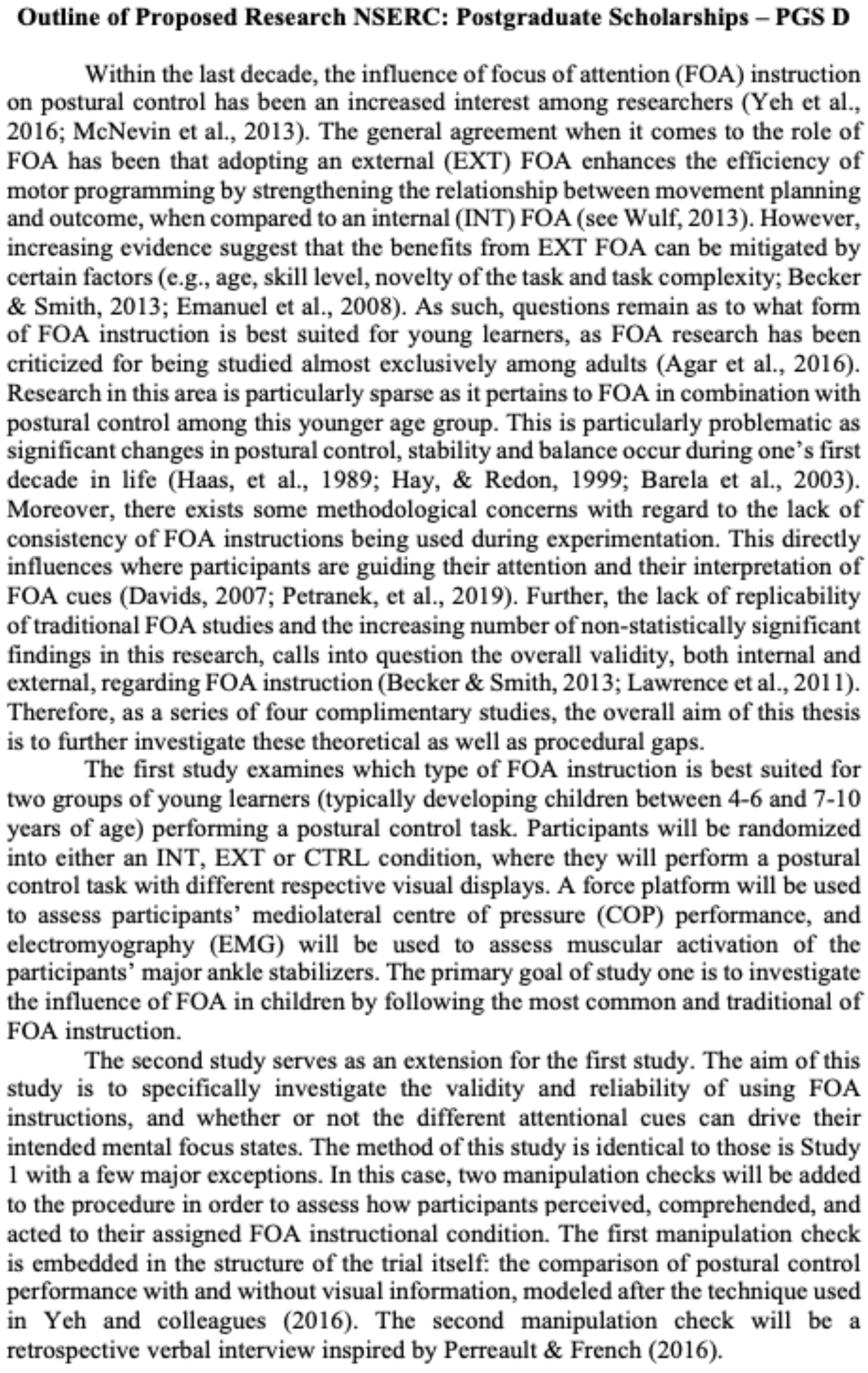
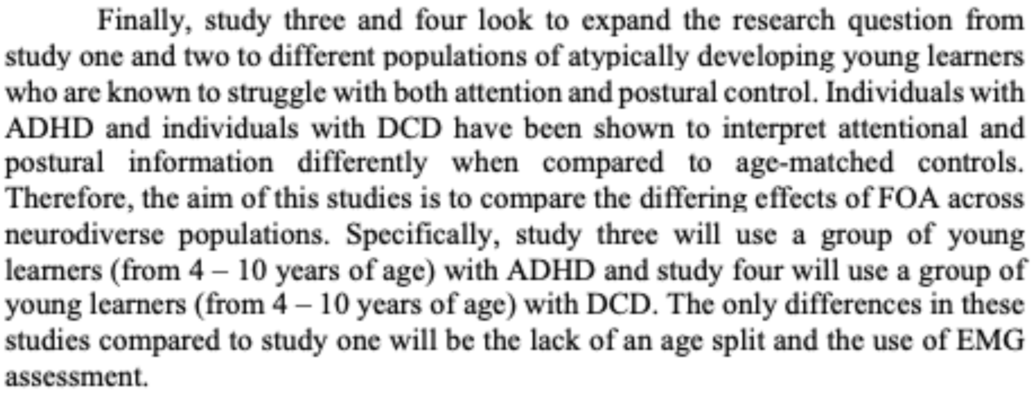


Outline of Proposed Research NSERC: Postgraduate Scholarships – PGS D

Within the last decade, the influence of focus of attention (FOA) instruction on postural control has been an increased interest among researchers (Yeh et al., 2016; McNevin et al., 2013). The general agreement when it comes to the role of FOA has been that adopting an external (EXT) FOA enhances the efficiency of motor programming by strengthening the relationship between movement planning and outcome, when compared to an internal (INT) FOA (see Wulf, 2013). However, increasing evidence suggest that the benefits from EXT FOA can be mitigated by certain factors (e.g., age, skill level, novelty of the task and task complexity; Becker & Smith, 2013; Emanuel et al., 2008). As such, questions remain as to what form of FOA instruction is best suited for young learners, as FOA research has been criticized for being studied almost exclusively among adults (Agar et al., 2016). Research in this area is particularly sparse as it pertains to FOA in combination with postural control among this younger age group. This is particularly problematic as significant changes in postural control, stability and balance occur during one's first decade in life (Haas, et al., 1989; Hay, & Redon, 1999; Barela et al., 2003). Moreover, there exists some methodological concerns with regard to the lack of consistency of FOA instructions being used during experimentation. This directly influences where participants are guiding their attention and their interpretation of FOA cues (Davids, 2007; Petranek, et al., 2019). Further, the lack of replicability of traditional FOA studies and the increasing number of non-statistically significant findings in this research, calls into question the overall validity, both internal and external, regarding FOA instruction (Becker & Smith, 2013; Lawrence et al., 2011). Therefore, as a series of four complimentary studies, the overall aim of this thesis is to further investigate these theoretical as well as procedural gaps.

The first study examines which type of FOA instruction is best suited for two groups of young learners (typically developing children between 4-6 and 7-10 years of age) performing a postural control task. Participants will be randomized into either an INT, EXT or CTRL condition, where they will perform a postural control task with different respective visual displays. A force platform will be used to assess participants' mediolateral centre of pressure (COP) performance, and electromyography (EMG) will be used to assess muscular activation of the participants' major ankle stabilizers. The primary goal of study one is to investigate the influence of FOA in children by following the most common and traditional of FOA instruction.

The second study serves as an extension for the first study. The aim of this study is to specifically investigate the validity and reliability of using FOA instructions, and whether or not the different attentional cues can drive their intended mental focus states. The method of this study is identical to those is Study 1 with a few major exceptions. In this case, two manipulation checks will be added to the procedure in order to assess how participants perceived, comprehended, and acted to their assigned FOA instructional condition. The first manipulation check is embedded in the structure of the trial itself: the comparison of postural control performance with and without visual information, modeled after the technique used in Yeh and colleagues (2016). The second manipulation check will be a retrospective verbal interview inspired by Perreault & French (2016).



Finally, study three and four look to expand the research question from study one and two to different populations of atypically developing young learners who are known to struggle with both attention and postural control. Individuals with ADHD and individuals with DCD have been shown to interpret attentional and postural information differently when compared to age-matched controls. Therefore, the aim of this studies is to compare the differing effects of FOA across neurodiverse populations. Specifically, study three will use a group of young learners (from 4 – 10 years of age) with ADHD and study four will use a group of young learners (from 4 – 10 years of age) with DCD. The only differences in these studies compared to study one will be the lack of an age split and the use of EMG assessment.

Bibliography: NSERC Postgraduate Scholarships – PGS D

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Becker, K., & Smith, P. J. (2013). Age, task complexity, and sex as potential moderators of attentional focus effects. *Perceptual and motor skills*, *117*(1), 130-144.

Davids, K. (2007). Increases in jump-and-reach height through an external focus of attention: A commentary. *International Journal of Sports Science & Coaching*, *2*(3), 285-288.

Emanuel, M., Jarus, T., & Bart, O. (2008). Effect of focus of attention and age on motor acquisition, retention, and transfer: A randomized trial. Physical Therapy, 88, 251-260.

Haas, G., Diener, H., Rapp, H., & Dichgans, J. (1989). Development of feedback and feedforward control of upright stance. *Developmental Medicine and Child Neurology, 31*, 481–488.

Hay, L., & Redon, C. (1999). Feedforward versus feedback control in children and adults subjected to a postural disturbance. *Experimental Brain Research*, *125*(2), 153-162.

McNevin, N., Weir, P., & Quinn, T. (2013). Effects of attentional focus and age on suprapostural task performance and postural control. Research quarterly for exercise and sport, 84(1), 96-103.

Lawrence, G. P., Gottwald, V. M., Hardy, J., & Khan, M. A. (2011). Internal and external focus of attention in a novice form sport. Research Quarterly for Exercise and Sport, 82, 431-441.

Perreault, M. E., & French, K. E. (2016). Differences in children's thinking and learning during attentional focus instruction. *Human movement science*, *45*, 154-160.

Petranek, L. J., Bolter, N. D., & Bell, K. (2019). Attentional focus and feedback frequency among first graders in physical education. *Journal of Teaching in Physical Education*, *38*(3), 199-206.

Wulf, G. (2013). Attentional focus and motor learning: a review of 15 years. *International Review of sport and Exercise psychology*, *6*(1), 77-104.

Yeh, T. T., Cinelli, M. E., Lyons, J., & Lee, T. D. (2016). Using a manipulation check to uncover age-related difference in focus of attention instruction during a balance task. *Experimental aging research*, *42*(3), 307-313.

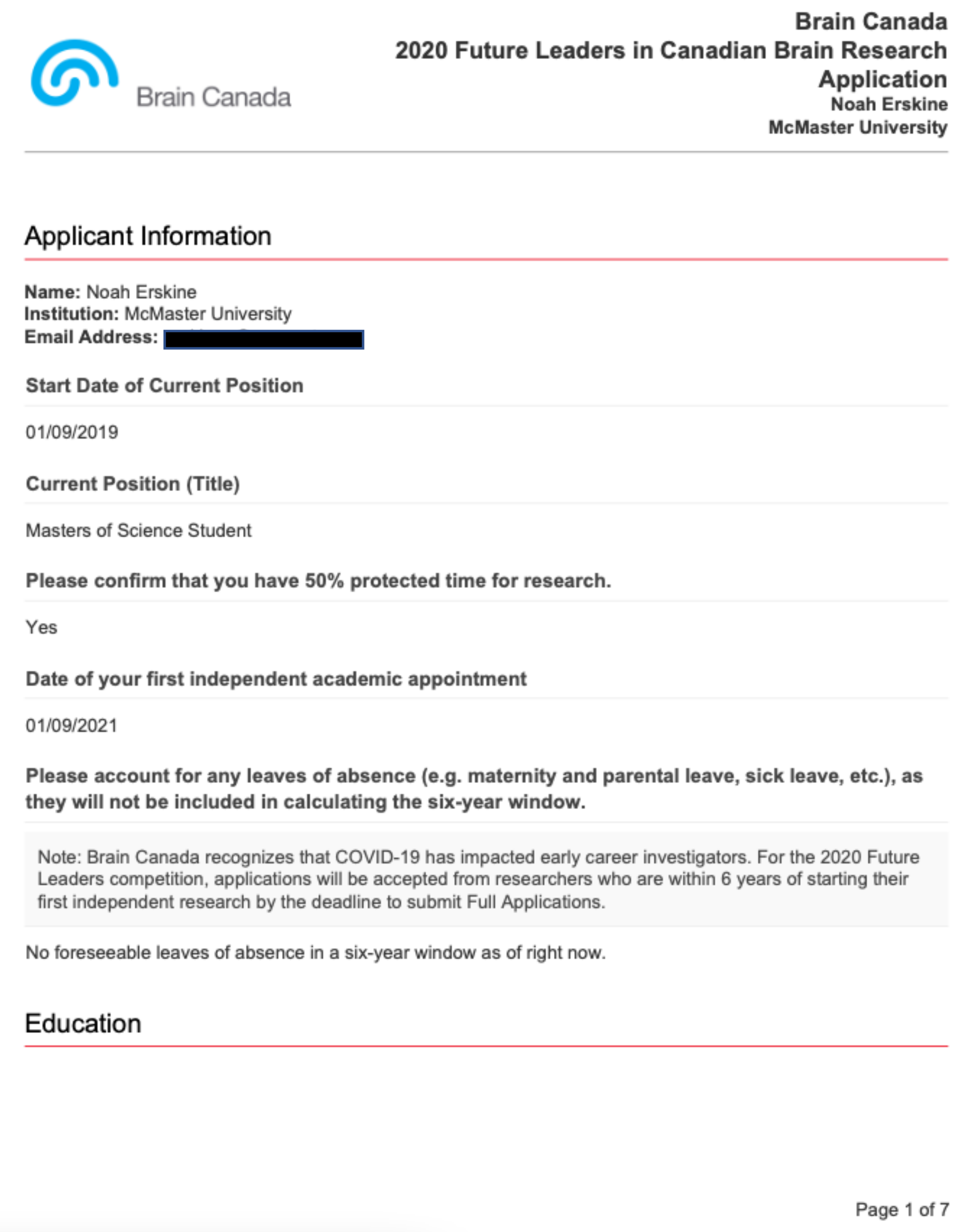
Justification for Eligibility of Proposed Research

As summarized in my project proposal, my research looks to meaningful extend the FOA literature by assessing the differential effects of FOA instruction in typically developing children, children with ADHD and children with DCD. Study 1 specifically looks to examine the effect of FOA instruction on postural control performance among children, in order to assess which type of FOA instruction leads to better performance and motor learning in children. Study 2 is an extension to Study 1, as it looks to address the remaining questions surrounding the experimental instruction design and the logic behind the assumption that FOA states are dichotomous. Study 2 aims to address these questions by assessing the reliability and validity of FOA instruction usage with children via the implementation of experimental manipulation checks. The first manipulation check is a vision non-vision paradigm that is embedded in the trial (modelled after Yeh et al., 2016). This serves to evaluate participants adherence to their respective FOA instructions. The second manipulation check is a retrospective verbal report, which functions as a tool to assess what participants are focusing on during their trials. Study 3 looks to theoretically extend the FOA research by investigating the influence of FOA instruction in a population with a known attentional deficit. The aim of this study is to evaluate the degree to which compromised abilities in the selection and focus of attention meditates FOA instructional sets. In addition, the results of this study hope to offer some applied insight as to whether FOA instruction can be an effective support for non-neurotypical individuals who struggle with attentional control. The final study, Study 4, as previously mentioned is theoretically complementary to Study 3 as it looks to examine the influence of FOA instruction in children who have a known motor performance deficit, children with DCD. ADHD and DCD are believed to be closely linked, as they are often comorbid in children.

My numerous years of experience as an educator and a volunteer working with both typically developing and atypically developing children will be invaluable towards understanding how participants will respond with regard to their respective FOA instruction. I also have an up-to-date vulnerable sectors check issued by Hamilton Police. I additionally have assisted with several studies in the Sensorimotor and Behavioural Neuroscience Laboratory at McMaster University throughout my time as an undergraduate and master's student.

My research will take place at McMaster University in the Sensorimotor and Behavioural Neuroscience Laboratory and will be supervised by Dr. Jim Lyons. Dr. Lyons is a Professor in the Department of Kinesiology at McMaster University. He is an expert in perceptual-motor skill development and the role that environmental affordances play in goal-directed behaviour. Dr. Lyons has over 50 peer-reviewed publications that span both psychological and movement science journals, along with experience working with special populations. His years of experience will be instrumental in conducting this research proposal. This project has McMaster Research Ethics Board approval.

APPENDIX E: BRAIN CANADA: FUTURE LEADERS IN CANADIAN BRAIN RESEARCH SCHOLARSHIP



Brain Canada

Brain Canada
2020 Future Leaders in Canadian Brain Research
Application
Noah Erskine
McMaster University

Applicant Information

Name: Noah Erskine
Institution: McMaster University
Email Address: [redacted]

Start Date of Current Position

01/09/2019

Current Position (Title)

Masters of Science Student

Please confirm that you have 50% protected time for research.

Yes

Date of your first independent academic appointment

01/09/2021

Please account for any leaves of absence (e.g. maternity and parental leave, sick leave, etc.), as they will not be included in calculating the six-year window.

Note: Brain Canada recognizes that COVID-19 has impacted early career investigators. For the 2020 Future Leaders competition, applications will be accepted from researchers who are within 6 years of starting their first independent research by the deadline to submit Full Applications.

No foreseeable leaves of absence in a six-year window as of right now.

Education

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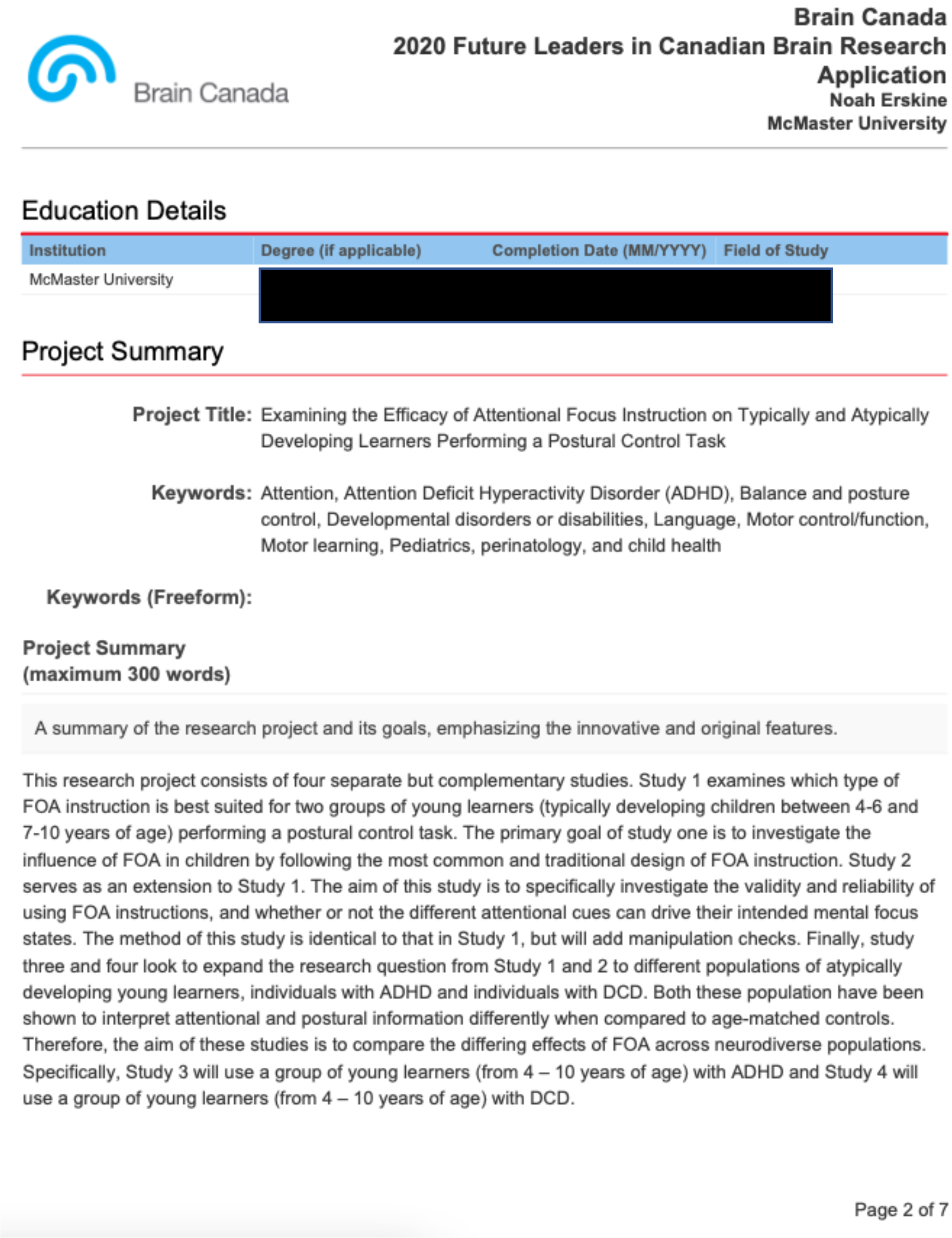

Brain Canada

Brain Canada
2020 Future Leaders in Canadian Brain Research
Application
Noah Erskine
McMaster University

Education Details

Institution	Degree (if applicable)	Completion Date (MM/YYYY)	Field of Study
McMaster University	[redacted]	[redacted]	[redacted]

Project Summary

Project Title: Examining the Efficacy of Attentional Focus Instruction on Typically and Atypically Developing Learners Performing a Postural Control Task

Keywords: Attention, Attention Deficit Hyperactivity Disorder (ADHD), Balance and posture control, Developmental disorders or disabilities, Language, Motor control/function, Motor learning, Pediatrics, perinatology, and child health

Keywords (Freeform):

Project Summary (maximum 300 words)

A summary of the research project and its goals, emphasizing the innovative and original features.

This research project consists of four separate but complementary studies. Study 1 examines which type of FOA instruction is best suited for two groups of young learners (typically developing children between 4-6 and 7-10 years of age) performing a postural control task. The primary goal of study one is to investigate the influence of FOA in children by following the most common and traditional design of FOA instruction. Study 2 serves as an extension to Study 1. The aim of this study is to specifically investigate the validity and reliability of using FOA instructions, and whether or not the different attentional cues can drive their intended mental focus states. The method of this study is identical to that in Study 1, but will add manipulation checks. Finally, study three and four look to expand the research question from Study 1 and 2 to different populations of atypically developing young learners, individuals with ADHD and individuals with DCD. Both these population have been shown to interpret attentional and postural information differently when compared to age-matched controls. Therefore, the aim of these studies is to compare the differing effects of FOA across neurodiverse populations. Specifically, Study 3 will use a group of young learners (from 4 – 10 years of age) with ADHD and Study 4 will use a group of young learners (from 4 – 10 years of age) with DCD.

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Describe how this proposal differs from past and/or current lines of research. (maximum 300 words)

Note: Research applications may be related but cannot be identical to any other currently funded projects. It is the responsibility of the applicant to notify Brain Canada immediately should substantial overlap arise from new funding awards during the application and review process of this competition

This research proposals differs from the current literature in numerous ways. First, FOA research is criticized for being predominantly studied in adult populations, where there is a certain omission with regard to children. Findings from adult populations are not directly transferable to children given the numerous differences between the populations, such as differences in general motor skill expertise level, differences information-processing, memory encoding strategies, emotional regulation, and attentional capacities. Therefore, my research proposal looks to further investigate which form of FOA instruction is best suited for children. Second, FOA research is limited by a lack of experimental controls or manipulation checks concerning where participants are directing their attention and if they are adhering to their respective instructional set. Therefore, my proposal, specifically in Study 2, looks to add manipulation checks to assess the validity and reliability of using FOA instructional feedback with children. Third, research examining the effects of FOA instruction in atypical child populations is limited. Study 3 and 4, look to assess the role of FOA instruction in populations with a known attentional deficit, in order evaluate the degree in which compromised abilities in the selection and focus of attention mediates FOA instructional sets. Study 3 will specifically look at FOA instruction in children with ADHD, while Study 4 will examine FOA instruction in children with DCD.

Primary Type of Research

Basic/Fundamental

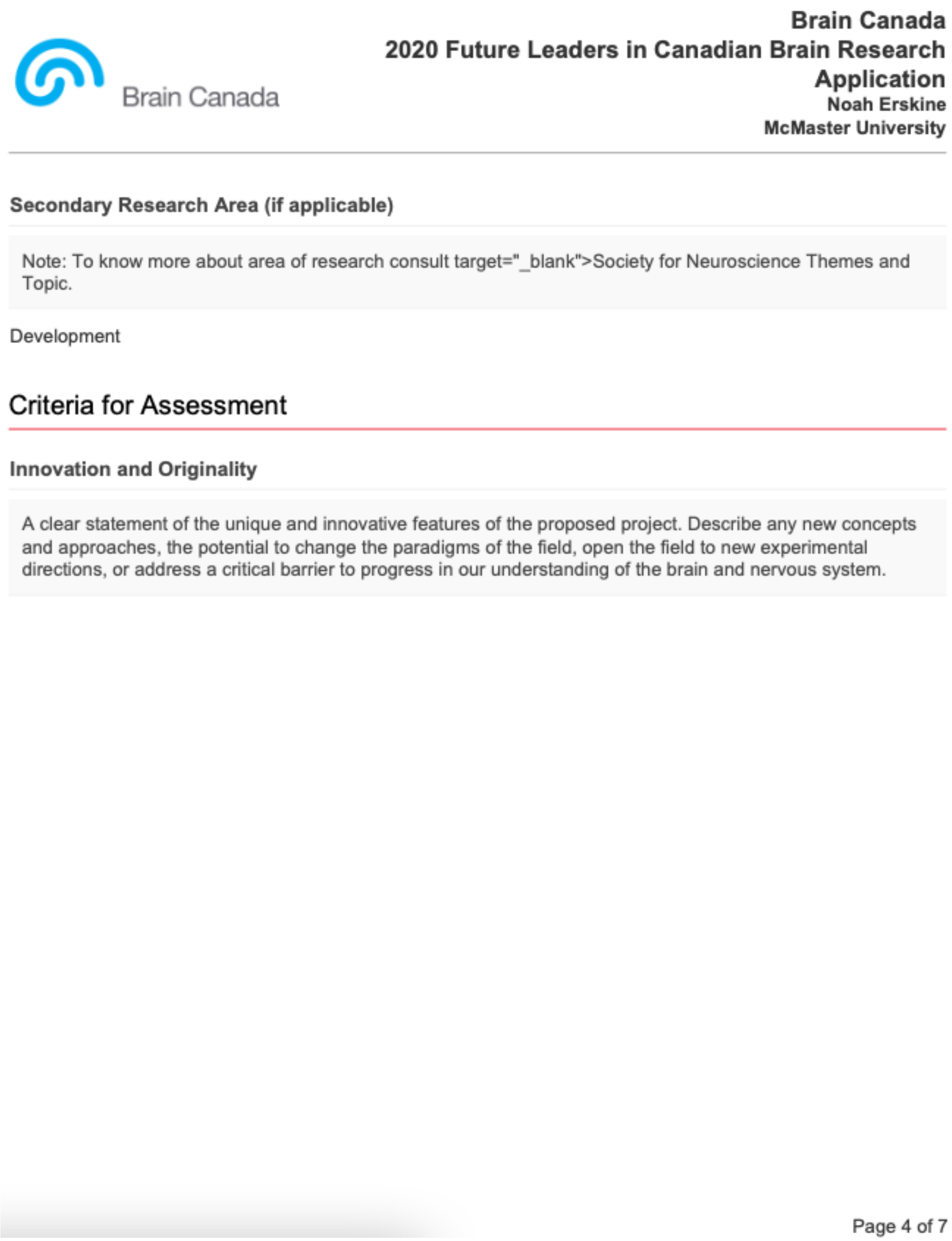
Secondary Type of Research (if applicable)

Knowledge Translation

Primary Research Area

Note: To know more about area of research consult target="_blank">Society for Neuroscience Themes and Topic.

Motor Systems



Secondary Research Area (if applicable)

Note: To know more about area of research consult target="_blank">Society for Neuroscience Themes and Topic.

Development

Criteria for Assessment

Innovation and Originality

A clear statement of the unique and innovative features of the proposed project. Describe any new concepts and approaches, the potential to change the paradigms of the field, open the field to new experimental directions, or address a critical barrier to progress in our understanding of the brain and nervous system.

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As previously mentioned, there are various limitations within the FOA literature. FOA is seldom researched in children. This is problematic given that children differ substantially from adults in general motor skill expertise level, differences information-processing, memory encoding strategies, emotional regulation, and attentional capacities. These differences can be attributed to the lack of developmental maturity in various brain regions, such as the prefrontal and frontal brain areas in children. This proposal thus looks to examine the influence FOA instruction may have in children, and to assess which form will yield better results for motor performance and learning among this population. This proposal additionally has the potential to provide insights on motor behavioural changes in relation to the development of these brain regions. Another barrier in the FOA research relates to the validity and reliability of utilizing FOA instruction with children. Study 2 of this proposal looks to specifically address these concerns by implementing dual manipulations checks. The first manipulation check is a vision non-vision paradigm embedded within the experimental trials. This serves the purpose to assess participants' adherence to their respective FOA instructions. The second manipulation is a retrospective verbal report which will be used to gauge what participants were thinking about during their trial, and whether or not the FOA experimental instructions were able to successfully create their intended mental foci states. Moreover, Studies 3 and 4 look to theoretically extend the FOA literature by assessing the influence that FOA instruction may have on populations of children who are known to have an attentional processing and postural control deficit. The aim of these studies is to examine the degree to which compromised abilities in the selection and focus of attention mediate FOA instructions, and if FOA instruction can be a viable tool for children with ADHD and children with DCD. Study 3 looks to determine which type of FOA instruction is best suited for children with ADHD, and Study 4 looks to examine which type of FOA instruction yields better results for motor performance and learning in children DCD. Children with ADHD are evidenced to struggle with the external components of attention, which is suggested to be linked to a frontostriatal dysfunction. In contrast, children with DCD are depicted to struggle with the internal aspects of attention, which is attributable to this population having an internal image processing deficit.

Feasibility

The degree to which the proposed research can be successfully executed. Provide appropriate background and justification for the proposed research, and describe the approaches, methods and techniques that will be used.

As summarized in my project proposal, my research looks to meaningful extend the FOA literature by assessing the differential effects of FOA instruction in typically developing children, children with ADHD and children with DCD. Study 1 specifically looks to examine the effect of FOA instruction on postural control performance among children, in order to assess which type of FOA instruction leads to better performance and motor learning for children. Study 2 is an extension to Study 1, as it looks to address the remaining questions surrounding the experimental instruction design and the logic behind the assumption that FOA states are dichotomous. Study 2 aims to address these questions by assessing the reliability and validity of FOA instruction usage with children via the implementation of experimental manipulation checks. The first manipulation check is a vision non-vision paradigm that is embedded in the trial (modelled after Yeh et al., 2016). This serves to evaluate participants adherence to their respective FOA instructions. The second manipulation check is a retrospective verbal report, which functions as a tool to assess what participants are focusing on during their trials. Study 3 looks to theoretically extend the FOA research by investigating the influence of FOA instruction in a population with a known attentional deficit, children with ADHD. The aim of this study is to evaluate the degree to which compromised abilities in the selection and focus of attention meditates FOA instructional sets. In addition, the results of this study hope to offer some applied insight as to whether FOA instruction can be an effective support for non-neurotypical individuals who struggle with attentional control. Study 4, as previously mentioned is theoretically complementary to Study 3 as it looks to examine the influence of FOA instruction in children who have a known motor performance deficit, children with DCD. ADHD and DCD are believed to be closely linked, as they are often comorbid in children.

My numerous years of experience working as an educator and volunteer for both typically developing and atypically developing children will be invaluable towards understanding how participants will respond with regard to their respective FOA instruction. I also have an up-to-date vulnerable sectors check issued by Hamilton Police. I additionally have assisted with several studies in the Sensorimotor and Behavioural Neuroscience Laboratory at McMaster University throughout my time as an undergraduate and master's student.

My research will take place at McMaster University in the Sensorimotor and Behavioural Neuroscience Laboratory and will be supervised by Dr. Jim Lyons. Dr. Lyons is a Professor in the Department of Kinesiology at McMaster University. He is an expert in perceptual-motor skill development and the role that environmental affordances play in goal-directed behaviour. Dr. Lyons has over 50 peer-reviewed publications that span both psychological and movement science journals, along with experience working with special populations. His years of experience will be instrumental in conducting this research proposal.

COP will be collected via force platform, and ankle-strategy muscular activation will be calculated via EMG. This is study is approved by the MREB.

Potential for Impact

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The degree to which the new lines of research that could be developed from this project has the potential to fundamentally change our understanding of brain and nervous system function in the long-term. Please also describe any targeted research including diverse populations, such as that based on gender, age, Indigenous identity, visible minority identity, or disability.

The knowledge gained through a better understanding of which type of FOA instruction is best suited for typically developing children, children with ADHD and children with DCD hopes to meaningfully extend current research exploring the effects of instructional language used during motor skill learning. Additionally, potential results from this study may provide new fundamental insights on whether or not FOA instruction may be a viable tool for these populations, along with providing insights pertaining to attentional capacities and information processing differences across neurodiverse children. This proposal looks to provide evidence that can inform educators and coaches with the best suited practices for pedagogical and motor behavioural research working with these populations.

Certification and Signatures