The Influence of General Cognitive Training on Sport-Specific Performance in Wheelchair Basketball

By

Annie Pietroniro

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Masters of Health Sciences

Faculty of Health Sciences

Kinesiology

University of Ontario Institute of Technology

August, 2018

ABSTRACT

There has been tremendous growth of sport-science literature completed on able-bodied or mainstream athletes. However, research completed on the development of perceptual-cognitive skills on athletes with physical disabilities is scarce. Twelve Senior high performance/National Academy athletes were recruited from Wheelchair Basketball Canada to participate in a pre-test vs. post-test intervention study of general cognitive training (GCT) effects on sport-specific performance. Athletes were tested in general executive functioning, sport-specific cognitive skills (pattern recall), and sport-specific physical performance indicators. The intervention was 4-weeks of multiple object tracking (MOT). Results from statistical analysis show little-to-no changes over the study period, which supports the hypothesis that participation in MOT would have no effect on performance in wheelchair basketball. Future research is needed in this area and would benefit from a larger sample size, a control-group, and extended study period. Coaches are encouraged to be cautious in their use of GCT programs in high performance athlete training environments.

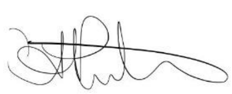
Keywords: perceptual-cognitive training, general-cognitive training, Paralympics, athlete development, sport expertise

DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I authorize the University of Ontario Institute of Technology to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize University of Ontario Institute of Technology to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research. I understand that my thesis will be made electronically available to the public.

The research work in this thesis that was performed in compliance with the regulations of UOIT's Research Ethics Board/Canadian Sport Institute of Ontario Research Ethics Board under **#11671/#2017-02.**



Annie Pietroniro

STATEMENT OF CONTRIBUTIONS

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others. Furthermore, with support from my supervisor, I hereby certify that I am the sole source of the creative works and/or inventive knowledge described in this thesis.

The work described in Chapter 3 was performed at the Toronto Pan Am Sports Centre (TPASC), where the National Training Centre (NTC) of Wheelchair Basketball Canada (WBC) resides (Toronto, Ontario). All technology used in the study was previously installed (i.e. Neurotracker™ license), or delivered via portable laptop computer. I was responsible for ensuring proper use and maintenance of license and corresponding equipment.

I dedicate this thesis and continuous work to my Grandfather, Victor Pietroniro. I never officially had the opportunity to tell you I had been accepted as a Masters student, but I know you would have been proud, and curious about the work I am doing.

Wherever you are, I know that you are always watching over my shoulder, and always by my side. I miss you every day, and I will always keep our memories in my heart.

ACKNOWLEDGEMENTS

Thank you to my supervisor Dr. Nick Wattie for all of your support and encouragement throughout every step of this process. Even more, thank you for your mentorship and countless opportunities you give me to become a greater researcher. Lastly, thank you for your endless supply of jokes, movie-puns, and stories. You always kept a sense of humor even when I had lost mine; this has made the entire process even more enjoyable, and I couldn't have imagined working with a greater supervisor.

Thank you to my committee members Dr. Joseph Baker, and Dr. Meghann Lloyd for taking the time out of your busy schedules to help me with this project. Your time and input has been greatly appreciated. Also, thank you to my lab partners Lojain Farah, Kelly Webdale, Matt McCue, and Jason Mergler, you all have been a tremendous help for me with running stats, and listening to my presentations over and over and over and over and over and over again.

Thank you to my mentor Mike Frogley. Thank you for always believing in me, and always giving me great advice in academics, and in life. You believed in me when I had just started as an intern at WBC, and asked me if I wanted to turn my pilot project into a Masters Thesis. Your excitement and passion for new research is contagious, and I am fortunate to have worked alongside you.

Thank you to my Mom, Dad and Sisters. Thank you for always supporting me and believing in my chaotic ways and aspirations. You continuously put up with me leaving for research and travel and are always excited to hear the results of what I'm doing in research. You always push me to go farther in education and I would not have been able to continue with my dreams if you were not there supporting me with love and encouragement.

Lastly, thank you to my life partner, Nik. Thank you for putting up with my headaches, and always challenging me to answer the hard questions. Thank you for making me coffee in the early mornings, and thank you for also pushing me to get back to writing my research. You have kept me sane throughout this process, and I am so lucky to have you by my side for our future milestones.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

- CBS – Cambridge Brain Sciences
- CDC – Centre for Disease Control and Prevention
- CPC – Canadian Paralympic Committee
- DP – Deliberate Practice
- DTE – Daily Training Environment
- DV – Dependent Variable
- GCT – General Cognitive Training
- GEF – General Executive Functioning
- HP – High Performance
- IPC – International Paralympic Committee
- IST – Integrated Support Team
- ITQMT – Individual Technical Quality Measurement Tool
- IV – Independent Variable
- IWBF – International Wheelchair Basketball Federation
- MOT – Multiple Object Tracking
- PR – Pattern Recall
- PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- SD – Standard Deviation
- UE – Ultra Endurance
- WBC – Wheelchair Basketball Canada
- WM – Working Memory

NOTES

1. This paper was written conforming to the Centre for Disease Control and Prevention (CDC)'s language policy and a person-first approach to disability language. The language used in this thesis differs from articles reviewed and mentioned, as this was to adhere to more current, respectful, and accurate terminology when describing individuals with disabilities (www.cdc.gov).
2. The following thesis is organized in a manuscript-style. This paper contains separate stand-alone chapters for: Introduction, Literature Review, Study 1 (which contains an Introduction, Methods, Results, and Discussion), and General Discussion of the overall study. References are at the end of each chapter.

CHAPTER 1 – INTRODUCTION

1.1 THESIS INTRODUCTION

1.12 Developing Elite Performers

There is extensive literature dedicated to understanding the development of elite athletes. Along with a variety of empirical studies (Starkes & Ericsson, 2003; Helsen, Starkes, & Hodges, 1998; Helsen & Starkes, 1999), there are popular books (Coyle, 2009; Syed, 2011; Epstein, 2014; Gladwell, 2008), reviews (Baker & Young, 2014), as well as models of athlete development (Scanlan et al., 1993a, 1993b). The diverse information on athlete development, in different sports, highlights the challenges of developing elite performers (Baker & Farrow, 2015). For example, a review of The Great British Medalists Project (Rees et al., 2016) highlights many multidisciplinary constraints that influence athlete development (i.e. birthdate and relative age effects, genetics and physiological characteristics, motivational orientations, support networks, practice and training, and onset of specialization), and reinforces the complexity of developing elite athletes. This review also touches on the increasing financial investments into athletic programs and major Olympic Games (Rees et al., 2016). Although sport scientists have completed in depth research to develop our knowledge of human performance over the past 40 years (Baker & Farrow, 2015), there is still a need for additional research in this field. One particular area that has been comparatively under researched is parasport, and para-athlete development.

1.13 History of the Paralympic Movement

Humble Beginnings

Between 1944 and 1945, by request of the British government, a neurologist by the name of Dr. Ludwig Guttman was asked to create the National Spinal Injuries Centre at the Stoke Mandeville Hospital in Great Britain. This was to assist the high number of injured veterans returning home at the end of World War II, who were receiving treatment at the Stoke Mandeville Hospital (“Mandeville Legacy”, 2014). As part of the treatment for injured veterans, sport was introduced as a tool for rehabilitation, which soon turned into recreation and competition. When sport was first introduced, games were played between the veterans and the physiotherapists. These games were considered a hybrid between wheelchair polo (although typically played on horses) and wheelchair hockey. (“Mandeville Legacy”, 2014).

The First Games

On July 29th, 1948, Dr. Guttman organized a wheelchair archery demonstration to coincide with the Opening Ceremonies for the London 1948 Summer Olympic Games. This event included sixteen participants (14 men, 2 women) from Stoke Mandeville and the Star and Garter Home for Injured War Veterans in Richmond, Surrey (“Mandeville Legacy”, 2014; “Paralympics – History of the Movement”, n.d.). After the success of the event, Dr. Guttman decided to create an annual exhibition of the, ‘Grand Festival of Paraplegic Sport’, which later became known at the Stoke Mandeville Games (“Mandeville Legacy”, 2014).

The Paralympic Games

It was only in Rome 1960, that the International Stoke Mandeville Games were held immediately after their closing ceremonies of the Olympic Games. This was considered the first ‘official’ Paralympic Games, although the name was not formally used then. These games included approximately 400 athletes from 23 different countries. The first Winter Paralympic Games took place in Sweden, 1976. The term, ‘Paralympic’ was officially coined at the Seoul 1988 Summer Games. The term ‘para’ is Greek to mean ‘alongside’ or ‘beside’, and was chosen to illustrate that both the Olympic and Paralympic movement can exist side-by-side ("Mandeville Legacy", 2014; "Paralympics – History of the Movement", n.d.).

1.14 Para-Athlete and Parasport Research

The Paralympics has seen significant growth from 1960 (considered the first year of the games) to the 2016 Paralympics in Rio de Janeiro, Brazil. From this time, there has been over a 1000% increase athlete participation; with 400 athletes in 1960, and 4,328 in 2016 (Murdoch, 2012; "Rio 2016" n.d.). With increased participation in parasport major games (i.e., Paralympics and Para Pan American Games), there has also been growth in sport-science literature (see Burkett, Melfont & Mason, 2012; Goosey-Tolfrey et al., 2002; Daly et al., 2003) that has contributed to understanding certain aspects of performance and competition. Studies have looked at mechanical efficiency in Paralympic hand-cyclers (Goosey-Tolfrey, Alfano & Fowler, 2008), cooling techniques and speed profiles in wheelchair rugby athletes (Griggs, Havenith, Price, Paulson, & Goosey-Tolfrey, 2015; Rhodes, Mason, Paulson, & Goosey-Tolfrey, 2016), psychosocial impact (Richardson, Papathomas, Smith, & Goosey-Tolfrey, 2017), raquet holding techniques in wheelchair tennis (de Groot, Bos, Koopman, Hoekstra, & Vegter, 2017;2016), free-throw shooting techniques of wheelchair basketball athletes (Goosey-Tolfrey et al., 2002), as well as developmental histories (Dehghansai, Lemez, Wattie, & Baker, 2017a).

While this research has made contributions to the Paralympic movement, there is still a need for research on the development of expertise in parasport. Considering the rapid growth of research completed on mainstream or able-bodied athletes, it is clear that research on the development of athletes with a physical disability has not matched the same level of growth (Dehghansai, Lemez, Wattie, & Baker, 2017b). A recent systematic review by Dehghansai et al., (2017b) was completed to look at the influences of developmental aspects of performance and competition on athletes with disabilities. After the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) evaluation, only 21 articles met the inclusion criteria. The small number of articles that were included in the review show that research on the developmental of athletes with physical disabilities is limited. Furthermore, the majority of the articles included in the review emphasized a common theme that there was a lack of training programs, and sport-specific guidelines for athletes with disabilities (Dehghansai et al., 2017b). The comparatively smaller amount of research completed on athletes with disabilities in parasport stresses the need for future directions and work examining the analysis and training development of athletes with disabilities (Deghgansai et al., 2017b).

1.15 Expert Performance in Sport

Expert performance in sport is defined as superior and consistent athletic performance and capabilities, over an extended period of time (Starkes, 1993). In order for an athlete to be considered an expert, he or she must excel in the following four domains: physiological, technical, emotional, and cognitive (decision-making/perceptual and tactical/strategic: Janelle & Hillman, 2003). One of the most enduring topics in the study of exceptional performances is whether such performances result predominantly from nature or nurture (Baker & Horton, 2004; Davids & Baker, 2007; Howe, Davidson & Sloboda, 1998). The nature-nurture debate outlines how individuals are products of either their genes or environments, outlining questions on the role of genetics, and the influence of environment and life experiences. This debate has been one of the most persistent in sport expertise research (Howe et al., 1998). Extensive research and reports have been completed on the different variables that are attributed to talent, athleticism, and performance (see Howe et al., 1998; Davids & Baker, 2007). Discussions from this research support the opinion that both nature and nurture play an important role in the development of individuals in physical and mental domains (Davids & Baker, 2007).

However, since an athlete's genes cannot be changed it is important to focus on the larger modifiable factors, such as athlete training environments and overall practice. The theory of deliberate practice, presented by Ericsson et al. (1993), suggests that innate talent – nature – does not have a primary role in the development expertise. Rather, the deliberate practice framework asserts that there is a monotonic relationship between practice and skill level, whereby the more an athlete practices, the greater their level of skill and expertise (Helsen et al., 1998). Importantly, deliberate practice activities are defined as those specifically done to improve performance in a certain domain (Ericsson et al., 1993). Furthermore, deliberate practice is also defined as effortful, not inherently enjoyable, and should not generate any immediate monetary or social incentives (Ericsson et al., 1993). In sport, deliberate practice are activities that athletes engage in with the sole intention of performance or competition improvement. When the guidelines of deliberate practice are met, motor, cognitive, and perceptual skills improve with overall performance (Ericsson et al., 1993). Research on superior performance of experts demonstrate that expertise development is largely dependent on the procurement of cognitive mechanisms resulting from engagement in deliberate practice (Ericsson & Ward, 2007)

1.16 Cognitive Performance in Sport

Cognitive performance domains include decision-making, strategic thinking, and perceptual and tactical skills (Janelle & Hillman, 2003). Domain-specific cognitive expertise in sports encompasses an athletes' ability to make rapid in-game decisions, as well as the athlete's technical and tactical knowledge of their sport (e.g. Prior knowledge of other teams, anticipation of movements from opposing teams. This is due to the fact that there are unique characteristics within each sport that are required for expertise (Baker & Horton, 2004). *Perceptual-cognitive skill* is an individual's ability to integrate environmental information with existing knowledge in order to return the appropriate response and execution (Marteniuk, 1976). In many team sports, athletes need to be able to execute a play, read their opponents, and make the correct move in order for success in performance (Williams, Davids, & Williams, 1999). Therefore, perceptual-cognitive skills are unique indicators to expert-performance.

Perceptual-cognitive skills are predominantly thought to be domain-specific and the result of domain-specific practice, and therefore specific to each sport (Mann et al., 2007; Nuri et al., 2013; Schapschröer et al., 2016). For example, Helsen & Starkes (1999) found no differences in general cognitive capacities in experts and non-experts (i.e. central and peripheral reaction and correction times), but differences between the groups in specific cognitive performance (i.e. when the tasks were specific to the domain of the participant; [soccer skills]). These findings supported the notion that perceptual-cognitive skills are the results of domain-specific practice. Similar findings have been found in multiple sports such as basketball (Allard, Graham, & Paarsalu, 1980), field hockey (Starkes, 1987), volleyball (Allard & Starkes, 1980; Ripoll, 1988) and soccer (Helsen & Pauwels 1993a,b). These results have been used to support the position that expert performance and perceptual-cognitive skills are predominantly the result of deliberate practice, and not innate genetic differences. However, contrary conceptualizations of expert perceptual-cognitive skills exists in research.

Proponents of general cognitive training have proposed that programs and activities with no domain-specific content, or motor control demands, could assist in improving athletes' mental abilities that involve processing dynamic situations. Supporters of general cognitive training suggest that a single training program could assist a variety of individuals, regardless of their domain of performance. An example of general cognitive training is multiple object tracking. Multiple object tracking (MOT) is a technique used to study and train how the human visual system tracks multiple objects over a period of time. Originally developed in 1988, this technique suggests that a number of objects (typically 4) can be attended to in an individuals' visual system, independent of dynamic environments, therefore allowing them to be consistently tracked (Pylyshyn & Storm, 1988). Researchers have proposed that MOT interventions can increase attention, working memory, and informational processing speed (Parsons et al., 2016). It has also been proposed that the benefits of MOT can extend to improving maneuvering and navigating through traffic (Faubert & Sidebottom, 2012), neurodevelopmental disorders (Tullo, Faubert & Bertone, 2017), learning disabilities (Tullo et al., 2016), and ageing populations (Assed et al., 2016; Legault, Allard, & Faubert, 2013. Proponents of MOT propose that the same technique could be used to train visual systems in athletes (Faubert, 2013)

The results on the effectiveness of general cognitive training have been mixed. A study completed by Wentink et al, (2016), looked at the effects of general cognitive training in post-stroke victims. This randomized control trial was completed on 107 patients, and tested the effect of an 8-week general cognitive training program supplied by Lumosity™. In total, sixteen games were used in the study and five cognitive domains were targeted: speed, memory, attention, flexibility, and problem solving. Results from this study showed that there was limited transfer to similar tasks (near transfer) and transfer to different or irrelevant tasks (far transfer) effects in the patients. The author also noted that, "… tasks need to be closely related to the impaired task itself", suggesting that domain-specificity is highly important in cognitive training techniques (Wentink et al., 2016).

Similarly, a comprehensive literature review by Simons et al., (2016), focused specifically on brain-training programs and interventions in current research. The review focused exclusively on published, peer-reviewed, scientific journal articles that Brain-Training companies cite for support and credibility for their claims – which included 132 studies. The authors concluded that while brain-training games improve performance on the trained task (i.e., the brain-training games themselves), there was little evidence to suggest that these interventions improve performance on closely related tasks, and minimal evidence showing that these interventions improve far-related tasks, or improves everyday general cognitive performance. They also found that many of the studies had gaps in design and analysis, which made it difficult to definitively conclude efficacy of training (as some of the published studies lacked specificity about design reporting – leaving room for subjective interpretation). The authors noted, "Practicing a cognitive task consistently improves performance on that task and closely related tasks, but the available evidence that such training generalizes to other tasks or to real-world performance is not compelling." (pg 71; Simons et al., 2016). In summary, it is important to understand that support for general-to-specific perceptual-cognitive skill transfers are scarce in research.

Despite conflicting claims about the importance of domain-specific practice and those about general cognitive training, many sports teams continue to use these training techniques in their daily schedules (www.neurotracker.net). Since there is limited evidence to say that a transfer occurs between general cognitive training and sport performance (Broadbent et al., 2015), more research is needed to understand the efficacy and utility of general cognitive training as a training tool. This project will add to current research on findings in perceptual-cognitive training programs. Furthermore, results from this study will add to the growth of para-sport research, and research on training development for athletes with physical disabilities (Dehghansai et al., 2016b).

1.2 RESEARCH QUESTIONS

1. What is the effect/impact of general cognitive training (GCT) on domain-specific skills in elite level athletes with physical disabilities?
2. What is the relationship between MOT training and on-court performance and sport-specific perceptual-cognitive skills (i.e. pattern recall) in Canadian elite level wheelchair basketball players

1.3 RESEARCH OBJECTIVES

The effect of general cognitive training and its impact on the execution of domain specific skills will be investigated. The research objectives are:

1. To investigate the effectiveness of a GCT intervention on sport-specific tasks in athletes with physical disabilities.
    a. To compare the following variables:
        i. Baseline data to follow-up data of sessions:
            - Multiple Object Tracking program: Neurotracker™
            - General Executive Functioning tasks: Cambridge Brain Sciences

- Temporal Occlusion Tasks: Wheelchair basketball specific Pattern recall
- Individual Technical Quality Measurement Tool (ITQMT) Measures: tool to measure specific on-court performance and skills

b. To look at potential mediating and moderating effects of performance on the MOT intervention

   i. Does the level of performance on the MOT intervention mediate on-court performance?
   ii. Does the level of performance on the MOT intervention moderate the strength of the relationship of on-court performance?
   iii. Does the intervention mediate sport-specific cognitive skills?
   iv. Does the intervention moderate the strength of the relationship of sport-specific skills?

c. To correlate all test components will overall intervention performance

   i. Are there statistically significant relationships present between the tests components?

1.4 RESEARCH HYPOTHESIS

1. Based on previous research findings (Simons et al., 2016; Wentink et al., 2016), it is hypothesized that participating in General Brain Training Games will have no effect on the sport-specific cognitive skills and performance in Canadian Wheelchair Basketball players
2. ITQMT Measures will be maintained, or vary only slightly from Week 1 comparisons to Week 6. According to the Power Law of Practice (Logan, 1988;

Newell & Rosenbloom, 1981), and looking at Practice Effects (Duff et al., 2007), performance is said to improve the most early in learning, begins to plateau over time, and approaches an asymptote later in learning (Logan 1988; Newell & Rosenbloom, 1981). Since this study explores learning and performance of high performance elite level athletes, the power law of practice (Logan, 1988; Newell & Rosenbloom, 1981) suggests it will likely take proportionately more time and practice to elicit improvements in skill.

3. According to previous research completed on attention and concentration tasks, people who completed the same test repeatedly improved their test performance. Furthermore, average reaction time and error rate decreases (see Bühner, 2001; Westhoff & Dewald, 1990). As such, it is hypothesized that tests scores on MOT will maintain or increase from Week 2 comparisons to Week 5 (the first and the last week of the MOT intervention; Faubert, 2013).

1.5 SIGNIFICANCE OF THE STUDY

1.51 Addressing the Gaps in Literature

Research has shown perceptual-cognitive skills to be task specific (Williams, Davids, Burwitz & Williams, 1994). This is based on the notion that different sports have different constraints, including sport-specific cues and perception-action demands (i.e. looking at your opponent’s swing and ball-air time in tennis vs. offensive/defensive plays in soccer; Mann et al., 2007). Athletes and performers need to be able to properly identify information in the environment, focus their attention, extract information from their environment, and create the appropriate response for success (Williams, Davids, & Williams, 1999). Past research has also consistently demonstrated that learning is domain and task specific (Williams, et al., 1994; Ericsson, 1993), and there is little evidence of transferability of general training or general cognitive skills into specific domains (Abernethy, et al., 2005; Wentink, et al., 2016).

Due to the fact that athletic expert performance involves both motor, and perceptual-cognitive skills (Williams & Ericsson, 2005), there needs to be more research focused on the deliberate practice of cognitive skills. Also, there is a need to test the hypothesis of transferability from general training to specific domains, as there is limited evidence to show that this exists (Wentink, et al., 2016). Future research is needed to understand if perceptual-cognitive training elicits a transfer in learning from a general to a specific domain (Broadbent, et al., 2015).

This study will also help to fill the gap in literature on the development of athletes with physical disabilities, as this research is currently underrepresented in the literature (Dehghansai et al., 2017b). Furthermore, there is little information published on the effect of general cognitive training programs on the parasport population. Therefore, the study will also be an addition to current research in cognitive training, but will shed light on this training in a new population.

1.52 Purpose and Overall Contribution

The overall purpose of this study is to test the effect of general cognitive training on domain-specific sport skills. Specifically, this study aims to test the relationship between MOT training, and on-court performance on-court and sport-specific perceptual-cognitive skills (i.e., pattern recall) in Canadian elite level wheelchair basketball players. This study and its results could be used to determine the possible implementation of MOT sessions into the Daily Training Environment (DTE) for Wheelchair Basketball Canada (WBC) and more generally, this research may also help to inform future training plans developed by coaches in wheelchair, or other Paralympic sports.

Although there is some literature published on the effect of general cognitive training into domain-specific skills, there is no known research testing this effect on elite level athletes with physical disabilities. This study will fill a void gap in literature by investigating the effect of general cognitive training (i.e. MOT sessions), on sport-specific performance and pattern recall skills in athletes with physical disabilities. This study may also help to shape individual reviews (i.e. how coaches design and implement individual performance plans) as well as practice plans in the future for para-sport programs.

1.6 REFERENCES

Abernethy, B., Baker, J., & Cotê, J. (2005). Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology, 19*(6), 705e718. http://dx.doi.org/10.1002/acp.1102

Allard, F., Graham, S. and Paarsalu, M. E. (1980). Perception in sport: basketball. *Journal of Sport Psychology*, *2*, 14±21.

Allard, F. and Starkes, J. L. (1980). Perception in sport: volleyball. *Journal of Sport Psychology, 2*, 22±23.

Baker, J., & Farrow, D. (2015). *Routledge handbook of sport expertise*. London: Routledge.

Baker, J., & Horton, S., (2004). A review of the primary and secondary influences on sport expertise. *High Ability Studies*, *15*:2, 211-228. doi: 10.1080/1359813042000314781

Baker, J., & Young, B. W., (2014). 20 years later: Deliberate practice and the development of expertise in sport. *International Review of Sport & Exercise Psychology,* 7(1), 135 – 157. doi: 10.1080/1750984X.2014.896024

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science, 15*(4), 322-331. doi:10.1080/17461391.2014.957727

Bühner, M. (2001). Die Bedeutung von mentaler Operation und Material bei der Erfassung von der Konzentrationstest-Leistung. Ein Beitrag zur Validität von

Durchstreichtests [The meaning of mental operation and material in the assessment of concentration performance. A contribution to validity of concentration tests of the cancelling type]. Hamburg: Kovac.

Burkett, B., Mellifont, R., & Mason, B., (2010). The influence of swimming start components for selected Olympic and Paralympic swimmers. *Journal of Applied Biomechanics,* 26(2), 134-141. Pubmed doi:10.1123/jab.26.2.134

Coyle, D., (2009). *The Talent Code: Greatness Isn't Born. It's Grown. Here's How.* New York, NY: Bantam Dell.

Daly, D. J., Djobova, S. K., Malone, L. A., Vanlandewijck, Y., & Steadward, R. D., (2003). Swimming speed patterns and stroking variables in the Paralympic 100-m freestyle. *Adapted Physical Activity Quarterly, 20*(3), 260 – 278. doi:10.1123/apaq.20.3.260

Davids, K., & Baker, J., (2007). Genes, environment, and sport performance: Why the nature-nurture dualism is no longer relevant. *Sports Medicine, 37*(11): 1.

de Groot, S., Bos, F., Koopman, J., Hoekstra, A. E., & Vegter, R. J. K., (2017;2016). Effect of holding a racket on propulsion technique of wheelchair tennis players. *Scandinavian Journal of Medicine & Science in Sports, 27*(9), 918-924. doi: 10.1111/sms.12701

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017a). Training and development of Canadian wheelchair basketball players. *European Journal of Sport Science,17*(5), 511-518. doi:10.1080/17461391.2016.1276636

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017b). A systematic review of influences on development of athletes with disabilities. *Adapted Physical Activity Quarterly, 34*(1), 72-90. doi: 10.1123/APAQ.2016-0030

Duff, K., Beglinger, L. J., Schultz, S. K., Moser, D. J., McCaffrey, R. J., Haase, R. F., Westervelt, H. JK., Langbehn, D. R., Paulsen, J. S., & Huntington's Study Group (2007). Practice effects in the prediction of long-term cognitive outcome in three patient samples: A novel prognostic index. *Archives of Neuropsychology: The Official Journal of the National Academy of Neuropsychologists, 22*(1), 15 – 24. doi: 10.1016/j.acn.2006.08.013

Epstein, D., (2014). *The Sports Gene: Inside the Science of Extraordinary Athletic Performance*. New York, NY: The Penguin Group

Ericsson, K.A., Krampe, R.T. and Tesch-Römer, C., (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance, *Psychological Review*, *100*, 363-406.

Ericsson, K. A., and Ward, P. (2007). Capturing the naturally occurring superior performance of experts in the laboratory. *Current Directions in Psychological Science, 16*, 346-350.

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports (Nature Publisher Group), 3,* 1154.

Faubert, J. & Sidebottom, L. (2012). Perceptual-cognitive training of athletes. *Journal of Clinical Sport Psychology, 6*, 85-102. doi:10.1123/jcsp.6.1.85

Gladwell, M., (2008). *Outliers: The Story of Success*. London: The Penguin Group.

Goosey-Tolfrey, V. L., Alfano, H., & Fowler, N (2008). The influence of crank length and cadence on mechanical efficiency in hand cycling. *European Journal of Applied Psychology, 102*, Issue 2, 189-194. doi:10.1007/s00421-007-0576-7

Goosey-Tolfrey, V. L., Butterworth, D., & Morriss, C. (2002). Free throw shooting technique of male wheelchair basketball players. *Adapted Physical Activity Quarterly*, *19*(2), 238-250.

Griggs, K., Havenith, G., Price, M., Paulson, T., & Goosey-Tolfrey, V. (2015). Effectiveness of pre-cooling and cooling during play on wheelchair rugby performance. *Extreme Physiology & Medicine*, *4*(Suppl 1), A4. doi:10.1186/2046-7648-4-S1-A4

Helsen, W. and Pauwels, J. M. (1993a). A cognitive approach to visual search in sport. In D. Brogan, A. Gale and K. Carr K (Eds), *Visual search II* (pp.379±388).

Helsen, W. and Pauwels, J. M. (1993b). The relationship between expertise and visual information processing in sport. In J. Starkes and F. Allard (Eds), Cognitive issues in motor expertise (pp.109±134). Amsterdam: North-Holland.

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology*, *20*(1), 12

Helsen, W., & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, *13,* 1-27.

Hodges, N. J., & Williams, M. A. (2012). *Skill acquisition in sport: theory and practice*. London: Routledge.

Howe, M. J. A., Davidson, J., & Sloboda, J. A., (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences, 21*, 399 - 442

Janelle, C.M., & Hillman, C.H. (2003). Expert performance in sport: Current perspective and critical issues. In J.L. Starkes & K.A. Ericsson (Eds.), Expert Performance in sports: Advances in research on sport expertise. Champaign, IL: Human Kinetics

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*, 492–527

Mandeville Legacy (2014). Retrieved December 10th, 2017, from: http://www.mandevillelegacy.org.uk/category/topics

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: a meta-analysis. *Journal of Sport & Exercise Psychology, 29*(4), 457478.

Marteniuk, R.G. (1976). *Information processing in motor skills*. New York: Holt, Rinehart, and Winston.

Murdoch, J., (2012, August 30). London 2012 Paralympic athletes: The full list of competitors and disciplines. *The Guardian*. Retrieved from: http://www.theguardian.com/ news/datablog/2012/aug/30/every-paralympic-athlete-and-their-sport-data

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition*, 1–55. Hillsdale, N.J.: Erlbaum

Nuri, L., Shadmehr, A., Ghotbi, N., & Attarbashi Moghadam, B. (2013). Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport. *European Journal of Science, Vol. 13*, No. 5, 431-436. doi:10.1080/17461391.2012.738712

Paralympics – History of the Movement (n.d.) Retrieved on January 3rd, 2018 from, https://www.paralympic.org/the-ipc/history-of-the-movement

Parsons, B., Magill, T., Boucher, A., Zhang, M., Zogbo, K., Bérubé, S., Scheffer, O., Beauregard, M., & Faubert, J. (2016). Enhancing cognitive function using perceptual-cognitive training. *Clinical EEG and Neuroscience, Vol. 47*(1), 37-47. doi:10.1177/1550059414563746

Pylyshyn, Z. W., & Storm, R. W., (1988). Tracking multiple independent targets: evidence for parallel tracking mechanism. *Spatial Vision*, *3*(3): 179 – 197

Rees, T., Hardy, L., Güllich, A., Abernethy, B., Côté, J., Woodman, T., Montgomery, H., Laing, S., Warr, C., (2016). The Great British medalists project: A review of current knowledge on the development of the world's best sporting talent. *Sports Medicine*, *46*(8). doi:10.1007/s40279-016-0476-2

Rhodes, J. M., Mason, B. S., Paulson, T. A. W., & Goosey-Tolfrey, V. L. (2016). A comparison of speed profiles during training and competition in elite wheelchair rugby players. *International Journal of Sports Physiology and Performance*, 1-20. doi:10.1123/ijspp.2016-0218

Richardson, E. V., Papathomas, A., Smith, B., & Goosey-Tolfrey, V. L. (2017). The psychosocial impact of wheelchair tennis on participants from developing countries. *Disability and Rehabilitation, 39*(2), 193-200. doi:10.3109/09638288.2015.1073372

Rio 2016. (n.d.) Retrieved September 5th, 2017 from, http://paralympic.ca/rio2016

Ripoll, H. (1988). Analysis of visual scanning patterns of volleyball players in a problem solving task. *International Journal of Sport Psychology, 19*, 9±25.

Scanlan, T. K., Carpenter, P. J., Schmidt, G. W., Simons, J. P., & Keeler, B. (1993a). An Introduction to the Sport Commitment Model. *Journal of Sport & Exercise Psychology, 15*(1), 1-15. 4.

Scanlan, T. K., Simons, J. P., Carpenter, P. J., Schmidt, G. W., & Keeler, B. (1993b). The Sport Commitment Model: Development for the Youth-Sport Domain. *Journal of Sport & Exercise Psychology, 15*(1), 16-38.

Schapschröer, M., Baker, J., & Schorer, J. (2016). Effects of domain-specific exercise load on speed and accuracy of a domain-specific perceptual-cognitive task. *Human movement science, 48*, 121-131. doi:10.1016/j.humov.2016.05.001

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., Stine-Morrow, E. A. L. (2016). Do “brain training” programs work? *Psychological Science in the Public Interest, Vol. 17*(3), 103-186. doi:10.1177/1529100616661983

Starkes, J. L. (1987). Skill in field hockey: the nature of the cognitive advantage. *Journal of Sport Psychology, 9*, 146–160.

Starkes, J. L., (1993). Motor experts: Opening thoughts. In J. L. Starkes & F. Allard (eds.), *Cognitive Issues in Motor Expertise* (pp. 3-16). Amsterdam: Elsevier

Starkes, J. L., & Ericsson, K. A. (2003). *Expert performance in sport: advances in research on sport expertise.* Champaign: Human Kinetics.

Syed, M., (2011). *Bounce: The Myth of Talent and the Power of Practice*. London: HarperCollins

Wentink, M. M., Berger, M. A., de Kloet, A. J., Meesters, J., Band, G. P., Wolterbeek, R., Goossens, P. H., Vlieland, T. P. (2016). The effects of an 8-week computer-based brain training programme on cognitive functioning, QOL, and self-efficacy after stroke. *Neuropsychological Rehabilitation, 26(*5-6):847-65. doi:10.1080/09602011.2016.1162175.

Westhoff, K., & Dewald, D., (1990). Effekte der Übung in der Bearbeitung von Konzentrationstests [Effects of practice in concentration tests.]. *Diagnostica, 26*, 1–15

Williams, A.M., Davids, K., Burwitz, L., & Williams, J.G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport*, *6*(2), 127-135.

Williams, A.M., Davids, K., & Williams, J.G. (1999). *Visual Perception and Action in Sport*. London: E & FN Spon

Williams, A. M., & Ericsson, A. K., (2005). Perceptual-cognitive expertise in sport: some considerations when applying the expert performance approach. *Human Movement Science, 24*(3): 283-307.

CHAPTER 2: REVIEW OF THE LITERATURE

Literature Review

The following literature review will highlight evidence and findings relevant to the acquisition of skill regarding Deliberate Practice (DP), perceptual-cognitive skills, pattern-recall skills, and general-cognitive training in athletes in high performance sport. Table 1 outlines definitions of cognitive function and common terms used in the literature review (adapted from Harris, Wilson & Vine, 2018).

Table 1. Description of common terms and associated tests used in present study

Cognitive Function	**Description** (*tests used in present study*)
Sport Expertise	The ability to consistently demonstrate superior athletic performance (Starkes, 1993)
Perceptual-cognitive Skills	"Ability to identify and acquire environmental information for integration with existing knowledge, so that appropriate responses can be selected and executed" (Marteniuk, 1973)
Working Memory (WM)	Mechanism of cognitive capacity that is capable of information retention in a dynamic setting for on-going use (Harris, Wilson & Vine, 2018). *Spatial Span, Token Search*
Executive Function (EF)	Multi-component construct that includes attentional control, planning, fluid intelligence, organization, evaluation, and coordination. Important for attention allocation in high-level function (i.e. reasoning, problem solving; Harris, Wilson & Vine, 2018). *Double Trouble, Feature Match, Rotations, Spatial Span, Token Search, Multiple Object Tracking*
Inhibition	"Construct of WM and component of EF which suppresses irrelevant or unimportant information" (Harris, Wilson & Vine, 2018). *Double Trouble (i.e. Stroop Test)*
Divided Attention	Ability to simultaneously process different sources of information and multitask at any time (Harris, Wilson & Vine, 2018). *Multiple Object Tracking.*
Selective Attention	A cognitive process whereby someone can search for relevant information, while disregarding irrelevant information at hand (i.e. completing a word-search; Harris, Wilson & Vine, 2018). *Token Search, Feature Match, Spatial Span*
Crystalline Intelligence	"One's ability to use learned knowledge and experience" (Harris, Wilson & Vine, 2018). *Pattern-Recall Task.*

Processing Speed	Overall time used to possess, process, and use (respond to) information. Can be domain specific in some instances (Harris, Wilson & Vine, 2018). *Double Trouble, Rotations, Token Search, Feature Match*
Short Term Memory (STM)	The limited capacity to temporarily retain a small amount of information to be used in WM (Harris, Wilson & Vine, 2018). *Spatial Span, Pattern-Recall*
Reasoning	"The process of making judgements (i.e. conclusions) in a sensible, logical way" (Harris, Wilson & Vine, 2018).
Anticipation	Ability to predict a future outcome or event (North, Hope & Williams, 2016)
Decision-Making	Individual's capability to process information and choose an appropriate corresponding action to achieve a specific task goal (Hastie, 2001)
Pattern-Recall	"Ability to accurately and effectively 'read' and recall patterns" (Helsen & Starkes, 1999)
Deliberate Practice (DP)	"Highly effortful, unenjoyable, structured activities with the sole goal of improving performance. These activities are done with the express purpose of improving performance" (Ericsson et al., 1993).

2.1 DELIBERATE PRACTICE AND SPORTS

Twenty-four years ago, psychologist Anders Ericsson introduced the theory of deliberate practice (Ericsson et al., 1993). This theory proposed that engaging in any training was not enough to acquire expertise, but rather "deliberate practice" was necessary to explain expert achievement. *Deliberate practice* (DP) is defined as a highly effortful, unenjoyable and structured activity with the sole goal of improving performance (Baker & Young, 2014; Ericsson et al., 1993). Ericsson et al. (1993) proposed that DP is the primary type of activity necessary to develop expert performers, and it has been highly researched as a constraint on the attainment for elite athleticism and expert performance (Baker & Young, 2014). DP is also defined as activities that are done for the express purpose of improving performance (Ericsson et al., 1993). When the guidelines of DP are met, practice improves the speed and accuracy of motor, cognitive and perceptual tasks in a given domain (Ericsson et al., 1993). It is important to note that the theory of DP is based on the engagement of domain-specific forms of practice, rather than general practice (Ericsson et al., 1993; Baker, Côté, & Deakin 2005).

Studies on deliberate practice in sports have consistently shown that experts spend more time in overall training, when compared to novices (Baker & Young, 2014). Studies have shown that experts allocate more time to engaging in specific activities that are the most relevant to the development of critical skills for expert performance (Baker, Côté, & Abernethy, 2003). For example, the Baker et al., (2005) study, looked at the accumulated hours of practice (deliberate practice) within ultra-endurance (UE) triathletes. Participants (n=28) were divided into 'front of the pack', 'middle of the pack', and 'back of the pack' groups based on their finishing times compared to the mean (average) finishing time of their population (i.e. 25-40 years). Detailed athlete history questionnaires were completed, as well as an in depth one-on-one interview with each participant about training histories. Results showed that the expert (front of the pack) athletes accumulated approximately 12,558 hours of triathlon (cumulative running, swimming and cycling training) training, with 'middle of the pack' accumulating 6,195 hours, and 'back of the pack' accumulating 4,122 hours total. This study supports that expert athletes partake in a greater amount of quality training than their less skilled counterparts (Baker et al., 2005). Results also demonstrated that the experts engaged in more sport-specific training, including phases of periodization, when compared to their intermediate counterparts. Although this study may not explain the cause-and-effect relationship between DP and expert development, it suggests that expert performance likely originates from a greater amount of accumulated hours of specific training.

Studies completed on figure skaters, and karate athletes (Baker et al., 2003) provide strong support for Ericsson et al.'s (1993) original theory about hours of practice being related to level of performance (Baker et al., 2003). The same relationship can be found in team sports. The aforementioned study by Baker et al., (2003) looked at the effects of accumulated hours (deliberate practice) between experts and non-experts from team ball sports (netball, basketball, and field hockey). Fifteen expert decision makers and thirteen non-experts were recruited for the study, and provided extensive information about the quantity and quality of training (sport-specific and general) and training histories. Results showed that the experts in the study were involved in their sport for at least 10 years, and nearly 13 years on average before reaching National team selections. At the 13-year mark however, experts showed to have accumulated approximately 4,000 hours of sport-specific training, far below the 10,000 hour rule reported for expert musicians by Ericsson et al., (1993). Comparing the training hours between expert and non-expert performers, results showed that expert athletes invested a significantly greater amount of time in one-on-one coaching, video sessions and organized team practices, compared to the non-experts (Baker et al., 2003). The results from this study concluded that the original theory of 10-years of participation, developed from Simon and Chase (1973), remains a good base to explain the level of minimal involvement needed for expertise development. However, this study also found that there was large variability between the numbers of accumulated hours between sports, which indicates that there are additional factors that contribute to expert performance along with hours of Deliberate Practice (Baker et al., 2003).

Specific to team sports, much of the practice that occurs is coach-determined. Considering team practices, it can be predicted that overall time spent practicing as a team can be less predictive of individual skill attainment (Helsen et al., 1998). This is due to allocation of practice devoted to the lowest or highest skill needed for a team, and not necessarily a skill that would advance each individual (Helsen et al., 1998). Deliberate practice in team sports can also be considered a 'grey area' in the development of expertise, as both team and individual practice occurs in these domains. Therefore, it is important to consider the sport-specific practice involved in team sports for the overall team, as well as the individual (Helsen et al., 1998). A two-part study completed by Helsen et al., (1998) tested the theory of deliberate practice in team sport athletes. The first-part method looking at the deliberate practice of soccer players, included three groups of male soccer players from international divisions (n=17), World Cup athletes (n=12), and national team players (n=21). The procedure included the participants completing a questionnaire reflecting on their careers, and recalling the amount of time they spent practicing for soccer, soccer-related activities, and other everyday activities. The second part of the procedure was to get the participants to rate each activity within four domains: relevance to improve soccer performance, effort required for activity, enjoyment derived from each activity, and concentration necessary to perform activity. Results from the questionnaire showed that all soccer groups began playing soccer, and took part in team practices around the same age (average 2 years after starting soccer). National and international players showed peak accumulated practice at 15 years into soccer career, while the provincial players showed their peak at 6 years into their career. The international players showed 2 hours of individual practice per week, in addition to approximately 11 hours of team practice per week. At the ten year mark of career progression, all groups showed to be significantly below the suggested 10,000 accumulated hours of practice (Ericsson, 1993) with the international group at approximately 4,000 hours, the national group at 3,800 and the provincial group at 3,000 hours, respectively. The same questionnaire (from first group of participants) was given to field hockey players who decided to participate in the study. All groups began field hockey and team practices at the same times. Results from the latter part of the study showed that similar to soccer players, field hockey players exhibited practiced far below the suggested 10,000 hour mark. International field hockey players demonstrated to have accumulated 10,237 of combined individual and team practice hours at 18 years into their career – soccer players attained 9,332 hours by the same benchmark. Overall, the results suggests that approximately 10 years into an athletes' career is when important choices and decisions are made about training. Furthermore, data analysis showed a direct relationship between accumulated hours of practice, and eventual performance level achieved, which coincides to Ericsson's (1993) original findings.

In summary, there is compelling evidence that a primary factor in the development of expertise is due to accumulated hours of practice and DP. (Ericsson et al., 1993; Williams & Ward, 2003). One of the reasons deliberate practice is likely so important to expertise development is because it is related to the development perceptual cognitive skills, a consistent differentiator between athletes of different skill levels (Hodges & Starkes, 1996; Starkes et al., 1996).

2.2 PERCEPTUAL-COGNITIVE SKILLS

Although elite sport performance is readily evident through observation, mechanisms that contribute to *expert* performance are less apparent (Mann et al., 2007). Perceptual-cognitive skill is defined as an individual's ability to integrate environmental information with existing knowledge in order for appropriate responses to be selected and executed (Marteniuk, 1976). Athletes depend on their perceptual-cognitive skills to achieve the best possible results in their sport domain. For example, knowing when and where to look in practice or competition, is a vital key for successful performance (Mann et al., 2007). Perceptual-cognitive skill training research emerged as early as the 1950s, when Damron (1955) trained two groups of American high school football players using slide presentations. Players participated in 16 sessions of slide presentations, and were able to accurately recognize 75% of football-specific plays (Damron, 1955, Ward et al., 2008). Furthermore, when the two groups were retested in a temporal occlusion task with the same plays (using live players), they were then able to recognize 95% of defensive plays shown. Results from this study suggest that perceptual-cognitive skills are trainable, and also, these skills can be recognized within on-field performance (Ward et al., 2008). In many cases, athletes are faced with saturated visual displays that are rich with both relevant and irrelevant information needed for a task. As such, sport performers must be able to identify the relevant information, appropriately direct their attention, and effectively extract meaning from these areas (Williams, Davids & Williams, 1999).

Initially, it was hypothesized that differences between experts and non-experts were the result of innate differences in general perceptual-cognitive and motor skills, such as reaction time, static and dynamic visual acuity, and range of peripheral vision (Starkes et al., 1995). However, findings suggest that superior performance in experts is not likely due to differences in visual and sensory abilities (Starkes et al., 1995). In a seminal study, Helsen and Starkes (1999) looked at these impacts of domain-specific cognitive skills between expert and novice soccer players. Specifically, they focused on differences between skilled and less skilled athlete’s information processing (i.e. how athletes attain information in their environment) by measuring eye-movements (Helsen & Starkes, 1999).

Base on the skills that were assessed, a number of participants were identified. Twenty-eight male subjects volunteered to take part in the study, and took part in all three experiments. The expert group consisted of 14 semi-professional soccer players, who had approximately 10 years of prior competition experience. The intermediate group consisted of 14 kinesiology undergraduate students, with physical activity experience, enough soccer experience to perform in a game. The intermediate group had no competitive soccer experience post high school, and reported no previous experience or skill in any interceptive ball sport. The first experiment was a laboratory test of non-specific abilities. The methods for Experiment 1 measured processing parameters (i.e. central and peripheral reaction time, and visual correction time), optometric measures (i.e. static visual acuity, and dynamic visual acuity), and perimetric parameters (i.e. differential light threshold). To test the non-specific abilities of the athletes, they were subject to a target detection task, which involved them in a seated position with a head-apparatus showing different points of light at various angles. The participants job was to focus on a target and use a button on a stylus (in their dominant hand) to indicate when the light had appeared (i.e. central vs. peripheral signals in the vertical and horizontal plane). Participants eye movements and fixations could be checked through a reticulate telescope during the tests. Results from experiment 1 showed that the experts performed no greater than the intermediate group of participants. The experts did not possess superior central and peripheral visual reaction times, or correction times.

Experiment 2 looked at whether differences between the groups would emerge in a soccer-specific task of static slide stimuli. In the second experiment, each subject looked at 30 game-typical offensive plays (in the point-of-view of the ball handler). Once the slide was presented, the participant verbalized the next offensive move, with possible answers as, “shoot at the goal”, “dribble around the goal keeper or opponent”, or “pass to one of four teammates”. The time for reaction was stopped as soon as the participant responded to the slide. Reaction time results showed that the experts performed greater in verbal responses of shooting (1081ms), dribbling (1332ms), and passing (1560ms), when compared to the intermediate group (shooting = 1502ms, dribbling = 2070ms, passing = 2064ms). As well, results showed that the experts performed significantly better than the less skilled participants in response accuracy percentage. These results suggest that response speed and accuracy are dependent on participant competence, with experts showing faster response times and higher accuracy in tactical game problems, compared to the less-skilled counterparts. Fixation results also showed that experts used less fixations overall when making-decisions about tactical game play. This suggests that experts can ‘do more with less’, and they can make thorough decisions, with less information from the environment. This is probably due to expert’s previous domain-specific knowledge, which allows them to use present information and make a decision faster, and more accurately.

Previous researchers (Starkes, 1987; Abernethy et al., 1994; Starkes et al., 1995, 1996) have shown that the more task-specific the cognitive test is to the actual game, the greater the difference between experts and non-experts. With this, Experiment 3 was to take the participants through the same responses as Experiment 2, but now with sport-specific simulated video clips, as well with a soccer-specific motor response instead of a verbal response. The film was projected onto a wall in front of the participant, in order to make it more real-life. At one part in each of the film slides, the ball is passed to the participant, who then needed to make a movement decision as quickly and as accurately as possible. The responses were the same as the previous experiment (i.e. shoot at the goal, dribble around the goalkeeper or opponent, or pass to a specific and free teammate). The total timing of the response was broken into 3 divisions from when the subject started their movement (i.e. initiation time), when they touched the ball (i.e. ball/foot contact time), and when the ball finally reached the screen (i.e. total response time). The results from this experiment show that when participants were shown dynamic, domain-relevant tasks, experts were able to use early information before responding to the stimuli. As well, they were able to make better use of the information from the player's position in a game, whereas non-experts looked primarily at the soccer ball, attackers and the goal. The results from the three experiments outline that variables involved in perceptual-cognitive training (i.e. decision-making skills, anticipation) of expert performers are domain-specific (Helsen & Starkes, 1999).

Subsequent research has confirmed that perceptual-cognitive skills between experts and non-experts are domain specific (Williams, Davids, Burwitz, & Williams, 1993, 1994; Williams & Davids, 1995). For example, research suggests that experts recall, retain, and recognize a greater amount of information in structured contexts than novice performers, when information is brief and domain-specific (Helsen & Starkes, 1999). These findings have been found in team sports such as field hockey (Starkes, 1987), soccer (Helsen & Pauwels, 1993a), and basketball (Allard, Graham, & Paarsalu, 1980). These findings highlight the importance of structured vs. unstructured patterns in anticipation and decision-making skills (see: Chase & Simon, 1973; Abernethy et al., 2005; Schapschröer et al., 2016; Baker et al., 2005). A classic example of this is Chase and Simon's (1973) study on chess players. They looked at the differences in performance between world-class chess players, compared to skilled recreational chess players. They hypothesized that both leveled players did not differ in their basic abilities, cognitive make-up, and general capabilities. Moreover, the theory proposed that experts had the same mental constraints as their novice counter-parts in regards the limits of short-term memory (STM), and processing speed. Simon and Chase suggested that performance from experts resulted from their immense knowledge and understanding, which had been acquired from many years of experience within their particular domains (Simon & Chase, 1973). In a series of studies, Simon and Chase (1973) showed the effects of expert's memory on domain-specific chess configurations. The methods included showing structured and unstructured chess patterns to the subjects. When presented with structured patterns, experts were able to more accurately recall the structure of chess piece patterns compared to non-experts. However, when the structure (and domain-specific relevance) was removed from the patterns, the experts demonstrated similar recall capacity as the less-skilled subjects; only being able to recall a few pieces (Simon & Chase, 1973). These findings support the notion that expert performance can be attributed to meaningful and specific training in a specific domain, not to general short-term working memory, or general cognitive capacities.

Expert performers from various domains have demonstrated the ability to accurately recall information contained within complex patterns in performance (Gorman et al., 2013). When shown unstructured random patterns, experts perform no differently than non-experts in recall tasks (Simon & Chase, 1973; Helsen & Starkes, 1999). As such, characteristics that distinguish between experts and non-experts appear to be primarily the result of domain-specific knowledge and experience rather than general capacity (Abernethy, Neal, & Koning, 1994; Helsen & Starkes, 1999; Starkes, 1987).

Moreover, research has shown that experts differ from non-experts regarding sport-specific cognitive measures (Mann et al., 2007; Abernethy et al., 2005; Chamberlain & Coehlho, 1993). A meta-analysis of (N=42, 388 effect sizes) conducted by Mann et al., (2007) found that experts out performed novice counterparts on a range of perceptual-cognitive skills, including decision-making skills and anticipation.

In addition, a study conducted by Allard et al., (1980) used static basketball images. It was found that the expert basketball players recalled the positions of more players when compared to the novices. This study and other examples (see Gilhooly et al., 1988; Adelson, 1981), use testing measures in the form of a structured or unstructured patterns. Furthermore, these situations all show that the highly skilled individuals are superior at pattern recall and recognition in their domain of expertise, when compared to their less-skilled counterparts (Gorman et al.,2013; Helsen & Starkes, 1999). Given the expert-novice differences in perceptual-cognitive skills researchers have explored whether perceptual-cognitive skills can be trained in interventions.

An example of perceptual-cognitive training interventions is also seen in the study by Adolphe, Vickers, and Laplante (1997), which used similar to above training interventions to improve the accuracy of elite tennis player’s gaze during a serve. Using a video-based simulation, and on-court practice as the training apparatus, participants were subjected to 6-weeks of training in gaze behaviour and ball tracking in tennis. Results from the study displayed improvements in ball tracking from the participants. Furthermore, a 3-year follow-up was conducted, and participants exhibited improvements in accuracy of returns (i.e. Tennis serves; Adolphe et al., 1997; Ward et al., 2008). However, given the extended period of practice time in this study (i.e. 3 years), it is hard to establish whether solely perceptual-cognitive training explains improvements in performance (Ward et al., 2008). Moving forward, it is important to understand the issues and limitations (i.e. identifying whether rate of return is based on intervention alone, or in combination with other training) in perceptual-cognitive training interventions in sport performance.

In summary, results from the above studies demonstrate that perceptual cognitive skill differentiates expert from non-expert performers. Furthermore, perceptual-cognitive skills are domain specific, and presumably, the result of domain-specific deliberate practice. We observe from these studies that the perceptual-cognitive skills being tested had to be deliberately trained through sport-specific, domain-specific practice. However, there has been a resurgence in the notion that general cognitive training applications to sport are also beneficial to performance, and that perhaps skills may not be solely in need of sport-specific, domain-specific practice.

2.3 GENERAL COGNITIVE TRAINING

Recently, a number of *general* brain training tools and software programs have emerged on the market (i.e. games or activities that hypothesize to exercise the brain, similar to exercising the body. These games tend to have no domain-specific movements or perceptual information). Commonly advertised on television, radio, internet and magazines, it is easy to come across claims about how these games will improve your life using the 'power of your brain' (Simons et al., 2016). For example, Lumosity is a product that involves cognitive tasks as fun-to-do games and notes that, "every game targets an important ability to you, like memory, attention, problem-solving, and more" ("Learn How Lumosity Works" video previously hosted at www.lumosity.com: "Cutting Edge Science Personalized for You," 2015; Simons et al., 2016). Other programs such as Cogmed and CogniFit use similar marketing strategies to target other niche markets such as schools and therapists (“How Cogmed is Different”, 2015), by noting it will decrease distractions, improve your daily life, and help you socially, academically and in the professional world (“How Cogmed is Different”, 2015; “Improve Your Brain While Having Fun”, 2015; Simons et al., 2016). These companies cite published articles, and referring to the company founders’ expertise (Simons et al., 2016). For example, Lumosity’s website provides customers or readers with 46 papers, conference presentations, and posters from the Human Cognition Project (www.lumosity.com/hcp/research/bibliography). Other companies such as CogniFit make similar statements, and say their games are designed by neuroscientists (“Improve Your Brain While Having Fun”, 2015; Simons et al., 2016).

However, researchers have raised questions about the validity and reliability of the claims these companies are making (Simons et al., 2016). Do these brain-training interventions make a difference in many real-world domains, such as social, academic and professional (Simons et al., 2016)? In October 2014, and open letter was issued by the Stanford Centre on Longevity and the Max Planck Institute for Human Development. This letter – signed by 70 neuroscientists and psychologists – objected to claims that, “brain games offer consumers a scientifically grounded avenue to reduce or reverse cognitive decline… there is no compelling scientific evidence to date that they do” (“A Consensus on the Brain Training Industry From the Scientific Community”, 2014). A similar open letter was released in December 2014, from over 133 scientists that agreed claims made by brain training companies may be exaggerated and misleading (www.cognitive-trainingdata.org/; Simons et al., 2016).

The controversy over general cognitive training continued in January 2016 when the Federal Trade Commission (FTC; Federal Trade Commission, 2016a) charged Lumos

Labs with “deceptive advertising”. This charge was the result of claims they had made about Lumosity’s effectiveness and success. “Lumosity preyed on consumers’ fears about age-related cognitive decline, suggesting their games could stave off memory loss, dementia, and even Alzheimer’s disease. But Lumosity simply did not have the science to back up its’ ads”, said by an FTC official (Federal Trade Commission, 2016a). After the $2M settlement, the FTC and Lumos Labs agreed that any future claims made by the company would have to be substantiated with competent scientific evidence, and test standards would need to be, “randomized, adequately controlled, and blinded to the maximum extent practicable” (Federal Trade Commission, 2016b).

Brain-training companies market their products claiming the success rate of decreasing many cognitive impairments and outcomes (Simons et al., 2016). Age-related cognitive impairment, Alzheimer’s, Turner syndrome, and schizophrenia, are all examples of specific diagnoses that are said to decrease with the use of brain-training games (Simons et al., 2016). Contrary to arguments that expertise results from domain-specific practice (Abernethy, Neal, & Koning, 1994; Helsen & Starkes, 1999; Starkes, 1987), these programs claim that single non-specific interventions can have an array of positive outcomes (Simons et al., 2016). Research on general cognitive training has spanned across multiple domains with studies looking at post-stroke victims (Wentink et al., 2016), healthy aging populations (Roudaia, Lacoste & Faubert, 2016), individuals with learning disabilities (Tullo, Guy, Faubert, & Bertone, 2016), and professional athletes (Faubert, 2013).

For example, Wentink et al. (2016), used Lumosity as their protocol for testing cognitive function in post-stroke patients. Their purpose for the study was to assess the effect of a general computer-based brain training program on multiple aspects of cognitive function, quality of life (QoL), and self-efficacy, compared to the control group. 110 post-stroke patients enrolled and participated in the study (107 were included in post-study follow-up), and were instructed to complete 600 minutes of computer-based games (8 weeks, ~5 days/week, approximately 15-20 minutes/day). In using Lumosity, sixteen games were used that targeted five cognitive domains: attention, working memory, speed, flexibility, and problem-solving. The control group in the study received information online about post-stroke characteristics, and brain-damage. Every week of the intervention, new information was added online for the control group. The statistical analysis of scores (i.e. either speed of reaction time, or answers correct in testing) indicated little near and far transfer of the patients, and only performance on cognitive tests that were similar to the computer-based game improved in the training group and not the control group (Wentink, et al., 2016). In conclusion, the author noted that the tasks being learned need to be "…closely related to the impaired task itself" (Wentink et al., 2016). This study suggests that use of general cognitive training programs still lack context-specific motor demands, and therefore lack ability of transfer from general task to specific task. Regardless of this, some researchers claim that general to specific skill transfer (i.e. far transfer) is trainable, and exists in sport performance.

Supporters of general cognitive training have proposed that programs and activities with no domain-specific content, or motor control demands, could assist in improving athletes' mental abilities that involve processing dynamic situations (Faubert & Sidebottom 2012). An example of general cognitive training is multiple object tracking. Multiple object tracking (MOT) is a technique used to study and train how the human visual system tracks multiple objects over a period of time. This technique suggests that a number of objects (typically 4) can be attended to an individuals' visual system, independent of dynamic environments, therefore allowing them to be consistently tracked (Pylyshyn & Storm, 1988). MOT testing is used as a 'gold standard' for testing in a variety of populations. This is because MOT claims: no side effects, no risk of toxicity, minimal time investments, and lasting effects for the participant (Parsons et al., 2014). The cognitive functions hypothesized to be engaged when using MOT are attention, working memory, and processing speed (Faubert & Sidebottom, 2012; Parsons et al., 2016). Studies using MOT have reported benefits in an array of different populations including neurodevelopmental disorders (Tullo, Faubert & Bertone, 2017), learning disabilities (Tullo et al., 2016), ageing populations (Assed et al., 2016; Legault, Allard, & Faubert, 2013), and military training (Vartanian, Coady, & Blackler, 2016). In another example, Tullo et al., (2016), used MOT as a means to train attention in participants with learning disabilities. However, proposed interventions (i.e. pencil-and-paper tests, computer-game programs, nutritional supplements, and stimulants) have raised complaints that there is a lack of consistency in transfer effects, intervention can be costly, invasive to the participants, and associated ethical issues such as using supplements or nootropics (i.e. cognitive enhancing drugs; Parsons et al., 2016).

Parsons et al., (2016) used MOT to see if there were improvements in working memory, attention, and information processing speed. Twenty university-aged students were recruited to participate in the study and were randomly assigned to either the 3D-MOT group (n=10), or the control group (n=10). All subjects were required to complete neurophysiological tests, electroencephalogram (EEG), and a 3D-MOT session, regardless of the group they were placed in. For the MOT group, each participant was required to complete 3 sessions (20 trials/session) of MOT, twice per week, for a period of 5 weeks. The results showed that both the MOT and the control group improved their scores, but significantly differed in their final session scores as the control group's final MOT scores reflected only Week 2 of the MOT group. EEG results showed increases in theta and alpha frequency bands in the MOT group, and no changes were demonstrated in the control group. Overall results from the study showed that the MOT group made significant improvements in task scores, with a suggestion that the results may persist over time. Despite the 7-week delay from baseline to end-test scores, the control group also showed improvements in their scores (with scores resembling the first 2 week from the MOT group). The authors concluded that, in healthy populations, MOT training could improve some cognitive function in participants (Parsons et al., 2016).

Some general cognitive training programs using MOT are being used by elite level athletes (Neurotracker, 2016). One of these products, known as *The Neurotracker*™, is being used by many sports teams, including the Vancouver Canucks, Canadian Olympic Committee, Manchester United, and Atlanta Falcons (Neurotracker, 2016). These programs advocate that skills learned and retained from general brain training activities are transferable to specific domains (e.g., sport). Using MOT, 3D visual frames and speed thresholds, the technique of MOT claims to improve athletic performance by widening an athlete's visual field, as well as increase their general attention and memory capacity during performance (Neurotracker, 2016). Claims made from use of MOT training include: improvement proficiency for player and movement tracking on-court or in a field of play, increases in dual-perception tasks (i.e. reading the body language of an opponent without faulting in own performance), and increased ability to process patterns for in-field performance (Faubert et al., 2012; Romeas, Guldner, & Faubert, 2016; Perico et al., 2014; Faubert, 2013; Tinjust, Allard, & Faubert, 2008; Vartanian, Coady, & Blackler, 2016).

A study completed by Romeas, Guldner and Faubert (2016), assesses the transfer capabilities with 3D-MOT training in elite soccer players. This study hypothesized that the selective attention and processing speed of multiple moving targets would be crucial to assist in expert-decision making skills (Romeas, Guldner & Faubert, 2016). Therefore, the hypothesized skills that could improve through MOT training are passing, dribbling, and shooting, as these skills require navigating through many targets in a given time. Twenty-three males from the Carabins soccer team at the Université de Montréal were recruited to participate in the study, and were divided into 3D-MOT group (n=9), active control group (n=7), and passive control group (n=7). The experimental group (3D-MOT) completed 30 sessions of MOT (and were also actively trained for 10 training sessions; twice a week for five consecutive weeks). The active control participants watched 2010 FIFA World Cup soccer videos twice a week for five weeks. Participants in the active control group were informed prior to the test that this would have a positive effect on decision-making skills in performance. The participants in the passive control group received no instruction or training for the study. Subjective and objective decision-making field assessments were completed pre- and post-test (i.e. surveys on players confidence in decision-making [subjective], and short-sided-game [SSG] skill assessment of passing, dribbling, and shooting). Results from the experimental group showed that there was a significant improvement in passing accuracy between pre- and post-test sessions (15%, respectively). However, no differences were seen in decision-making accuracy for shooting and dribbling in this group compared to other groups. While no differences were observed in the active and passive control groups, participants in the experimental group reported improvements in confidence levels on decision-making skills. Results from this study indicate potential skill transfer from MOT sessions to on-field performance (Romeas, Guldner, & Faubert, 2016).

An earlier conference abstract by Perico, Tullo, Perrotti, Faubert, and Bertone (2014) looked at transferability from MOT tasks to other measures of attention with the use of feedback. Forty healthy adults participated in the 4-consecutive day trial, and were split into 2 experimental groups (one group received feedback during MOT sessions and attentional tasks, and the other group did not). On the 4th day of the trials, the feedback group performed significantly greater on MOT tasks, as well as greater transferability to other cognitive tasks (Perico et al., 2014). These results suggest that over the short 4-day trial, there appeared to be some level of transferability in the participants after their MOT sessions.

Although these programs are a seemingly compelling platform for developing anticipation and decision-making in athletes, there is limited evidence to say that a transfer of learning occurs between training using programs and sport performance (Broadbent et al., 2015). Claims that general cognitive training programs (i.e. non-specific to domains) have beneficial impacts on high performance sports may raise concerns to how general programs can have specific significance to improving high performance athletes. Conflicting findings exist about the effect of general cognitive training programs. Previous studies on such programs have shown that there are limited effects in the transferability of general skills to domain specific areas (Wentink et al., 2016).

For over 130 years, cognitive performance has been a focus of psychological studies and research (Tricot & Sweller, 2013). Much of that research has been focused on the effects of general cognitive skills and learning, despite a large body of research outlining the importance of domain-specific knowledge (Helsen & Starkes, 1999; Tricot & Sweller, 2013). Researchers concentrating in sport expertise, have focused on the perceptual-cognitive skills that are used in anticipation and decision making, and identified how these processes are acquired through engagement of practice (Williams et al., 2011).

In dynamic team sports, such as basketball, hockey, and soccer, knowing “when-and-where” to look is the difference between a successful and unsuccessful game (Williams, 2000). As well, the athlete’s ability to “read” the game (i.e., perceptual-cognitive skill) distinguishes expert (skilled) and non-expert (less skilled) athletes (Helsen & Starkes, 1999; Starkes et al., 1998; Williams, 2000). However, athletes in team and individual sports are not ranked based on superior vision (Abernethy 1987; Helsen & Starkes, 1999), and visual training programs have not shown transfer to the field of play/competition (Wood & Abernethy, 1997). However, there is some evidence to suggest that 3D-MOT can enhance cognitive function in healthy young adults (i.e. attention, visual information processing speed, and working memory; Parsons et al., 2016), and transfer to biological motion perception within laboratory settings in ageing populations (Legault & Faubert, 2012). Therefore, further research is needed to test similar effects in high performance athletes, or athletes in competitive playing fields.

Sport science literature suggests that an athlete’s perception of the environment and their attention allocation is a determining factor between expert and non-expert performers (Williams, Davids, & Williams, 1999). In comparison between skilled and non-skilled athletes, skilled athletes show greater proficiency in anticipation and decision-making skills, as well as pattern recall and technical awareness when the context is specific to the task (Helsen & Starkes, 1999; Williams, 2000).

2.4 CONCLUSION

Sport science literature focusing on deliberate practice in sports have consistently shown that experts spend more time in overall training, when compared to novices (Baker & Young, 2014; Helsen, Starkes, & Hodges, 1998; Helsen & Starkes, 1999). Experts also allocate more time to engaging in specific activities that are the most relevant to the development of critical skills for expert performance (i.e. deliberate practice; Baker, Côté, & Abernethy, 2003; Helsen, Starkes, & Hodges, 1998). With the use of DP in sports, future research is needed to confirm how general cognitive training fits into a specific athletic plan, or deliberate practice.

Athletes depend on their perceptual-cognitive skills to achieve the best possible results in their sport domain. For example, knowing when and where to look in practice or competition, is a vital key for successful performance (Mann et al., 2007). In many cases, athletes are faced with saturated visual displays that are rich with both relevant and irrelevant information needed for a task (Williams, Davids & Williams, 1999). Therefore, interventions that are inclusive of perceptual-cognitive training need to be related to the domain of the participant. Perceptual-cognitive skills are demonstrated to be the results of specific training and practice. However, some claims are made towards the benefit of general cognitive training when trying to increase these skills.

General cognitive programs pose an alluring platform for developing anticipation and decision-making in athletes. However, there is limited evidence that a transfer of learning occurs between training using programs and sport performance (Broadbent et al., 2015). Although some studies have reported transfer from general cognitive training to in-field performance and other cognitive abilities (Romeas, Guldner, & Faubert, 2016;

Perico et al., 2014; Faubert, 2013), there are conflicting findings that exist about the effect of general cognitive training programs to domain specific areas (Wentink et al., 2016).

2.5 THEORETICAL FRAMEWORK: THE EXPERT PERFORMANCE APPROACH

Ericsson and Smith (1991) proposed the Expert-Performance Approach as a framework to study expertise. This framework has been useful for studying expertise development, and it aligns with the aims of this project. Transferable across multiple domains (i.e. music, medicine, education, and sport; Ericsson, Krampe & Tesch-Römer, 1993; Ericsson, 2004; Plant, Ericsson, Hill & Asberg, 2004; Williams & Ward, 2003), the Expert-Performance Approach contains three interrelated stages: capture, identify, and examine (see Figure 1 – adapted from Ford, Coughlan & Williams, 2009; Ericsson, 2003; Ericsson & Smith, 1991). The first stage is to observe expert performance *in situ* or in experiments to see the essential skills that relate to the performance. Observation findings are then used to develop a representative simulated task that allows for reproduction of the essential skill in a controlled environment (Ford, Coughlan & Williams, 2009; Ericsson, 2003). The second stage of identifying the underlying mechanisms of expert performance are measured. This can be through cognitive processes (i.e. verbal reports, decision making skills), or gaze behavior (i.e. eye movements, temporal or spatial occlusion). The third and final stage is used to trace back expert mechanisms and identify how and when they were acquired; to be used for future implication or development of practice (Ford, Coughlan & Williams, 2009; Ericsson, 2003).

This framework was used in the present study to test the underlying mechanisms that lead to expert development, and if MOT has an effect on the development of sport-specific perceptual motor performance. Proponents of MOT typically market this technique as a way to increase expert performance, and to significantly increase already developed mechanisms for performance (Faubert & Sidebottom, 2012). Therefore, this framework was instrumental in determining the study design for the present study. Using tools that measure sport-specific perceptual-cognitive skill, as well as preexisting information on physical performance, we were able to use an intervention design (i.e., Stage 3) as a way to compare the differences from the start to the end of the study. Furthermore, this framework and study design allowed for the determination of MOT as a potentially useful training modality in this population. A description of each stage of the Expert Performance Approach, are presented below.

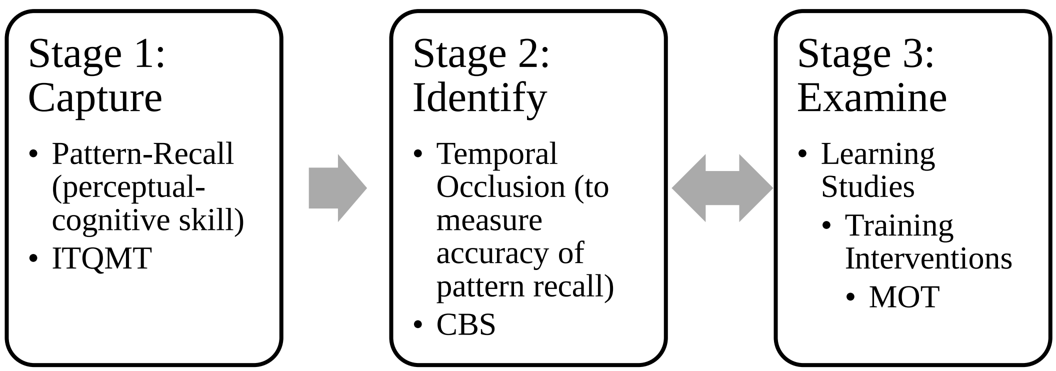


Figure 1. The Three Stages of the Expert-Performance Approach (adapted from: Ericsson & Smith, 1991; Ford, Coughlan, & Williams, 2009; Ericsson, 2003).

Stage 1: Capture

Previous research (Simon & Chase, 1973; Helsen & Starkes, 1999) has shown that expert-novice differences exist in many different fields of practice. For example, expert golfers outperform novices in putting accuracy (Beilock, Wierenga & Carr, 2003), and elite figure skaters and gymnasts outperform novices in technical jumps and combinations (Deakin & Cobley, 2003). Capturing expert performance in team sports can raise some challenges however, as there are defining roles for different players, but one consistent goal among all players. Furthermore, defining roles on teams would infer that each roles carries a specific goal (i.e. guard the defender/offender, create space for teammates, get the ball into the basket, etc.; Ericsson, 2003). With this, team sport domains carry challenges in measuring individual performance, and subsequently measuring performance on a single task (Ericsson, 2003).

Stage 2: Identify

After developing tasks to capture expertise in sport, the goal is then to identify the mechanisms that contribute to the superior performance over an intermediate or novice performer (Williams & Ericsson, 2005). Identifying the mechanisms that contribute to expert performance has often been overlooked as an aspect of the Expert Performance Approach. This is because previous studies have identified the differences between experts and novices, but not specifically mechanisms that mediate expertise (Williams & Ericsson, 2005). One of the techniques that is used in this stage is film/photo occlusion. The temporal occlusion technique involves filming an action from the participants' perspective. The film is then edited at certain parts to provide the viewer with limited information about the following action (i.e. baseball pitch in air prior to reaching the batter). The temporal occlusion paradigm is used in research to test prediction accuracy in experts compared to novice performers. Previous research that has used this has demonstrated that experts have greater anticipatory skills, and they are also greater at using relevant anticipatory information from opponents' early movement behaviours (Abernethy & Russell, 1987; Goulet, Bard, & Fleury, 1989). As such, the occlusion paradigm is used to test perceptual-cognitive mechanisms that lead to expert performance (see Section 2.2).

Stage 3: Examine

The final stage is used to determine and examine *how* experts attain skills that are needed and used in superior performance. For example, past studies demonstrate that expert performers displayed a significantly greater amount of time in practice compared to less-superior counterparts performance (see Deakin & Cobley, 2003; Ericsson et al., 1993). Based on mechanisms of expert performance (Stage 2) specific training interventions can also be tested as part of Stage 3. Indeed, results suggest that such training interventions can be beneficial for enhancing mechanisms of expertise, such as perceptual-cognitive skills in performers (Williams & Grant, 1999), reinforcing this framework has valuable tool for understanding expertise development.

The Expert Performance Approach in the current study

Stage 1

The present study allows for the use of the Expert-Performance framework (Stage 1) under two conditions: population sample, and the Individual Technical Quality Measurement Tool (ITQMT). In order to be eligible to participate in the present study, the athletes at Wheelchair Basketball Canada needed to have at least 5 years of wheelchair basketball specific training, and at least 2 years of National or International Competition Experience. Indeed, we are observing movement patterns and perceptual-cognitive skills in athletes who can be considered 'advanced' or 'expert' in their field (see Baker, Wattie & Schorer, 2015). As previously mentioned, there are challenges when trying to capture expert performance in team sport. Therefore, we used the ITMQT in order to measure individual categorized differences (i.e. individual components in General, Offensive and Defensive skills). The ITMQT is the closest tool to measure physical on-court performance in wheelchair basketball athletes, which allowed us to further distinguish the finer differences in skill between participants.

Stage 2

Stage 2 (Identify) was represented in the present study by components of General Executive Functioning (i.e. verbal/non-verbal reasoning, and short term memory [STM]) and sport-specific cognitive skills (i.e. Pattern Recall – photo temporal occlusion), as these were considered potential mechanisms that could mediate expert performance in the participants (Mann et al., 2007; Faubert & Sidebottom, 2012). Both tools were used as comparisons from pre-test measurements to post-test (i.e. repeated measures), to look at the potential changes and/or effect of the intervention over time.

Stage 3

The current study examined mechanisms that may contribute to expert performance by using Multiple Object Tracking (MOT) sessions as a training intervention. This type of training modality is typically marketed as a way to increase mechanisms of expert performance (i.e. perceptual-cognitive skills) as well as performance itself (i.e., ITQMT) (Faubert & Sidebottom, 2012). Therefore, we incorporated MOT as a training intervention to examine efficacy of MOT training on mechanisms that may contribute to expert performance in the participants.

2.6 REFERENCES

Abernethy, B., Baker, J., & Cotê, J. (2005). Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology, 19*(6), 705e718. http://dx.doi.org/10.1002/acp.1102

Abernethy, B., Neal, R. J., & Koning, P. (1994). Visual-perceptual and cognitive differences between expert, intermediate and novice snooker players. *Applied Cognitive Psychology, 8,* 185–211.

Abernethy, B. & Russell, D. G. (1984). Advance in cue utilisation by skilled cricket batsmen. *Australian Journal of Science and Medicine in Sport, 16*, 2±10.

Abernethy, B., & Russell, D. G. (1987). The relationship between expertise and visual search strategy in a racquet sport. *Human Movement Science, 6*, 283–319. doi:283319.10.1016/0167-9457(87)90001-7.

Adelson, B., (1981). Problem solving and the development of abstract categories in programming languages. *Memory & Cognition*, *9*, 422 – 433

Adolphe, R., Vickers, J., & Laplante, G., (1997). The effects of training visual attention on gaze behaviour and accuracy: A pilot study. *International Journal of Sports Vision, 4*(1), 28-33.

Allard, F., Graham, S. and Paarsalu, M. E. (1980). Perception in sport: basketball. *Journal of Sport Psychology, 2,* 14±21

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise, 7*(6), 653e676. http:// dx.doi.org/10.1016/j.psychsport.2006.07.002.

Assed, M. M., de Carvalho, M. K. H. V., de Almeida Rocca, C. C., & de Pádua Serafim, A., (2016). Memory training and benefits for quality of life in the elderly: A case report. *Dementia & Neuropsychologica*, *10*(2): 152 – 155

Baker, J., Côté, J., & Abernethy, B. (2003). Sport specific practice and the development of expert-decision making in team ball sports. *Journal of Applied Sport Psychology, 15*:1, 12-25. doi:10.1080/10413200305400

Baker, J., Côté, J., & Deakin, J. (2005). Expertise in ultra-endurance triathletes early sport involvement, training structure, and the theory of deliberate practice. *Journal of Applied Sport Psychology*, *17*; 64-78. doi:10.1080/10413200590907577

Baker, J., Wattie, N., & Schorer, J., (2015). Defining expertise: A taxonomy for researchers in skill acquisition and expertise. In J. Baker, & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pg. 145 – 155). United Kingdom: Routledge.

Baker, J., & Young, B. W., (2014). 20 years later: Deliberate practice and the development of expertise in sport. *International Review of Sport & Exercise Psychology, 7*(1), 135 – 157. doi:10.1080/1750984X.2014.896024

Bar-Eli, M., & Raab, M. (2009). Judgment and decision making in sport and exercise: a concise history and present and future perspectives. In D. Araújo, H. Ripoll, & M. Raab (Eds.), *Perspectives on cognition and action in sport* (pp. 149e156). New York: Nova Science Publishers

Bard, C., & Fleury, M., (1976). Analysis of visual search activity during sport problem situations. *Journal of Human Movement Studies*, *3*, 214 – 222

Beilock, S. L., Wierenga, S. A., & Carr, T. H., (2003). Memory and experise: What do experienced athletes remember? In: Starkes, J., & Ericsson, K. A., eds., *Expert Performance in Sport: Recent Advances in Research on Sport Expertise,* Human Kinetics, Champaign, IL, 2003, 295-321

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science*, *15*(4), 322-331. doi:10.1080/17461391.2014.957727

Chamberlain, C., & Coehlo, A. (1993). The perceptual side of action: Decision-making in sport. In J. L. Starkes and F. Allard (Eds.), *Cognitive Issues in Motor Expertise*. Amsterdam: North Holland.

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215–281). New York: Academic Press

"A consensus on the brain training industry from the scientific community." (2014). Retrieved from http://longevity3. stanford.edu/blog/2014/10/15/the-consensus-on-the-braintraining-industry-from-the-scientific-community-2/

"Cutting edge science personalized for you." (2015, September 4). [Internet Archive]. Retrieved from https://web.archive.org/web/20150904041409/http://www.lumosity.com

Damron, C. F., (1955). Two and three dimensional slide images used in tachistoscopic training techniques in instructing high school football players in defenses. *Research Quarterly*, *26*, 26-43

Deakin, J. M., & Cobley, S., (2003). A search for deliberate practice: An examination of the practice environments in figure skating and volleyball. In: Starkes, J., & Ericsson, K. A., eds., *Expert Performance in Sport: Recent Advances in Research on Sport Expertise*, Human Kinetics, Champaign, IL., 2003, 115-137.

Didierjean, A., & Marmèche, E. (2005). Anticipatory representation of visual basketball scenes by novice and expert players. *Visual Cognition, 12*, 265–283

Ericsson, K.A., (2003). The development of elite performance and deliberate practice: An update from perspective of the expert-performance approach. In: Starkes, J., & Ericsson, K. A., eds., *Expert Performance in Sport: Recent Advances in Research on Sport Expertise*, Human Kinetics, Champaign, IL, 2003, 49-81.

Ericsson, K.A., (2004). Deliberate Practice and the Acquisition and Maintenance of Expert Performance in Medicine and Related Domains, *Academic Medicine*, *10*, S1-S12.

Ericsson, K.A., Krampe, R.T. and Tesch-Römer, C., (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance, *Psychological Review*, *100,* 363-406.

Ericsson, K. A., Patel, V. L., & Kintsch, W., (2000). How experts' adaptations to representative task demands account for the expertise effect in memory recall: Comment on Vincente and Wang (1998). *Psychological Review*, *107*, 578-592.

Ericsson, K.A. and Smith, J., (1991). Prospects and Limits of the Empirical Study of Expertise: An Introduction, in: Ericsson, K.A. and Smith, J., eds., *Toward a General Theory of Expertise: Prospects and Limits*, Cambridge University Press, New York, 1991, 1-38

Farrow, D., Abernethy, B., & Jackson, R. C., (2005). Probing expert anticipation with the temporal occlusion paradigm: experimental investigations of some methodological issues. *Motor Control, 9*(3); 332 – 351.

Farrow, D., McCrae, J., Gross, J., & Abernethy, B. (2010). Revisiting the relationship between pattern recall and anticipatory skill. *International Journal of Sport Psychology, 41*, 91–106

Faubert, J. & Sidebottom, L. (2012). Perceptual-cognitive training of athletes. *Journal of Clinical Sport Psychology, 6,* 85-102. doi:10.1123/jcsp.6.1.85

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports (Nature Publisher Group), 3*, 1154.

Federal Trade Commission (2016a). [Press release] https://www.ftc.gov/news-events/press-releases/2016/01/lumosity-pay-2-million-settle-ftc-deceptive-advertising-charges

Federal Trade Commission. (2016b). Settlement with Lumos Labs. Retrieved from https://www.ftc.gov/system/files/documents/cases/160105lumoslabsstip.pdf

Ford, P., Coughlan, E., & Williams, M., (2009). The expert-performance approach as a framework for understanding and enhancing coaching performance, expertise and learning. *International Journal of Sports Science & Coaching, Volume 4,* Number 3, 451-463.

Gilhooly, K. J., Wood, M., Kinnear, P. R., & Green, C., (1988). Skill in map reading and memory for maps. *Quarterly Journal of Experimental Psychology*, *40A*, 87 – 107

Gorman, A., Abernethy, B., & Farrow, D. (2011). Investigating the anticipatory nature of pattern perception in sport. *Memory & Cognition, Vol. 39*, Issue 5, 894-901. doi:10.3758/s13421-010-0067-7

Gorman, A. D., Abernethy, B., & Farrow, D. (2012). Classical pattern recall tests and the prospective nature of expert performance. *The Quarterly Journal of Experimental Psychology, 65*, 1151–1160.

Gorman, A. D., Abernethy, B., & Farrow, D. (2013). Is the relationship between pattern recall and decisionmaking influenced by anticipatory recall? *The Quarterly Journal of Experimental Psychology*, *66*, 2219–2236

Gorman, A. D., & Farrow, D. (2009). Perceptual training using explicit and implicit instructional techniques: Does it benefit skilled performers? *International Journal of Sports Science & Coaching, 4*, 193–208.

Goulet, C., Bard, C., & Fleury, M. (1989). Expertise differences in preparing to return a tennis serve: A visual information processing approach. *Journal of Sport & Exercise Psychology, 11*, 382-398.

Harris, D. J., Wilson, M. R., & Vine, S. J., (2018). A systematic review of commercial cognitive training devices: Implications for use in sport. *Frontiers in Psychology*, *9*:709. doi:10.3389/fpsyg.2018.00709

Hastie, R. (2001). Problems for judgment and decision making. *Annual Review of Psychology, 52*(1), 653e683. http://dx.doi.org/10.1146/annurev.psych.52.1.653.

Helsen, W. and Pauwels, J. M. (1993a). A cognitive approach to visual search in sport. In D. Brogan, A. Gale and K. Carr K (Eds), *Visual search II* (pp.379±388)

Helsen, W., & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology, 13*, 1-27.

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology, 20*(1), 12

Hodges, N. J., & Starkes, J. L. (1996). Wrestling with the nature of expertise: A sport specific test of Ericsson, Krampe and Tesch-Romer's (1993) theory of "deliberate practice." *International Journal of Sport Psychology, 27*, 400-424

"How is Cogmed different." (2015). Retrieved from http://www. cogmed.com/how-is-cogmed-different

"The Human Cognition Project: Bibliography." (n.d.). Retrieved from http://www.lumosity.com/hcp/research/bibliography

"Improve your brain while having fun." (2015, September 6). [Internet archive]. Retrieved from https://web.archive.org/ web/20150906125111/https://www.cognifit.com/

Legault, I., Allard, R., & Faubert, J., (2013). Healthy older observers show equivalent perceptual-cognitive training benefits to young adults for multiple object tracking. *Frontiers in Psychology, 2013;4*. doi:10.3389/fpsyg.2013.00323

Legault, I., & Faubert, J., (2012). Perceptual-cognitive training improves biological motion perception: evidence for transferability of training in healthy ageing. *Neuroreport, 30*;23(8): 469 – 473. doi:10.1097/WNR.0b013e328353e48a

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: a meta-analysis. *Journal of Sport & Exercise Psychology, 29*(4), 457478.

Müller, S., Abernethy, B., & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *The Quarterly Journal of Experimental Psychology, 59*, 2162–2186. http://dx.doi.org/10.1080/02643290600576595.

Neurotracker (2016). *Athletics*. Retrieved from: https://neurotracker.net/athletics/

North, J. S., Hope, E., Williams, M. A. (2016). The relative importance of different perceptual-cognitive skills during anticipation. *Human Movement Science, 49* (2016), 170-177. doi:10.1016/j.humov.2016.06.013

Parsons, B., Magill, T., Boucher, A., Zhang, M., Zogbo, K., Bérubé, S., Scheffer, O., Beauregard, M., & Faubert, J. (2016). Enhancing cognitive function using perceptual-cognitive training. *Clinical EEG and Neuroscience, Vol. 47*(1), 37-47. doi:10.1177/1550059414563746

Pylyshyn, Z.W. and R.W. Storm,. (1988). Tracking multiple independent targets: evidence for a parallel tracking mechanism. *Spatial Vision, 3*(3): p. 1-19.

Perico, C., Tullo, D., Perrotti, K., Faubert, J., & Bertone, A., (2014). The effect of feedback on 3D multiple object tracking performance and its transferability to other attentional tasks [ABSTRACT]. *Journal of Vision, Vol. 14*, 357. doi:10.1167/14.10.357

Plant, E.A., Ericsson, K.A., Hill, L. and Asberg, K., (2004). Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance. *Contemporary Educational Psychology*, *30*, 96-116.

Romeas, T., Guldner, A., & Faubert, J., (2016). 3D-multiple object tracking training task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise*, *22* (2016), 1-9. doi:10.1016/j.psychsport.2015.06.002

Roudaia, E., Lacoste. S., & Faubert, J. (2016). The hemifield independence in multiple object tracking is preserved in healthy ageing. *Journal of Vision*, *16*(12), 779. doi:10.1167/16.12.779

Schapschröer, M., Baker, J., & Schorer, J. (2016). Effects of domain-specific exercise load on speed and accuracy of a domain-specific perceptual-cognitive task. *Human movement science*, *48*, 121-131. doi:10.1016/j.humov.2016.05.001

Shim, J., Carlton, L. G., Chow, J. W., & Chae, W. -S. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behavior, 37*, 164–175. http://dx.doi.org/10.3200/JMBR.37.2.164-175.

Simon, H. A., & Chase, W. G. (1973). Skill in chess. American Scientist, 61, 394403.

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., Stine-Morrow, E. A. L. (2016). Do “brain training” programs work? *Psychological Science in the Public Interest, Vol. 17*(3), 103-186. doi:10.1177/1529100616661983

Starkes, J. L. (1987). Skill in field hockey: the nature of the cognitive advantage. *Journal of Sport Psychology, 9*, 146–160.

Starkes, J., Allard, F., Lindley, S., & O’Reilly, K. (1994). Abilities and skill in basketball. *International Journal of Sport Psychology, 25*, 249–265.

Starkes, J. L., Deakin, J. M., Allard, F., Hodges, N. J., & Hayes, A. (1996). Deliberate practice in sports: What is it anyway? In K. A. Ericsson (Ed.), *The road to excellence: The acquisition of expert performance in the arts and sciences, sports and games* (pp. 81–106). Hillsdale, NJ: Erlbaum.

Starkes, J. L., Edwards, P., Dissanayake, P. and Dunn, T. (1995). A new technology and ®eld test of advance cue usage in volleyball, *Research Quarterly, 65,* 1±6.

Stone, J. A., Maynard, I. W., North, J. S., Panchuk, D., & Davids, K., (2017). Temporal and spatial occlusion of advanced visual information constrains movement (re)organization in one-handed catching behaviors. *Acta Psychologica, 174*: 80 – 88. doi:10.1016/j.actpsy.2017.01.009

Tinjust, D., Allard, R., & Faubert, J., (2008). Impact of stereoscopic vision and 3D representation of visual space on multiple object tracking performance. *Journal of Vision*, 8(6), 509.

Tricot, A., & Sweller, J., (2013). Domain-specific knowledge and why teaching generic skills does not work. *Educational Psychology Review (2014), Vol. 26*, No. 2, pp 265 – 283

Tullo, D., Faubert, J., & Bertone, A., (2017). The cognitive benefits of NeuroTracker training across neurodevelopmental disorders: Who benefits from training attention with multiple object-tracking? [ABSTRACT]. *Journal of Vision, Vol. 17,* 1307. doi:10.1167/17.10.1307.

Tullo, D., Guy, J., Faubert, J., Bertone, A. (2016). Using a three-dimensional multiple object tracking paradigm to train attention in students with a learning disability [ABSRACT]. *Journal of Vision, Vol. 6*, 488. doi:10.1167/16.12.488

Vartanian, O., Coady, L., & Blackler, K., (2016). 3D multiple object tracking boosts working memory span: Implications for cognitive training in military populations. *Military Psychology, Vol. 28*, No. 5, 353-360

Ward, P., Farrow, D., Harris, K. R., Williams, A. M., Eccles, D. W., & Ericsson, K. A., (2008). Training perceptual-cognitive skills: Can sport psychology research inform military decision training? *Military Psychology, 20*:71-102. doi:10.1080/08995600701804814

Wentink, M. M., Berger, M. A., de Kloet, A. J., Meesters, J., Band, G. P., Wolterbeek, R., Goossens, P. H., Vliet Vlieland, T. P. (2016). The effects of an 8-week computer-based brain training programme on cognitive functioning, QOL, and self-efficacy after stroke. *Neuropsychological Rehabilitation*, *26*(5-6):847-65. doi:10.1080/09602011.2016.1162175.

Williams, A.M. (2000). Perceptual skill in soccer: implications for talent identification and development. *Journal of Sports Sciences*, *18*(9), 737–750.

Williams, A.M., & Davids, K. (1995). Declarative knowledge in sport: A by-product of experience or a characteristic of expertise? *Journal of Sport and Exercise Psychology, 17*, 259-275.

Williams, A.M., Davids, K., Burwitz, L., & Williams, J.G. (1993). Visual search and sports performance. *The Australian Journal of Science and Medicine in Sport, 25*(2), 147204.

Williams, A.M., Davids, K., Burwitz, L., & Williams, J.G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport*, *6*(2), 127-135.

Williams, A.M., Davids, K., & Williams, J.G. (1999). *Visual Perception and Action in Sport*. London: E & FN Spon

Williams, A. M., & Ericsson, K. A., (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science, 24*: 283-307. doi: 10.1016/j.humov.2005.06.002

Williams, A. M., Ford, P. R., Eccles, D. W. and Ward, P. (2011), Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Appl. Cognit. Psychol., 25*: 432–442. doi:10.1002/acp.1710

Williams, A. M., & Grant, A., (1999). Training perceptual skill in sport. *International Journal of Sport Psychology, 30*, 194-220.

Williams, A. M., & Ward, P (2003). Perceptual expertise: development in sport. In: Starkes, J., & Ericsson, K. A., eds., *Expert Performance in Sport: Recent Advances in Research on Sport Expertise,* Human Kinetics, Champaign, IL, 2003, 49-81.

Williams, A. M., Ward, P., & Chapman, C., (2002). Training perceptual skill in field hockey: Is there transfer from the laboratory to the field? *Research Quarterly for Exercise and Sport, 74*, 98-103.

Wood, J. M., & Abernethy, B., (1997). An assessment of the efficacy of sports vision training programs. *Optometry and Vision Science: Official Publication of the American Academy of Optometry, 74*(8): 646 – 659

Wright, D. L., Pleasants, F. and Gomez-Meza, M. (1990). Use of advanced cue sources in volleyball. *Journal of Sport and Exercise Psychology, 12*, 406±414

CHAPTER 3: STUDY

KEEPING YOUR EYE ON THE BALL: THE INFLUENCE OF MULTIPLE OBJECT TRACKING IN SPORT-SPECIFIC PERFORMANCE OF WHEELCHAIR BASKETBALL

Authors: Annie Pietroniro, MHSc (cand), BHSc[1]; Dr. Joseph Baker[2]; Dr. Nick Wattie[1].

[1]Faculty of Health Sciences, University of Ontario Institute of Technology, Oshawa ON, Canada

[2]School of Kinesiology and Health Sciences, York University, Toronto ON, Canada

3.1 ABSTRACT

There has been tremendous growth of sport-science literature completed on able-bodied or mainstream athletes. However, research completed on the development of perceptual-cognitive skills on athletes with physical disabilities is scarce. Twelve Senior high performance/National Academy athletes were recruited from Wheelchair Basketball Canada to participate in a pre-test vs. post-test intervention study of general cognitive training (GCT) effects on sport-specific performance. Athletes were tested in general executive functioning, sport-specific cognitive skills (pattern recall), and sport-specific physical performance indicators. The intervention was 4-weeks of multiple object tracking (MOT). Results from statistical analyses showed little-to-no changes over the study period, which supports the hypothesis that participation in MOT would have no effect on performance in wheelchair basketball. Future research is needed in this area and would benefit from a larger sample size, a control-group, and extended study period. Coaches are encouraged to be cautious in their use of GCT programs in high performance athlete training environments.

Keywords: perceptual-cognitive training, general-cognitive training, Paralympics, athlete development, sport expertise

3.2 INTRODUCTION

Paralympic Research

There is extensive literature dedicated to understanding the development of elite athletes. The diverse information on athlete development in different sports, highlights the challenges of developing elite performers (Baker & Farrow, 2015). Research in the development of elite athletes has been prominent in Sport Psychology research for approximately 40 years. However, one area in particular that requires more research is the development of elite athletes in para-sport populations (Dehghansai et al., 2017a).

The Paralympic movement began in 1944 when the Stoke Mandeville games were created with the aftermath of veterans returning home from World War II ("Mandeville Legacy", 2014). Initially, sport was introduced as a form of rehabilitation, which soon turned into competitive showcases for the public ("Mandeville Legacy", 2014). The International Stoke Mandeville Games were held immediately after the Opening Ceremonies of the 1960 Rome, Summer Olympic Games; which was considered the first Paralympic Games ("Mandeville Legacy", 2014; "Paralympics – History of the Movement", n.d;). The Paralympic Games has seen significant growth from the 1960 Rome Summer Games, to the 2016 Rio de Janeiro Games (approximately 1000%; Murdoch, 2012; "Rio 2016" n.d.). With the growth of Parasport competitions there has been some sport-science literature dedicated to the Paralympic movement regarding athlete biomechanics, and developmental milestones (see Burkett, Melfont & Mason, 2012; Goosey-Tolfrey et al., 2002; Daly et al., 2003; Dehghansai et al., 2017b). A recent systematic review by Dehghansai et al., (2017a) was completed to look at the influences of development on athletes with disabilities, which only found 21 articles (majority published after 2001). Furthermore, the majority of the articles included emphasized a common theme that there was a lack of training programs, and sport-specific guidelines for athletes with disabilities (Dehghansai et al., 2017a). Of the 21 articles found and used in the review, none of those articles were completed on the perceptual-cognitive abilities in athletes with physical disabilities (Deghgansai et al., 2017a).

Perceptual-Cognitive Training

Perceptual-cognitive skill is an individual's ability to integrate environmental information with existing knowledge in order to return the appropriate response and execution (Marteniuk, 1976). In many team sports, athletes need to be able to execute a play, read their opponents, and make the correct move in order for success in performance (Williams, Davids, & Williams, 1999). Therefore, perceptual-cognitive skills are unique indicators to expert-performance. Perceptual-cognitive skills are predominantly thought to be domain-specific and the result of domain-specific practice, and therefore specific to each sport (Mann et al., 2007; Nuri et al., 2013; Schapschröer et al., 2016). For example, Helsen & Starkes (1999) found no differences in general cognitive capacities in experts and non-experts (i.e. central and peripheral reaction and correction times), but differences between the groups in specific cognitive capacities (i.e. when the tasks were specific to the domain of the participant; [soccer skills]). Similar findings have been found in multiple sports such as basketball (Allard, Graham, & Paarsalu, 1980), field hockey (Starkes, 1987), volleyball (Allard & Starkes, 1980; Ripoll, 1988) and soccer (Helsen & Pauwels 1993a,b). These findings suggest that the mechanisms that contribute to expertise development are the results of deliberate practice, and not innate differences. However, contrary opinions to domain-specific foundations of expert perceptual-cognitive skills exist.

General Cognitive Training

General Cognitive Training tools (GCT) are games or activities that exercise cognitive components (i.e. working memory, decision-making skills) with the goal of improving performance in everyday tasks (i.e. at home, at work, in school; Simons et al., 2016). Furthermore, GCT tools have no domain-specific motor control demands, or perceptual information. Proponents of GCT have proposed that a multiple-object tracking programs could assist in improving mental abilities that involve processing dynamic situations; such as, maneuvering and navigating through traffic, or athletes during sport activities (Faubert & Sidebottom, 2012). Supporters of GCT suggest that a single training program could assist a variety of individuals and outcomes, regardless of their domain of performance.

Research on GCT (i.e. Multiple Object Tracking is an example of GCT) has found that training interventions can increase attention, working memory, and informational processing speed (Parsons et al., 2016). Multiple object tracking (MOT) is a technique used to study and train how the human visual system tracks multiple objects at a given time (Pylyshyn & Storm, 1988). General cognitive programs like MOT pose an alluring platform for developing anticipation and decision-making in athletes. However, there is limited evidence to say that a transfer of learning occurs between training using programs and sport performance (Broadbent et al., 2015). Although some studies have reported transfer from general cognitive training to in-field performance and other cognitive abilities (Romeas, Guldner, & Faubert, 2016; Perico et al., 2014; Faubert, 2013), there are conflicting findings that exist about the effect of GCT programs to domain specific areas (Wentink et al., 2016). An example of this can be seen in Farrow et al., (2017) review on conceptualizing sport expertise. Farrow et al., (2017) notes that although general cognitive training is an inviting technique to use, there is a significant lack of evidence to support its utility in expert development. Furthermore, a recent systematic review by Harris, Wilson, and Vine (2018), looks at the implications of use for GCT in sport. Results of the review indicate that evidence from GCT programs to far transfer (i.e. irrelevant) tasks in sport is limited. Moreover, the authors noted this was because the tasks being tested (i.e. GCT program) did not reflect the sporting environment itself (i.e. making it less relevant to far transfer effects).

The sport science literature suggests that an athlete's perception of the environment and their attention allocation is a determining factor between expert and non-expert performers (Williams, Davids, & Williams, 1999). However - comparing between skilled and non-skilled athletes - skilled athletes show greater proficiency in anticipation and decision-making skills, as well as pattern recall and technical awareness, when the context is specific to the task (Helsen & Starkes, 1999; Williams, 2000).

Although there is some literature published on the transfer effect of GCT into domain-specific skills (see Romeas et al., 2016), there is no known research testing this effect on elite level athletes with physical disabilities (Dehghansai et al., 2016a). The purpose of this study is to look at the impact of a GCT program on the sport-specific skill, and pattern recall skills in Canadian Wheelchair Basketball athletes. Based on previous research findings (Simons et al., 2016; Wentink et al., 2016), we hypothesize that participating in General Brain Training Games will have no effect on the sport-specific cognitive skills and performance in Canadian Wheelchair Basketball players. Specifically, we hypothesize that sport-specific performance levels will be maintained, or minimally vary after participation in the intervention. Since this study explores learning and performance of high performance elite level athletes, the power law of practice

(Logan, 1988; Newell & Rosenbloom, 1981) suggests it will likely take proportionately more time and practice to elicit improvements in skill. Lastly, according to previous research completed on attention and concentration tasks, people who completed the same test repeatedly improved their performance on that tasks (Bühner, 2001). As such, it is hypothesized that tests scores on MOT will maintain or increase from Week 2 comparisons to Week 5 (the first and the last week of the MOT intervention).

3.3 METHODS

3.31 Study Design

The purpose of this study is to look at the impact of a GCT program on the sport-specific skill, and pattern recall skills in Canadian Wheelchair Basketball athletes. In order to test the effectiveness of the MOT program on physical and cognitive sport performance, we used a pre-test vs. post-test cohort case study design. This includes pre-test and post-test measurements of general executive function and sport-specific skills, and includes the MOT sessions as an intervention. The timeline and feasibility is shown below for a visual representation of the overall study (see section 3.331).

3.32 Ethical Approval

A letter of support to run the study at the National Training Centre, and permission to recruit athletes from Wheelchair Basketball Canada was received on Thursday, December 1st, 2016 (Appendix 1). Full ethical approval was received from Canadian Sport Institute of Ontario's Research Ethics Board on Tuesday, April 25th, 2017 (CSIO REB 2017-02: Appendix 2) and from the University of Ontario Institute of Technology's Research Ethics Board on Friday, September 29th, 2017 (REB #11671: Appendix 3).

3.33 Participants

Participants were recruited from Wheelchair Basketball Canada's high performance and National Academy programs out of the National Training Centre (Toronto, Ontario). A letter of approval for the study, and permission to recruit the athletes was received on Thursday, December 1st, 2016 (see Appendix 1). A PowerPoint presentation was presented to the athletes as part of the Informed Consent process. Interested participants were given an Informed Consent (Appendix 4), and asked to sign either Option 1, or Option 2. By signing Option 1, the athletes agreed to participate in the study in full, and allowed the release of their results to the Coach, Integrated Support Team (IST), or other support staff of WBC for the purpose of Individual Performance Plans (IPP). Option 2 agreed the athlete to participate in the study in full, but did not want to have their results shared with their Coach, IST, or support staff of WBC.

Participants are Senior and Academy level Athletes, from the Canadian National Wheelchair Basketball Team. Thirteen men (n=9) and women (n=4) ranging from age 18 – 40 years, were recruited to participate in the study. The participants have a medically documented disability, or are considered minimally-disabled by the policies of the International Wheelchair Basketball Federation (IWBF), the International Paralympic Committee (IPC), and Canadian Paralympic Committee (CPC; International Wheelchair Basketball Federation [IWBF], 2014). In order to be eligible to play Wheelchair Basketball under IWBF jurisdiction, an athlete must have a permanent physical disability that reduces the function of lower limbs. This must be to the degree the athlete cannot run, pivot, or jump at the speed and control, endurance, and safety required to play in stand-up basketball as an able-bodied player (IWBF, 2014). All participants who completed the study have ≥ 5 years of Wheelchair Basketball specific training and, ≥ 2 years of National or International competition experience. Informed consent was obtained from all participants prior to participation in the current study.

Due to physical disability-specific complications, one of the participants dropped out of the study. This created the final total of 12 participants (men: n=8, women: n=4).

3.331 Timeline

The timeline presented in Table 1 (see below) was shown to the participants prior to signing up for the duration of the study. This was to show those who would consent to participate, how much time was expected of them during the study process, and the differences between the groups.

Table 1. Study timeline for participants

Group 1	September 2017	Week 1	Baseline Measurements (~30 minutes per participant)
		Week 2	MOT Intervention (1 x 6 min session – 3x/week)
		Week 3	MOT Intervention (1 x 6 min session – 3x/week)
	October 2017	Week 4	MOT Intervention (1 x 6 min session – 3x/week)
		Week 5	MOT Intervention (1 x 6 min session – 3x/week)
		Week 6	Post-Test Measurements (~30 minutes per participant)
Group 2	October 2017	Week 1	Baseline Measurements (~30 minutes per participant)
		Week 2	MOT Intervention (1 x 6 min session – 3x/week)
		Week 3	MOT Intervention (1 x 6 min session – 3x/week)
		Week 4	MOT Intervention (1 x 6 min session – 3x/week)
	November 2017	Week 5	MOT Intervention (1 x 6 min session – 3x/week)
		Week 6	Post-Test Measurements (~30 minutes per participant)

*Groups are separated based on return from Recovery Period following World Qualifier in Cali, Colombia. Participants that were not in Colombia would fall under Group 1, and those that were in Colombia would go into Group 2.

**Participants completed 12 MOT at the end of the 4-week period

3.34 Pre-Test and Post-Test Measures

Prior to and after the MOT Neurotracker™ trials, athletes completed a baseline assessment of general cognitive skills (i.e. executive function) and sport-specific perceptual cognitive skills (using a temporal occlusion task), and on-court performance was assessed through the Individual Technical Quality Measurement Tool (see below for description).

Cambridge Brain Science tasks. General Executive Functioning (GEF), or Executive Function (EF), is considered responsible for regulating complicated tasks (Miyake et al., 2000). Measures of GEF were used to establish a baseline for participants and as a measure convergent validity, as one of the mechanisms (i.e. claims) from MOT training is that it is said to improve general cognitive functioning. The measure of GEF we used are from Cambridge Brain Sciences (CBS; http://www.cambridgebrainsciences.com/). All tests from CBS took approximately 15 – 20 minutes to complete, and were delivered via internet program (i.e. computer). The CBS battery is a highly researched tool with over 300 peer-reviewed publications. Some of their studies include age-related cognitive decline (Ferreira et al., 2015), effect of cognitive function post-physical activity (Nanda, Balde, & Manjunatha, 2013), 'brain-training' protocols (Owen, et al., 2010), and concussions in varsity athletes (Brewer-Deluce, Wilson, & Owen, 2017).

The tests that were included from the Cambridge battery are: Spatial Span – which measures spatial working memory (subject will watch a sequence of flashing boxes that appear one after another, and recall the previous sequence); Feature Match – reasoning and short term memory task (two boxes with shapes appear on the screen. Participants are required to figure out if the shapes are identical, or if they differ in some way); Rotations – this test relies mainly on reasoning, although some short term memory is used (this test requires the participant to rotate squares on a screen and determine if they would be matched or mismatched as a result); Double Trouble – relies on mainly verbal abilities, but also deals with reasoning and short-term memory (three words appear on the screen – 1 at the top and 2 on the bottom. The participant needs to choose the word that correctly describes the colour of the top word; similar technique to Stroop test; tests response inhibition). Token Search – assesses ability of retention and short-term working memory (a token is hidden under one of the squares on the screen. Once the first token is found, the participant needs to remember what square it was found other, and continue to click the squares until every token is found; a token will never appear in the same box twice; www. https://www.cambridgebrainsciences.com/tests).

Sport-specific pattern recall. Participants were required to complete a basketball 'temporal occlusion task' (see Figure 1), that aims to test sport-specific perceptual-cognitive skill. Participants completed this task pre-intervention to establish a baseline of this sport-specific cognitive skill. Post intervention with the MOT program, this task will be used to assess the transferability of general cognitive training to specific perceptual cognitive skills. The temporal occlusion task is a computer-based test that consists of actual video stills of real basketball plays on court (taken from non-Canadian Wheelchair Basketball games from the Rio 2016 Paralympic Games). Representative of wheelchair basketball games, each scenario had 10 players on court, with typical offensive and defensive positions or plays in overview angles. Previous studies that tested performance in pattern-recall using structured versus unstructured patterns have shown that experts will outperform novice counterparts when the pattern is domain-specific (e.g. Simon & Chase, 1973; Helsen & Starkes, 1998); therefore, only typical and specific wheelchair basketball patterns were available for this study. These stills, which go through different offensive and defensive plays, are taken from high-definition video footage from the Rio 2016 Paralympic Games. Each trial began with one of the stills being shown, and immediately showed a black screen for 5s. A frozen frame of sequence of the video reappeared for 5s immediately followed by a black screen again for 5s (temporal occlusion). The task is for

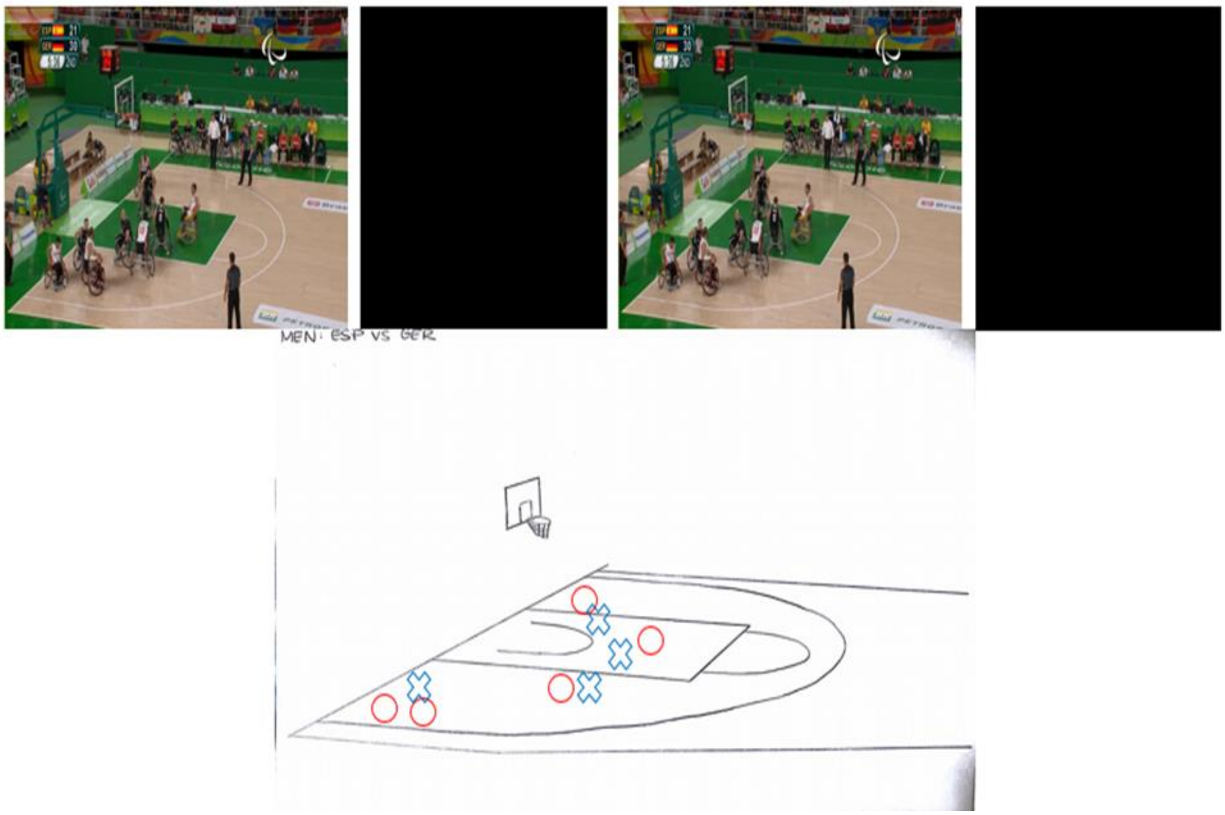


Figure 1. Example of a trial of the Sport-Specific Pattern Recall task (not used in present study). In the first image is a typical defensive vs. offensive play used in wheelchair basketball. This image is shown for 5s, then temporally occluded (image 2) for 5s. This is repeated for a second time (image 3 and 4). Immediately following this, the participant is required to recreate the pattern on a blank court using X and O to differentiate offensive and defensive players (image 5).

the participant to recreate the still on a blank basketball court (using X & O to represent either offensive or defensive players) as accurately as possible in relation to the head of the players on the screen. This test is a reliable indicator of pattern recall as well as decision making skills in the subjects. A similar protocol and test design has been performed on female handball athletes, to test the differences in decision making processes between expert and novice performers (Schapschröer et al., 2016).

Accuracy of player position reiteration (i.e. pattern-recall error) was determined using distance from actual player to recalled player. Participants would recreate the pattern on a blank identically sized basketball court. The principle investigator used "onion skin" (i.e. translucent paper), as an overlay with the correct pattern on it. This overlay was used as the "answer key" and compared to the reiterated pattern from the participant. With this, the distance between each of the recalled players and the correct player position (in cm) was measured in relation to the centre of the player (body with chair). A mean value and total sum (i.e. sum value that was larger than zero determined pattern accuracy – the larger the sum in turn means decreased accuracy of player position in the pattern; the larger the sum, the larger the error) was generated for each player in each pattern, as well as a mean value and sum for the entire pattern performed. This procedure has been previously used in a computer setting (i.e. measuring pixel length as opposed to pen and paper; see Schapschröer et al., 2016)

Individual Technical Quality Measurement Tool. The Individual Technical Quality Measurement Tool (ITQMT; Appendix 5) is a tool used within Wheelchair Basketball Canada (WBC) that assesses the General, Offensive and Defensive skills used within the game. The ITQMT was developed approximately three years ago by Michael Frogley (former World Champion and Paralympian [1990 & 1992], two-time Paralympic Gold Medal Senior Men's Head Coach [2000, 2004], Silver Medal Senior Men's Head Coach [2008], former Division 1 Head Coach [University of Illinois – Wheelchair Basketball], former Wheelchair Basketball/Adaptive Sports Professor [17 years, University of Wisconsin-Whitewater/University of Illinois], former WBC High-Performance Director [2015-2016], and current WBC National Academy Head Coach). The ITQMT was made to increase objectivity in evaluating athletes in coaching staff/integrated sport staff. Data from ITQMT is considered secondary data usage, as it is already being collected for a sole purpose (i.e. performance analytics) within the WBC program, and being used for athlete evaluation and research. Information from the ITQMT has been previously collected for over 3 years by the Performance Analyst at WBC, and the most recent data collection (< 6 months old) will be used in the pre-test design, and new grades will be taken after the MOT intervention for the post-test measures.

The ITQMT measures general, offensive, and defensive skills that are specific to wheelchair basketball. General skill measures include communication on court, seeing other players (teammates and opponents), and how the athlete is pushing in their chair. Offensive skill measures include ball handling/dribbling, passing/catching, and shooting mechanics. Defensive measures include 1-on-1 plays with the ball, 1-on-1 plays without the ball, and rebounding. Skills are measured on a scale from 0 – 4, and are calculated by each individual skill, and then averaged for an overall score (per athlete; for an example of the ITQMT rubric, see Appendix 5). This tool was used in practices and competition in order to track the changes in each athlete from the time they begin the study, to the time they have finished. All measurements with this tool were completed by Dylan Carter (Wheelchair Basketball Canada – Performance Analyst) in order to maintain standardization within the measurements (avoiding observer bias, as well as new individuals who may be just learning how to use the tool). Mr. Carter has been the Performance Analyst at WBC for three years, and was the first few people to use the ITQMT shortly after it was developed.

Similar to pattern-recall and CBS testing, ITQMT scores were determined in similar competitions, depending on the athlete. This means that some of the athletes'

ITQMT scores were used in an International Competition, while others were used in an at-home Academy scrimmage. This was to guarantee that comparative ITQMTs were based on similar start and finish events (i.e. level of competition). Depending on the participant, ITQMTs were used from the IWBF World Championship Qualifier (August 2017) and compared to the Japan National Team games (in Tokyo, Japan, or Toronto, Canada - December 2017), or Academy 5-on-5 games (September 2017 – December 2017).

3.35 Intervention

Since the study is focused on the impact of general cognitive training and its impact on sport-specific performance, MOT sessions were used as an intervention. The Neurotracker™ is a program that uses MOT as a main component of training. It is said to increase or improve athletic performance by training multiple object tracking skills, and challenges athletes to increase their focus and attention by tracking multiple objects at high speeds. The delivery of this tool can be through a computer, or a television, and requires the participant to either be seated, or performing an activity (ex. dribbling a basketball) for the duration of the trials. When subjects complete this test, they are required to focus on 4 of 8 objects moving around the screen (for approximately 6 seconds). These 4 objects will illuminate at the beginning of the trial, and all objects will be numbered. Once the trial starts, the numbers on the objects disappear. After the objects move about the screen for approximately 6 seconds and cease moving, the participant is required to successfully reiterate each of the 4 objects that were illuminated at the beginning of the trial, in order to receive a ‘pass’, and increase their speed for the following trial (Figure 2).

The participants were required to complete 12 sessions of MOT by the end of the study-intervention period (i.e. Week 2 – Week 5). The amount of sessions chosen for the overall study was based on previous literature, and the constraints within the teams' high performance training environment. Previous research has varied in amount of prescribed MOT sessions from testing tracking speed through 1 session (Mangine et al., 2014), no set amount of trials (although reported a maximum of 6 sessions; Tullo, Faubert & Bertone, 2018), 10 sessions (Vartanian, Coady, & Blackler, 2016), 15 sessions (Faubert, 2013; Faubert & Sidebottom, 2012), 30 sessions (Romeas, Guldner, & Faubert, 2016), and over 40 sessions (Faubert & Sidebottom, 2012). Due to the scheduling in high performance sport, the allotted study time of 6-weeks per participant was the maximum amount of time data collection could happen at the training centre (i.e. prior to teams leaving for away-tournaments, or decentralizing back home). Therefore, in order to attain a true intervention study design (including measuring baseline, and post-test data), we could only dedicate 4-consecutive weeks to training on MOT. In order to achieve the maximum amount of MOT training with the participants, and also be in accordance with current literature, 3-sessions per week was selected for the study (3 sessions/week for 4-weeks concluded the amount of total MOT sessions to twelve).

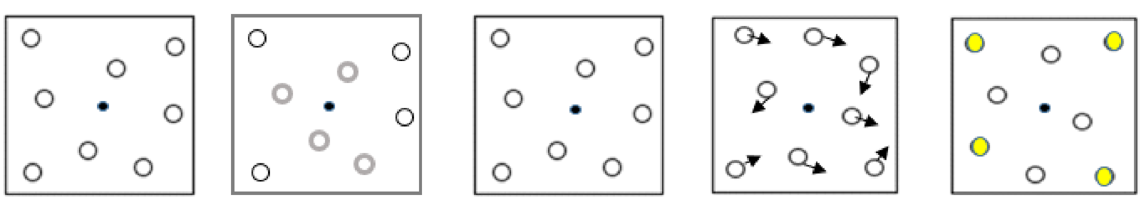


Figure 2. Example of the five stages of a typical MOT session. The first image is the presentation of all of the objects, and their starting position. The second image is the illumination of the targeted objects; the following image is the same position, without the illumination (removing target indicators). The fourth image is the multidirectional movement of all of the objects. The final image is the selection of the original targets from image 2.

The program used in this study formulates multiple variables after the participant has finished their session. Variables included: Score (considered the speed threshold of the total MOT session), % Target Correct (this is targets for the entire MOT session – 20 trials – which have a total of 80 targets. This percent is formulated from the total amount of targets the participant chose correctly), Start Speed (the start of the first trial of each session), Total test time (the total amount of time it takes the participant to complete the session), and current/initial baseline (Current Baseline is a mean of the first 3 CORE-sessions a participant completed. Whereas Initial Baseline is the average of the first three sessions). Regarding the present study, the variable we have chosen to isolate and use in analysis and results is Score. This is due to the generalizability of the values in this variable, and their relatedness to overall progress in the intervention, and comparison to the pre- and post-test measurements.

3.36 Individual Reviews

After the completion of MOT trials (intervention – end of Week 6), participants had the opportunity to sign up for Individual Reviews of progress, and were shown comparisons of results from Week 1 and Week 6, as well as Week 2 and Week 5.

3.4 MATERIALS

3.41 Apparatus

The pre-test and post-test tasks were presented on a 15-inch HP ENVY X360 Convertible Notebook (Hewlett-Packard, Palo-Alto, CA) laptop, and the participants were seated in a standard chair (approximately 18-inches from floor), their daily wheelchair (maximum 19-inches from floor), or their wheelchair basketball specific game chair (maximum 21-inches from floor). Seat height (excluding standard office chair) was dependent on participants' wheelchair basketball specific classification, or physical disability. The laptop was fixed on a table (maximum 30-inches from floor), directly in front of the participant. The distance between the laptop and participant was approximately 55cm.

The intervention MOT sessions were presented on a 42-inch SONY LCD TV (Sony Corporation, Tokyo, Japan). The television was fixed on a shelf (approximately 40-inches from the floor), directly in front of the participant. The distance between the television and the participant was between 5-feet and 8-feet – depending on the visual capacity of the participant (i.e. near vs. far-sighted). Participants were required to complete the intervention in the seated position (see above for chair specificity). Due to equipment availability, all pre-test, post-test, and intervention sessions were completed in 2D measurements.

3.42 Conditions

Participants completed pre-test, intervention, and post-test tasks either pre or post exercise (e.g. team practice, individual skills practice, or strength & conditioning). For further discussion of conditions, refer to “Limitations” section (see Chapter 3.7).

3.43 Procedure

Upon arriving at the laboratory (National Training Centre – Toronto, Ontario), participants registered and created a profile with Cambridge Brain Sciences, and The Neurotracker (basic demographics; outlining age, sport, and disability – if applicable). Prior to the start of the pre-test/post-test tasks, a visual and verbal explanation of the task was presented. In the pre-test/post-test and intervention conditions, participants were in the seated position in front of the apparatus.

For the GEF tasks, a short video was shown containing a written explanation of the task and a brief example of how the task looks. All of the participants completed the GEF tasks using the touch-screen option on the apparatus. For the sport-specific pattern recall task, the Principle Investigator verbally explained how the task works, what the participant was required to do, and showed the participant an example of the task (that was not used in the actual testing process). This was done to ensure the participant fully understood the task correctly.

Similar to the pre-test/post-test measurements, the intervention task was both verbally and visually explained to the participants via The Neurotracker. Each MOT session contained 20 trials and lasted for approximately 6 minutes.

Total data collection for each participant took approximately 110 – 120 minutes for the 6-week study.

3.44 Statistical Analysis

Descriptive statistics, such as means, standard deviations (SD) and proportions, were generated to describe the study sample and variables. Due to the pre-post design of the study, analyses compared multiple participant scores (independent variables (IV)) on the Cambridge Brain Sciences (CBS), Pattern Recall Task, and ITQMT from the pre-test baselines to the post-test results. As such, paired samples t-test, correlations, mediation and moderations were performed to compare the change in performance and effect of the intervention from pre-test to post-test. The criteria for statistical significance on all analyses will be a $p < 0.05$. All data was implemented in SPSS 21.0 and G*Power 3.1.7 for statistical analysis (Faul et al., 2007). Specific statistical analyses are described below. Analysis of data from this study follows a similar procedure to other studies by Abernethy et al., (1994), Abernethy et al., (2005), and Schapschröer et al., (2016).

3.441 Pattern-Recall

Averages were used in t-tests from pre- to post-test comparisons to assess changes in pattern-recall as a result of the MOT intervention.

3.442 Cambridge Brain Sciences

As the thesis requires a comparison from pre- to post-test, as well as looking at the convergent validity of the intervention and the CBS cognitive tests, paired t-tests were run to look at the changes over the time of the intervention of each of the scores. We used these results to determine if there were any changes in GEF in the participants.

In regards to convergent validity, we also ran a correlation table looking at all of the post-test measurements from CBS cognitive tests, Pattern-Recall error, and all ITQMT components, in relation to the final performance of the MOT intervention. MOT interventions are hypothesized to increase cognitive functions such as improving attention, working memory, and information processing speeds. In relation to this, the tests selected from the CBS battery for the present study test similar components of cognitive function. As such, the correlation table was primarily to test the degree at which two separate components (e.g. CBS vs. MOT performance) are in fact related to one another (i.e. convergent validity).

3.443 ITQMT

Individual components of ITQMT (i.e. Defensive skills, Offensive general skills) were assessed from pre- to post-test in t-tests. Furthermore, ITQMT overall averages were compared in t-tests.

3.444 Moderation of MOT-Intervention on ITQMT and Pattern-recall

To quantify how MOT performance relates to post-test on-court performance and domain-specific perceptual cognitive skill, moderation effects were run through PROCESS v3.0 by Andrew Hayes on SPSS (Hayes, 2012). This helps to indicate if level of MOT performance influences the relationship of ITQMT and Pattern-Recall from pre- to post-test measures. PROCESS for moderation requires three axis to be indicated for running the correlation of these tests. In the case for this study, the X and Y (outcome variable) variables are the pre-test and post-test results of the tests, the W variable (moderating variable) is the final score the participant had on Session 12 of MOT training. An example of this relationship can be seen in Figure 3.

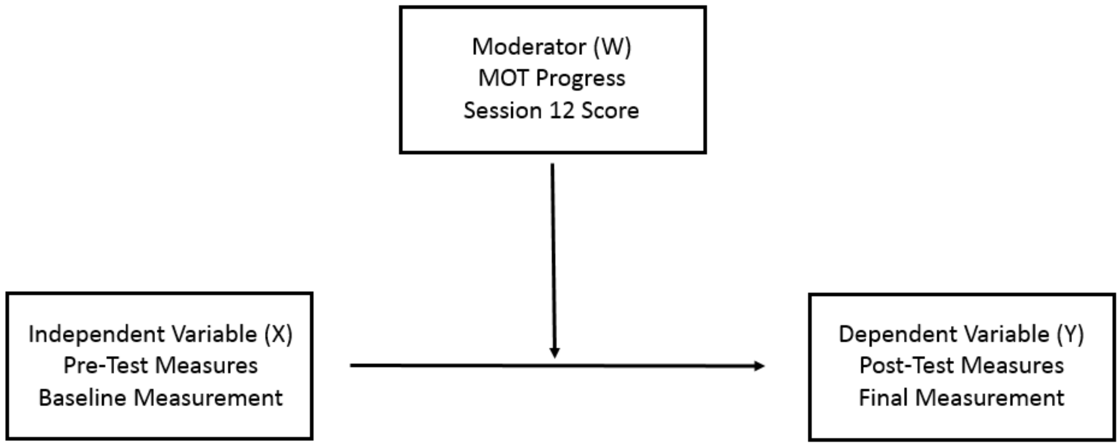


Figure 3. Moderating relationship of MOT intervention (final session score – Week 5, Session 12), on outcome. Outcome (dependent variable) is post-test results of pre-test measures (i.e. ITQMT and Pattern Recall).

3.445 Mediating Effect of MOT-Intervention on ITQMT and Pattern-recall

To quantify and explain the relationship between variables, and their potential affect of the intervention, mediation effects were run through PROCESS v3.0 by Andrew Hayes on SPSS (Hayes, 2012). Mediation effects require three variables to determine the correlation. X (pre-test measurement) and Y (outcome variable i.e. post-test measurement) variables, and M (mediation variable) is the final score of MOT performance (i.e. Session 12 MOT). An example of this relationship can be seen in Figure 4. The criteria for statistical significance on all analyses will be a $p < 0.05$.

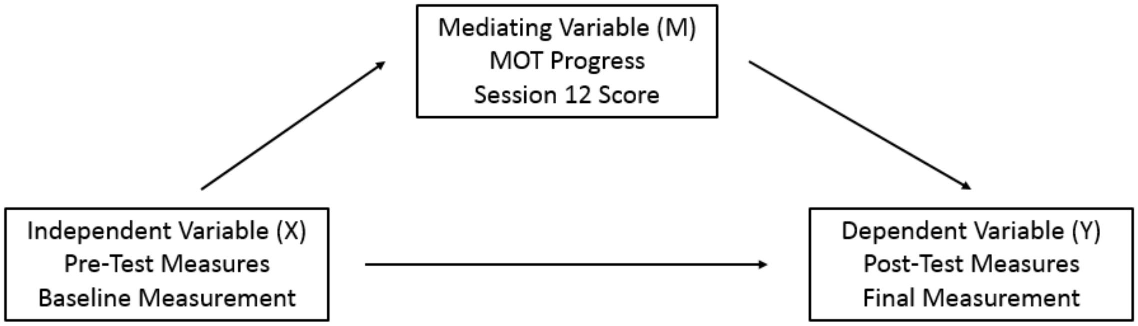


Figure 4. Mediating relationship of MOT intervention (final session score – Week 5, Session 12) on outcome. Outcome (dependent variable) is post-test results of pre-test measures (i.e. ITQMT and Pattern-Recall)

3.5 RESULTS

In regards to the aim of the study, we hypothesized that there would be no effect of GCT on sport-specific cognitive performance, and Wheelchair Basketball athletic performance. Furthermore, we hypothesized that ITQMT scores would vary only slightly, and MOT scores would maintain or slightly improve by the final session of training. Paired t-tests, correlations, moderation, and mediation effects were computed to look at the associations of test components (Pattern recall, CBS, and ITQMT) from pre- to post-test.

3.51 Descriptives

A total of 13 participants were recruited for the study. At the beginning of the trials, one of the participants dropped out due to a disability-specific medical emergency, leaving the final amount of participants at twelve. Of the sample, we had an uneven split between males (66.7%) and females (33.3%). Furthermore, the females were, on average, older than the males ($\Delta = 24.3$ *years*, $SD = \pm 3.77$). 41.7% of the total participants had congenital disabilities, and 58.3% of the total participants acquired physical disabilities. The participants were evenly divided in regards to placement on the National Team, versus placement on the Academy Team, or NWBA Team (Toronto Rollin' Raptors).

Table 1 shows descriptives of the participants in the study.

Table 2: Descriptive statistics of participants in study

	Group	Male	Female	Congenital Disability	Acquired Disability	National Team	Academy Team
Total	n=12	n=8	n=4	n=5	n=7	n=6	n=6
Mean Age (SD)	23.83 (±3.61)	23.62 (±3.77)	24.25 (±3.77)	21.20 (±1.10)	25.71 (±3.64)	23.83 (±3.25)	23.83 (±4.26)
Range (years)	20 – 32	20 - 32	21 - 28	20 - 23	21 - 32	21 - 28	20 - 32

SD = standard deviation

3.52 Pattern-Recall

Paired samples t-tests were carried out to compare pattern-recall performance before and after the MOT intervention. The analysis of pattern-recall results revealed statistical significance between pre and post-test results (see Figure 5: Δ = -0.17cm, SD = ±0.27, $t(11) = -2.20$, $p = 0.05$, $dz = 0.62$).

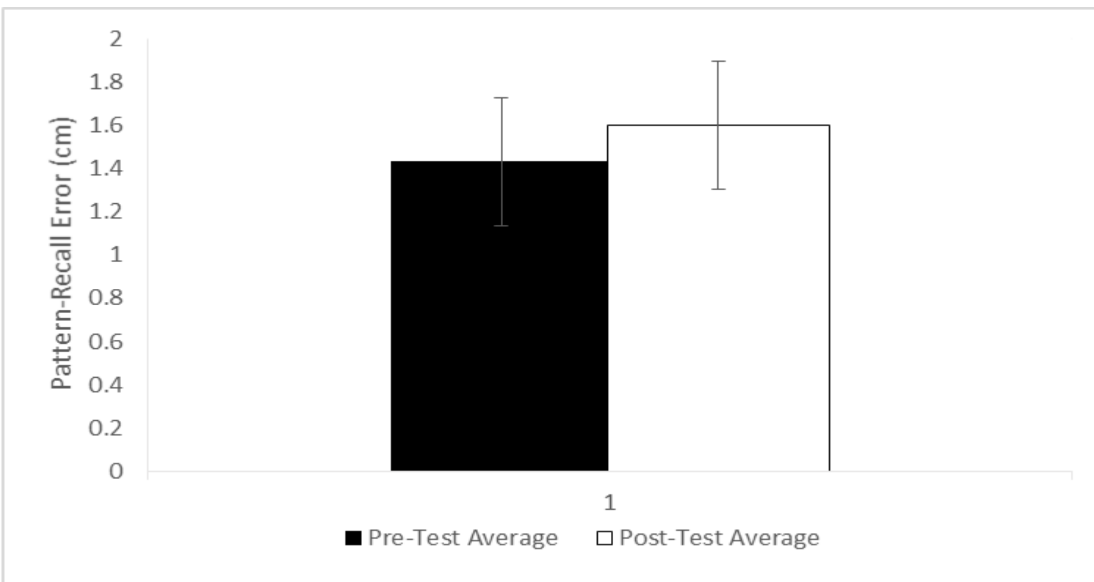


Figure 5: Average pre- and post-test comparisons for overall Pattern-Recall Error (cm)

3.53 Cambridge Brain Sciences

In order to compare the pre and post-test results of CBS scores (i.e. test results of Stroop Test, Search Task, Spatial Span, Feature Match, and Rotations), individual repeated measure t-tests were run. The analysis of CBS scores resulted in minute differences between pre-test and post-test sessions as a group. The Stroop test had an average difference of Δ=5.250, which was not statistically significant (*SD* = ±9.650, *t(11)* = -1.885, *p* = 0.086, *dz* = 0.54); Search Task showed no average changes (Δ = 0.00, *SD* = ±2.30, *t(10)* = 0.00, *p* = 1.00, *dz* = 0) Spatial-Span task had little changes with a mean of Δ=0.083 (*σ* = 0.669, *t(11)* = -0.423, *p* = 0.674, *dz* = 0.12). Although Feature Match, and Rotations showed a greater increase between pre-test and post-test results, the relationship of overall changes is a non-significant negative relationship (Feature Match: *Δ* = -9.833, *SD* = ±30.51, *t(11)* = -1.117, *p* = 0.29, *dz* = 0.32; Rotations: *Δ*=-12.33, *SD* = ±50.26, *t(11)* = -0.850, *p* = 0.41, *dz* = 0.25). Figures 6, 7, 8, 9, and 10 outline the pre- to post-test results of the CBS components.

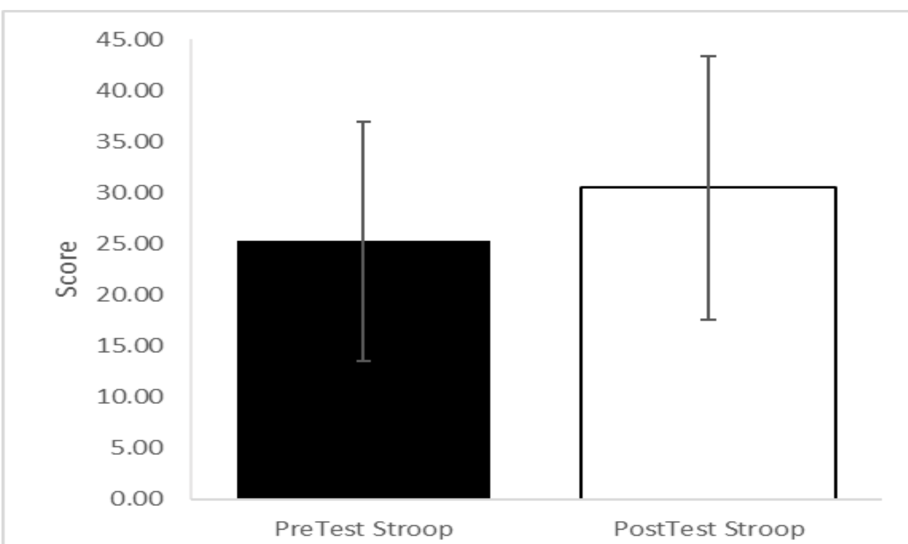


Figure 6: Average Pre-test to Post-test “Double Trouble” (i.e. Stroop Test)

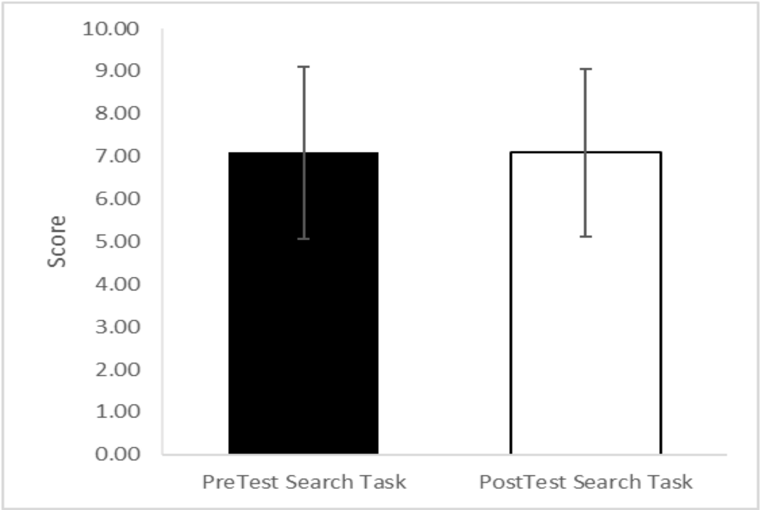


Figure 7: Average Pre-Test to Post-test results of Search Task

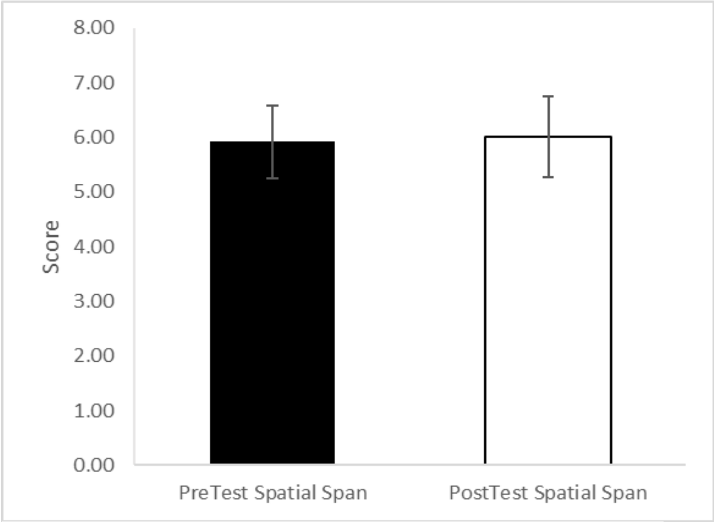


Figure 8: Average Pre-Test to Post-Test Spatial Span results

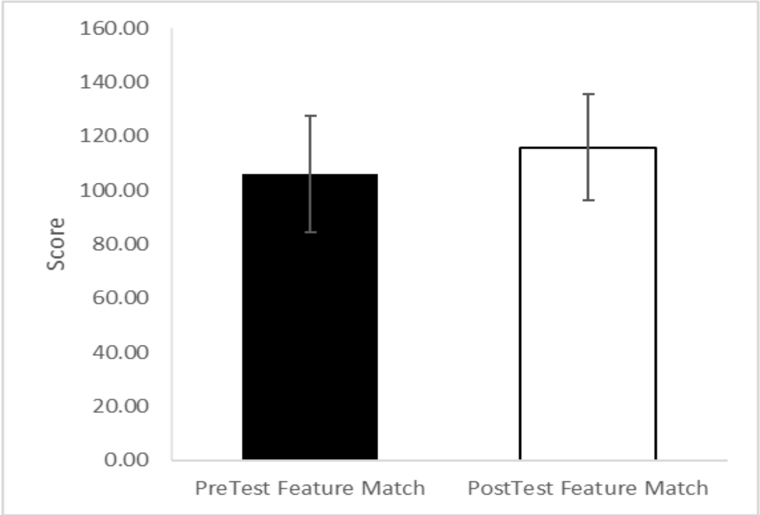


Figure 9: Average Pre-Test to Post-Test Feature Match results

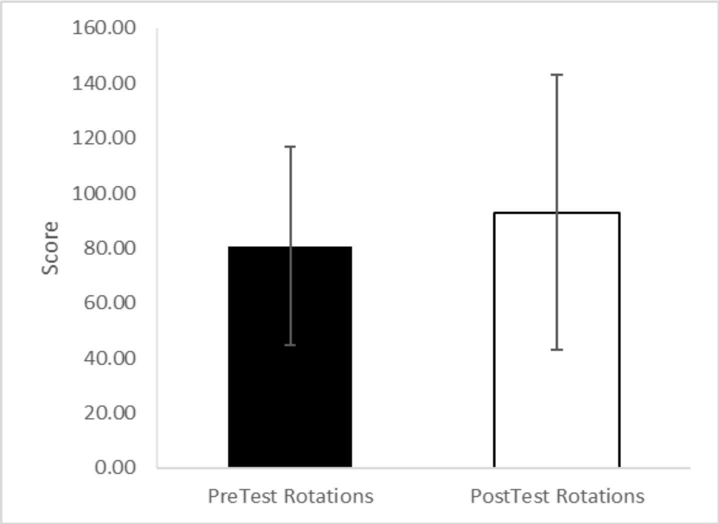


Figure 10: Average Pre-Test to Post-Test results of Rotation

3.54 ITQMT

ITQMT results demonstrated only subtle (in both positive and negative directions) differences from pre to post testing (see Figure 11). Paired t-test results for the overall group average were not statistically significant for the comparison ($\Delta = 0.10$, $SD = \pm0.22$, $t(11) = -1.57$, $p = 0.15$, $dz = 0.45$). Referring to Figure 11, ITQMT results in the participants' on-court performance minimally changed from pre to post testing on specific components. Defense on Ball (1-on-1; $\Delta = 0.11$, $SD = \pm0.35$, $t(11) = 1.10$, $p = 0.30$, $dz = 0.31$), Defense off Ball (1-on-1; $\Delta = 0.34$, $SD = \pm0.37$, $t(11) = -0.32$, $p = 0.80$, $dz = 0.08$), and Defense (2-on-2; $\Delta = 0.83$, $SD = \pm 0.17$, $t(11) = -1.70$, $p = 0.12$, $dz = 0.47$), and Offensive ITQMT components show similar results of minimal change, and statistically non-significant relationships. Ball Handling ($\Delta = 0.24$, SD = ±0.60, $t(9) = -1.40$, $p = 0.20$, $dz = 0.45$), Seeing ($\Delta = 0.10$, $SD = \pm0.26$, $t(11) = -1.31$, $p = 0.22$, $dz = 0.38$), Passing (Δ = 0. 13, $SD = \pm0.45$, $t(11) = -1.01$, $p = 0.34$, $dz = 0.29$), and Shooting ($\Delta = 0.27$, $SD = \pm0.65$, $t(11) = -1.5$, $p = 0.17$, $dz = 0.43$).

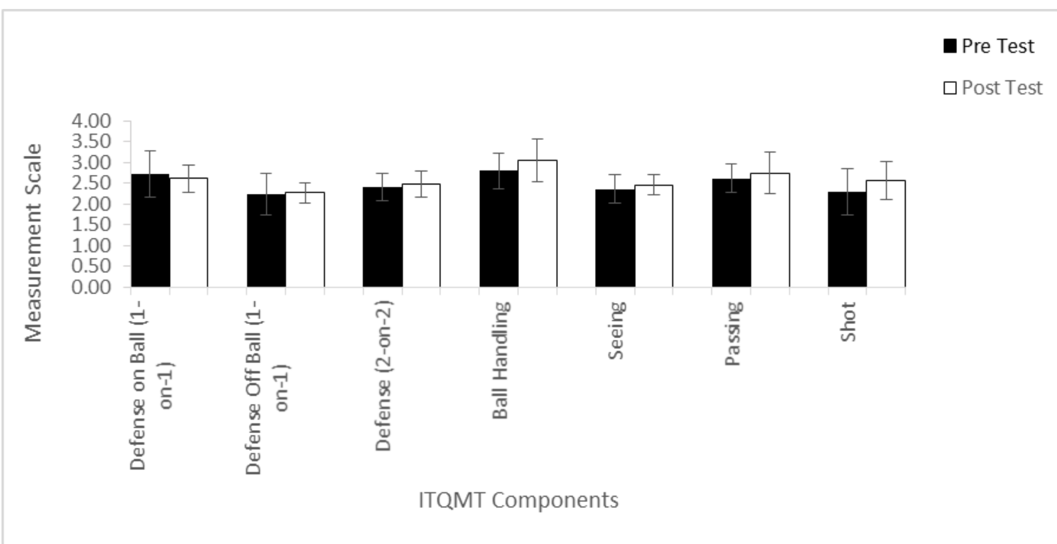


Figure 11: ITQMT comparisons from the pre-test to post-test timeline of the study

3.55 Correlations of Post-Test Measurements

In order to look at the relationships of all pre- to post-test had as a group (including final performance of the intervention), a correlation table was computed through SPSS. Pearson correlations can be seen in Table 3. Only those bolded have statistical significance at the $p < 0.05$, and $p < 0.01$ level (2-tailed).

Within the correlation table of post-test scores, there are only a few significant correlations. These include Defense Off-Ball with Passing ($r = 0.58$), Ball Handling and Passing ($r = 0.77$), ITQMT Post-test Average and Passing ($r = 0.78$), and Defense Off-Ball and Shooting ($r = 0.59$). Moreover, of the entire table, only one statistically significant correlation emerged that was not inclusive of the same test (i.e. ITQMT vs. ITQMT score; Feature Match with Defense 2-on-2 [$r = 0.67$])

Table 3: Correlations of Post-Test Measurements

	Pattern 1	Pattern 2	Pattern 3	Pass	Shot	Def. On-Ball (1-on-1)	Def. Off-Ball (1-on-1)	Def. 2-on-2	Ball Handling	Seeing	ITQMT Average	Double Trouble (Stroop)	Search Task	Spatial Span	Feature Match	Rotations	MOT Final Score
Pattern 1	.																
Pattern 2	0.61	.															
Pattern 3	0.39	0.36	.														
Pass	0.00	-0.03	0.01	.													
Shot	0.18	-0.25	-0.26	0.57	.												
Def. On-Ball (1-on-1)	-0.2	-0.09	-0.52	0.25	0.20	.											
Def. Off-Ball (1-on-1)	0.1	-0.26	-0.46	**0.58***	**0.59***	0.57	.										
Def. 2-on-2	0.6	-0.26	-0.30	0.27	0.49	**0.62***	0.18	.									
Ball Handling	-0.2	-0.13	-0.23	**0.77****	0.42	0.59	**0.77****	0.13	.								
Seeing	0.15	-0.33	-0.33	0.38	0.35	**0.58***	**0.73****	0.46	0.59	.							
ITQMT Average	0.00	-0.21	-0.37	**0.78****	**0.71***	**0.68***	**0.84****	0.57	**0.82****	**0.73****	.						
Double Trouble (Stroop)	0.08	0.37	0.17	-0.26	0.14	0.21	-0.24	0.41	-0.11	-0.04	0.04	.					
Search Task	-0.16	0.04	-0.31	0.50	0.41	0.17	0.45	0.10	0.30	0.22	0.45	-0.16	.				
Spatial Span	-0.37	-0.28	0.02	-0.16	0.17	-0.06	0.14	-0.23	-0.02	-0.08	-0.05	0.00	0.19	.			
Feature Match	0.12	0.42	0.58	-0.10	-0.10	-0.46	-0.15	**-0.67***	-0.08	-0.48	-0.35	0.02	-0.37	0.29	.		
Rotation	-0.19	0.03	0.31	-0.15	-0.01	-0.24	-0.04	-0.42	0.01	-0.17	-0.18	0.18	0.22	**0.66***	0.42	.	
MOT Final Score	-0.43	0.03	0.00	-0.09	-0.43	0.51	0.03	0.12	0.16	0.22	0.06	-0.02	-0.17	0.28	-0.10	-0.09	.

*correlation is significant at the 0.05 level (2-tailed)

**correlation is significant at the 0.01 level (2-tailed)

3.56 Moderating/Mediating Effects of MOT Intervention

When looking at the group as a whole, the results indicate that post-session scores increased from the beginning of the intervention (Week 2) to the end (Week 5). A repeated measures t-test was also conducted to look at the changes from Week 2 to Week 5 (i.e. 1st session to 12th session of MOT training). Results indicated a statistically significant relationship from the 1st session to the last session of MOT training ($\Delta = 0.38$, $SD = \pm 0.34$, $t(11) = -3.9$, $p = 0.003$, $dz = 1.11$). Individually, participants showed a great amount of variance in scores, with the highest being in Session 4 [0.65, 1.54] and Session 12 [0.47, 2.26]. Figure 12 shows the average MOT performance with standard deviations from the first MOT session to the final session.

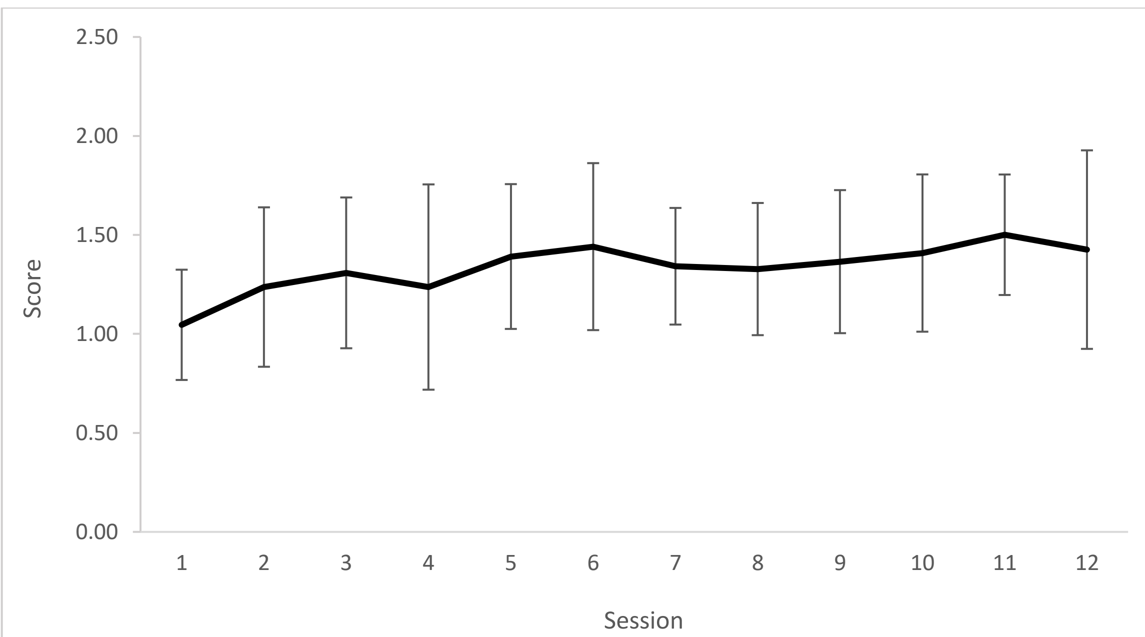


Figure 12: MOT scores from baseline (Session 1) to Session 12 of the study

3.561 Intervention vs. ITQMT

In order to observe the effect that performance on the MOT intervention had on the pre-test measurements, we computed moderation analyses (i.e. final MOT session score), with a specific outcome variable (i.e. post-test ITQMT average). When looking at moderating effects between sport-specific on-court performance (ITQMT pre and post-test), and last session of intervention (Session 12 MOT), we observe statistically significant results (b = 0.650, *95% CI* [0.07, 1.22], t = 2.58, p = 0.032). This indicates that the strength of the relationship of on-court performance (pre-test to post-test) was moderated by participants' performance level on the MOT task.

To better understand the moderating effect of MOT performance on ITQMT, a conditional effect was computed to look at the differences between low, medium, and high MOT scores (i.e. lowest, median and highest results – 16^{th}, 50^{th}, and 84^{th} percentile), and their effect on on-court performance (ITQMT). We can interpret the results in the following three ways:

1. 16^{th} percentile: When MOT scores are low, there is a non-significant positive relationship between the beginning of the study to the end (Pre-Test ITQMT to Post-Test), b = 0.423, *95%* CI [-0.016, 0.862], t = 2.22, p = 0.571.
2. 50^{th} percentile: At the mean value of MOT scores, there is a significant positive relationship between ITQMT Pre-test and Post-Test, b = 0.723, *95%* CI [0.360, 1.062], t = 5.04, p = 0.001.
3. 84^{th} percentile: When MOT scores are high, there is a significant positive relationship between ITQMT scores from Week 1 to Week 6, b = 1.140, *95%* CI [0.654, 1.624], t = 5.42, p = 0.0006.

These results suggest that the relationship between Week 1 and Week 6 of ITQMT (on-court performance), and effect of MOT training, emerged in participants who had medium to high scores on MOT sessions. Therefore, participants who had greater ITQMT scores from Week 1 to Week 6, were more likely to have a greater performance in the MOT sessions. Figure 13 shows the progress from the 1st – 12th MOT session, and the variance of ITQMT scores.

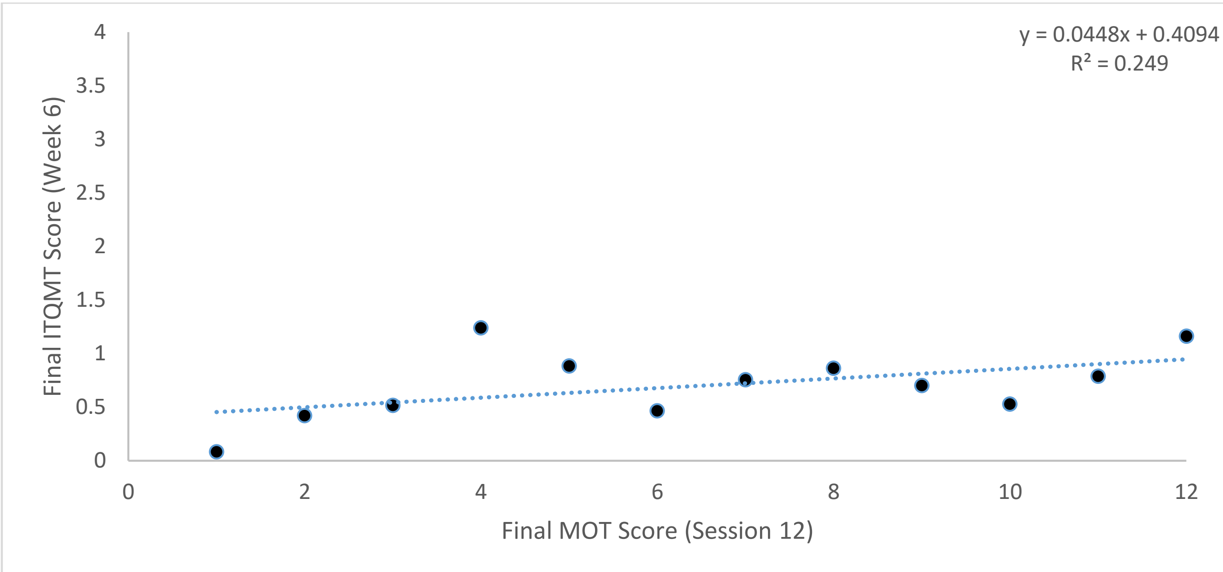


Figure 13: The look of MOT moderating effects on ITQMT scores throughout the intervention of the study.

Also, we computed mediating effects of ITQMT Pre-Test to the final performance of MOT Intervention (Session 12 Score), and the potential effect that had on ITQMT Post-Test. When looking at the mediating effects of MOT intervention, we see a statistically significant association ($p = 0.01$) on the direct relationship between ITQMT Pre-Test and Post-Test. The associations from the final MOT session indicate that on-court performance (i.e. ITQMT post-test) was not mediated by the intervention. Figure 14 outlines the mediating effects computed on each variable.

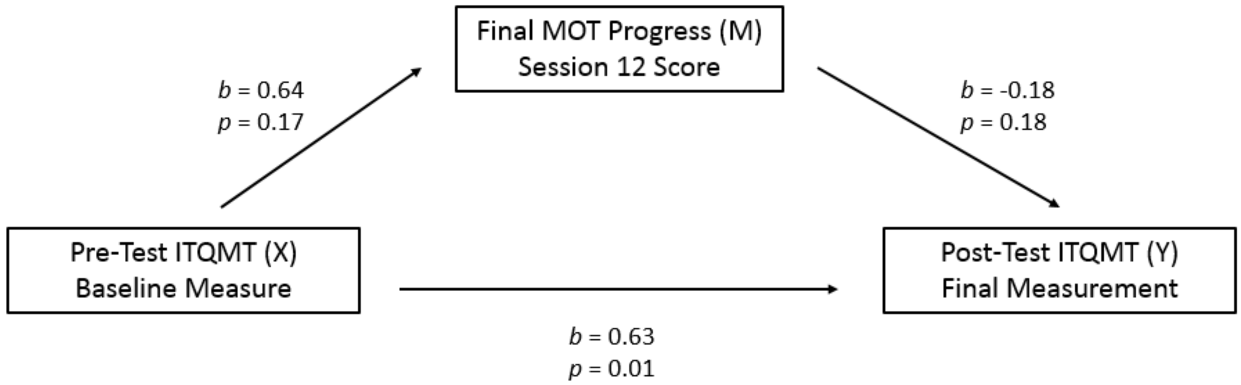


Figure 14. Mediating effects from Pre-Test ITQMT (X) to the final outcome of the MOT intervention (M), and then to the Post-Test ITQMT measurement (Y).

3.562 Intervention vs. Pattern-Recall Skills

In order to observe the effect that MOT training had on Pattern-Recall skills in the participants from pre- to post-test measurements, we computed moderating effects of the intervention (i.e. session 12 of MOT), with the specific outcome variable of post-test pattern-recall score (i.e. average score of pattern 1, 2, and 3). When looking at the moderating effects between sport-specific cognitive skill (i.e. pattern-recall averages pre- and post-test), and the last session of the intervention (i.e. Session 12 MOT), we observe non-statistically significant negative results (b = -0.93, *95%* CI [-2.13, 0.27], t = -1.79, p = 0.11). This indicates that progress in Week 1 to Week 6 of sport-specific cognitive performance was not moderated by performance in the intervention. Figure 15 shows progress from the 1^{st} – 12^{th} MOT session, and the variance of Pattern-Recall scores in the group. Since the above relationship was found to be statistically non-significant, no conditional effects of the relationship were computed.

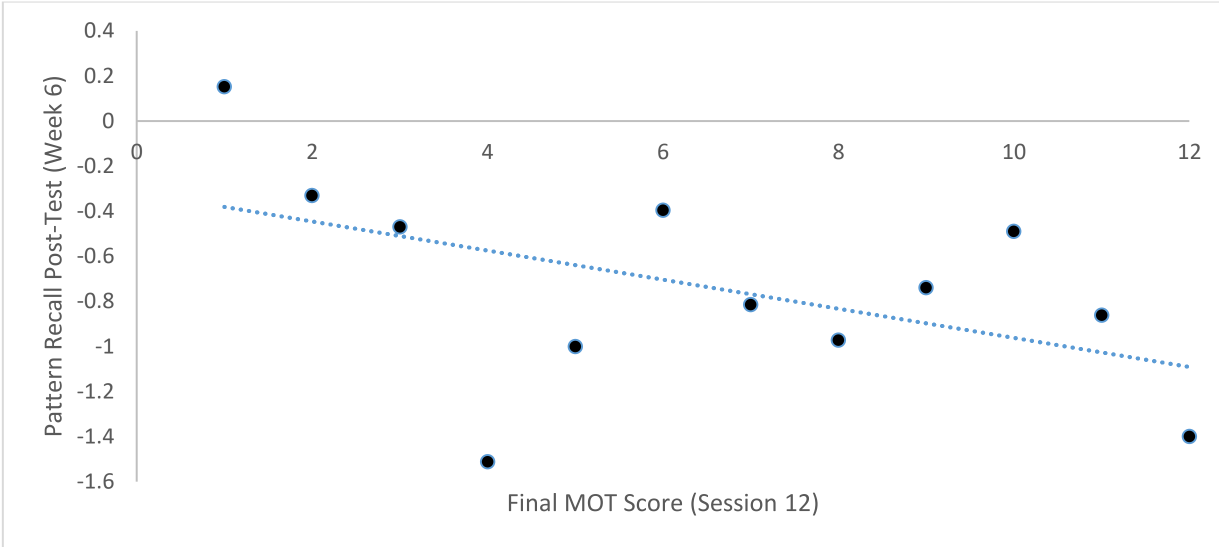


Figure 15: The look of MOT moderating effects on Pattern Recall scores throughout the intervention of the study

In order to look at the strength that the intervention directly and indirectly had on the pre-test (X) and post-test (Y) measurement results, we computed the final MOT session (Session 12 score) as a mediating variable (M). Referring to Figure 16, and looking at the mediating effects of the MOT intervention, we observe no statistically significant relationships. This indicates that the pre-test and post-test Pattern-recall results were not mediated by the intervention.

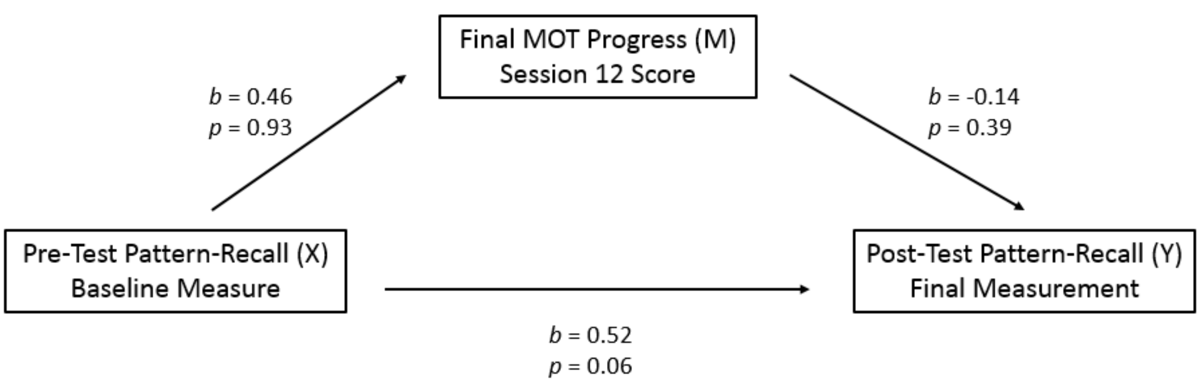


Figure 16. Outlining the mediating relationship between Pattern-Recall performance and MOT intervention performance.

3.6 DISCUSSION

3.61 Pattern Recall

The results of the Pattern Recall analysis show that the group average error (i.e. distance in cm) from pre to post testing increased. This suggests that accuracy in pattern-recall decreased with the participants as a group. Moreover, we observed variability in individual pattern-recall scores (i.e. some participants increased accuracy while other did not). Therefore, the effect of the MOT intervention on performance in pattern-recall was inconclusive.

Among reasons for variability in data (see Limitations section – 3.7), a potential reason we see a decrease in accuracy from the participants could be due to an inconsistent testing schedule. In order to attain all data in the study, the schedule needed to be fluid for all participants. Therefore, if a participant completed the pattern-recall assessment after practice, the effect of mental fatigue may have influenced the outcome of accuracy. Furthermore, participants are required to work on components of their Individual Performance Plan (IPP) from their coach. If a component of this involves a significantly higher amount of focus (compared to other days, or overall team practice), the participant may have exhausted components (i.e., cognitive effort) necessary for pattern-recall.

Another potential reason for findings may be the relationship between pattern-recall skills and anticipation. A study completed by Gorman, Abernethy, & Farrow, (2012), tested the pattern recall and accuracy in basketball and soccer players, demonstrates the insights of anticipation in domain-specific patterns (as anticipation is a characteristic of expert performance). In this study, experts and non-experts were shown various patterns in one domain (i.e. basketball), in random order of occurrence (i.e. chronological vs. reverse). Pattern-recall skills in this study were used to measure cognitive skill differences in pattern-recall and anticipation. Results from this study suggest that when experts are provided with static or moving patterns from their area expertise, they are better at anticipating the next likely pattern.

In regards to the present study, the anticipatory nature of pattern-recall in experts may be the reason why we observe decreases in accuracy over the study period. This may be due to the experts (or participants with greater wheelchair basketball development) anticipating the next likely pattern, rather than assessing the presented pattern for face-value.

3.62 Cambridge Brain Sciences

The five tests (i.e paired t-test results) from the CBS battery (i.e. Stroop test, Search task, Spatial Span, Feature Match, and Rotations) showed a variance (i.e. inconclusive) of results from pre- to post-test analysis. Overall all group comparisons had no statistical significance, however, most participants made improvements from Week 1 to Week 6 testing.

The lack of relation between MOT and GEF raises questions about the underlying process of MOT. Specific claims from GCT programs state that use of this technique (i.e. MOT) will result in increased attention, information processing speeds, and Working Memory (WM; Parsons et al., 2016). These same components are measured through the CBS battery test. As such, it is surprising to see that there is not a more explicit relationship between MOT and GEF. This also raises questions about the proposed underlying processes or mechanisms of MOT.

The role of WM capacity in sport and the development of expertise is something that has been previously disregarded in research (Farrow et al., 2017). WM is a construct of STM which is focused on the immediate conscious perceptual processing (i.e.

mechanism that is capable of information retention in a dynamic setting for on-going use; Furley & Memmert, 2015). Furthermore, WM is thought to be a general skill compared to long-term memory (LTM), which is thought to be a specific skill (i.e. very trainable through deliberate practice; Farrow et al., 2017). This in turn supports the concern that there was little-to-no changes in CBS testing results, as WM and STM should be impacted by general testing capacities.

In relation to sport-specific performance (i.e. ITQMT), there is some research that suggests WM is related to on-field performance (see: Farrow et al., 2017). In regards to the present study, we found that there were minor changes in both positive and negative directions, over the intervention period. This area of research, and exploring the role of WM in sport performance is an area that researchers (i.e. Farrow et al., 2017) say needs more evidence. Greater measurement techniques such as expert vs. novice paradigm may deliver considerably different results.

A limitation in looking at GEF in the present study, is that there is a lack of an ‘opposing’ group (i.e. novices). The sample we tested in the present study, essentially compares experts within the same cohort. We did not find any definitive direction in regards to GEF and MOT performance. This may be because there is no relationship between the two variables, or perhaps it is because this may only be useful when distinguishing between experts and non-experts, rather than experts in the same group.

3.63 ITQMT

Results from on-court performance are displayed through ITQMT scores (i.e. individual components and group-averages). Although all individual components, as well as group averages showed a non-statistically significant relationship, it is important to note that this relationship may still be important to the sport. According to the Power Law of Practice (Logan, 1988; Newell & Rosenbloom, 1981), and looking at Practice Effects (Duff et al., 2007), performance is said to improve the most early in learning, begins to plateau over time, and approaches an asymptote later in learning (Logan 1988; Newell & Rosenbloom, 1981). Therefore, since the study is dealing with high performance (HP) athletes (some who have reached Paralympic competition), it can be assumed that learning and technical development in Wheelchair Basketball occurred when the participant originally started to play basketball. Therefore, with the participants in this study, any development to on-court performance will require substantially more time to elicit any observable changes. Furthermore, the entire group showed improvements from the start of the study to the end, which is also instrumental to a proper and productive training environment (i.e. everyday practices, strength and conditioning, rehab programs etc.).

In summary, for these athletes, it is hypothesized that any changes in performance will be small. Furthermore, while these athletes were participating in the MOT intervention, they were still engaged in their daily training environment (DTE). This involves coaches still giving instruction in areas to improve. Therefore, the question of whether these changes are due to MOT or DTE remains. This is a limitation to the study, as we lose experimental control. Unfortunately, there was not a way to apply the intervention to some participants and not others; furthermore, it was not possible to stop all other training. However, this study is more ecologically valid as this is a typical environment of how MOT would be used in DTE.

In regards to the validity and utility of ITQMT we further question the impacts it may have on real performance in wheelchair basketball games. ITQMT is a proxy for performance (i.e. an indirect way of measuring physical skill), developed by an expert in the Para-sport community. However, this tool has not been further validated by researchers, and we understand that using this tool is as close as possible to look at performance measures for in-game performance. Furthermore, we suggest perhaps that different types of measures may also assist in looking at in-game physical performance.

Different measures may also help to assess in-game physical performance. For example, box scores (i.e. stats) from a game (i.e. points made, assists, steals, fouls). These in-game results are usually computed at a major competition (i.e. Para Pan American Games, Paralympics), or IWBF sanctioned event (i.e. Qualifiers, World Championships). These, in conjunction with the ITQMT, may help to further assess on-court performance. Results in the present study may have considerably changed if we considered the overall result of each participant at the ITQMT measured game – as we would be observing another dimension of performance.

3.64 Correlation of Post-Test Measurements

Correlational analysis were used to examine GEF, ITQMT components, Pattern-Recall scores, and final performance in the MOT intervention. Table 2 displays statistically significant associations between post-test measurements. Of the 15 statistically significant correlations listed, only one of the associations is comparative between two different measurements (i.e. ITQMT vs. CBS, as opposed to ITQMT vs. ITQMT). For example, most correlations are between ITQMT components (i.e. shooting vs. ITQMT overall average), which makes sense, as this is a component within itself. However, there is a statistically significant relationship between Feature Match (component of CBS), and Defense 2-on-2 (ITQMT component). There are two potential reasons as to why we observe this relationship. The first reason is that Feature Match, as well as 2-on-2 Defense, both involve short-term memory (STM) as well as reasoning in order to be successful. Therefore, this relationship may reflect similar characteristics of tests. The other reason is that this relationship may have occurred by chance. Replication of methods and results would be needed in future research to observe if this relationship would appear again in the results.

Although not reported as statistically significant, it is important to look at the Pearson Correlations between some of the variables in Table 2. What is demonstrated here is that the final MOT Session score does not have a strong linear relationship with any of the variables used in the study in both the positive and negative direction. This suggests that claims made in previous research about utility of MOT in benefitting working memory, attention, and processing speed (Parsons et al., 2016), are not conclusively supported here. Furthermore, sport-specific claims on physical performance (i.e. general technical skills such as passing or dribbling in soccer), improvement proficiency for player and movement tracking on-court or in a field of play, and increased ability to process patterns for in-field performance (Faubert et al., 2012; Romeas, Guldner, & Faubert, 2016; Perico et al., 2014; Faubert, 2013; Tinjust, Allard, & Faubert, 2008; Vartanian, Coady, & Blackler, 2016), were not conclusively supported here as there appears to be no strong relationship to the final MOT session, and test components in the study.

Potential reasons we would observe this result is due to there being no relationship between MOT performance and GEF, Pattern-Recall, and ITQMT. As Wentink et al. (2016), mentions in their study about near and far transfer from Lumosity to daily functioning of post-stroke patients, that the task being tested (i.e. GCT) needs to be closely related to the outcome task (i.e. functioning). Furthermore, researchers have questioned the validity of general-cognitive transfer to specific performance (Farrow et al., 2017). Results of the current study may therefore reflect a lack of relationship between MOT performance and improvement in skills.

3.65 Intervention – MOT Performance

As hypothesized, average group scores in MOT performance increased from Week 2 to Week 5. Although increased scores were displayed as a whole, it is important to look at the magnitude of increase, along with individual variance of scores. For example, the group increased performance from the start of the intervention to the end, however, all scores were between 1.00 and 1.50 (i.e. speed threshold of MOT). Therefore, this was not a substantially large increase in the MOT performance. Furthermore, even though the group showed an increase as a whole, standard deviation (i.e. variance) of the scores show that many participants were highly above or below that average. With the highest variance being in Session 4 and Session 12, future research would benefit from day-to-day surveys to attest for potential societal or environmental moderators the participants may be experiencing (i.e. sleep quality the night prior, exercise prior to MOT performance, overall interest in intervention task, past experience with video games, etc.). Moreover, a longer intervention time would be beneficial to account for learner effect of the intervention, as this may explain the variance of scores or improvement in score.

3.66 Moderation and Mediation of Intervention

MOT Intervention vs. ITQMT

In order to look at the effect that the MOT intervention had on the sport-specific test components of the study, we needed to look at how (if) performance measures were changed (negatively or positively) in relation to performance on the intervention. Moderation effects were computed with the X-variable being the pre-test measure, the Y-variable being the post-test measure (i.e. outcome variable) and the moderator (W-variable) being the final session score on MOT. For the specific relationship of the MOT intervention, and ITQMT measure, we observe a positive statistically significant association. These results indicate (without considering magnitude), that on-court performance from Week 1 to Week 6 was moderated (i.e. effected) by participants' performance on the MOT intervention.

In order to understand the previous relationship in greater detail, we computed conditional effects of the lowest, median, and highest MOT scores (16^{th}, 50^{th}, and 84^{th} percentile). This was to understand the positive relationship, and perhaps to differentiate where it may emerge in participants. This suggests that participants who had greater ITQMT scores from Week 1 to Week 6 of the study, were more likely to have a greater performance in the intervention. Mediating effects were also computed to look at the indirect relationship between pre- and post-test results (see Figure 14). From these results, we observe that there is no effect from the independent variable (Pre-test measurement) to the MOT intervention. Moreover, there was no association between MOT intervention to the dependent variable (post-test measurement). With this being said, level of on-court performance was not indicative of performance in MOT. Furthermore, performance in MOT intervention did not further predict on-court performance after usage.

The implications of these results suggest that there may be an effect, but it is not substantially increasing. This raises the question if you need to reach a certain level of MOT in order for it to beneficial? Previous research has not considered this, nor does this exist in any training documents (www.neurotracker.net). Furthermore, we question if there is a point in which MOT stop having benefits to performance? What are the points of diminishing returns (i.e. when does this stop working); are there any? Moreover, guidelines for use on MOT (i.e. how often; how many sessions per day/week/month, etc.)

are scarce. Therefore, we have very little information on use and benefits of this training tool.

MOT Intervention vs. Pattern-Recall

In order to observe if sport-specific cognitive performance was similarly moderated by the MOT intervention, we computed the relationship between performance on both testing measures. The results showed that there was a negative, non-statistically significant correlation between performance on MOT sessions, and performance on pattern-recall skills (i.e. no moderating effect occurred). This suggests that over the time of the study, the more the participants completed MOT sessions, the worse they performed in sport-specific pattern-recall measures. This relationship is one that could have occurred simply by chance. Furthermore, this relationship could exist to the pattern-recall task itself. Although only wheelchair basketball-specific patterns were used in the study, some of the patterns may have posed a greater challenge than others; specifically regarding recall skills in the participants. Therefore, future research would need to retest pattern-recall, perhaps with a greater amount of MOT sessions, a larger number of pattern-recall attempts, and increased participants, in order to test the validity of the results from the present study.

Due to the negative non-statistically significant relationship of moderation in MOT and pattern-recall, no conditional effects were computed to look at the emergence of the relationship. This is because a large majority of the participant's cognitive performance decreased throughout the intervention. As such, we can assume that no moderating effects occurred in regards to MOT intervention sessions, and performance on pattern-recall measures. This is also reflective of the dose-response relationship between MOT sessions, and impact on sport-specific cognitive skill. Therefore, future research would need to look at difference in amount of MOT sessions administered in an intervention to see if this could potentially have an influence on the strength of the relationship from pre- to post-test results.

In order to observe the indirect relationship of the intervention and pattern-recall, we computed mediating effects from pre- to post-test measurements. From this, we observe that the associations from pre-test, to MOT intervention, to post-test measurements, were not statistically significant. Therefore, we can infer that sport-specific cognitive skills did not dictate MOT performance, and further, MOT performance did not predict pattern-recall performance after intervention sessions.

In regards to moderating effects of MOT performance in pattern-recall outcome, we found statistically non-significant results. With this being said, we question the overall impact that MOT performance has on sport-specific cognitive skills. Moreover, do these results suggest that MOT training has a more tangible impact on on-court performance, and not perceptual-cognitive performance? Unfortunately for the present study, there is too much variation in the data in regards to participants with congenital vs. acquired physical disabilities, and sporting milestones (i.e. starting age of basketball – in participants with acquired physical disabilities, and accumulated hours of practice – i.e. DP; Dehghansai et al., 2016b). Referring to Figure 9 on the moderating effects of the MOT intervention on pattern-recall performance, it is important to note that we have a small sample size (n=12), therefore, we were not able to remove data. There were extreme values for two data points may have had an effect on findings. We chose not to remove these data points as they were not errors, or outside reasonable range. However, we understand that these points could have made an impact (also with SD, and standard error). A larger sample size would be beneficial for future research in order look at the impact of extreme values on data findings.

3.7 LIMITATIONS

Results from this study should be interpreted in light of the following limitations. Data analyses did not isolate for mediators and moderators that could affect anticipation, and decision making skills. These moderators include time of day test was taken (i.e. early morning before practice, or afternoon post practice), food intake prior to tests (i.e. carbohydrate intake can assist in preserving blood glucose concentrations and muscle glycogen – needed for competition; Hills & Russell, 2018), life events or trauma (which may serve as distracting to the participant), previous experience playing action video games (which have been shown to improve visual skills, attention, memory, and spatial resolution in some studies; Green & Bavelier, 2003; Green & Bavalier, 2006; Green & Bavalier, 2007; Li et al., 2009), preconceived notions about the utility and validity of the intervention (some participants were decided on whether the intervention was affective or not, prior to the start of the tests). The small sample size in the present study also demonstrates larges variation, which can have an impact on overall changes, averages, and trends in the data. As such, a larger sample size would help to create a better representation of normal distribution in data. These could serve partially to explain our findings.

The schedule for the participants to complete the tests had to be fluid in order for all tests to be completed. Due to the high performance population, many scheduling issues arose as a group, and individually. This resulted in inconsistencies of time and day of tests between and within participants. Future tests would potentially benefit from a more rigid schedule in the testing process. However, the study design and the MOT intervention was representative of how MOT would be used and scheduled within a HP training environment. Moreover, in regards to scheduling conflicts, two similar studies completed by Schapschröer et al., (pg 1717; 2016a,b), on pattern-recall skills in female handball players notes this as a potential influencer to results. The author notes, "The lack of significant changes for any of the groups at rest or during physical exercise in our study might relate to the specificity of the pattern recall task. It is possible that submaximal exercise only has a facilitating effect on general perceptual-cognitive abilities" (Schapschröer et al., 2016b). Conversely, authors McMorris and Graydon (1997), did not find any effect of physical exercise (70% of maximum output) on decision-making capabilities in soccer-specific tasks. For the purposes of the present study, results may have been altered if all participants completed MOT intervention sessions in the same exercise protocol (i.e. same practice times and resistance training times). Furthermore, high performance athletes are used to using their perceptual-cognitive skills while they are active. This also relates to domain-specificity in scheduling purposes as the practiced task would be more relevant to the real task. With this in mind, it would be beneficial for future studies to have more rigidity in scheduling in regards to either pre or post-physical exercise. This would allow for increased validity in results, as well as stern reasoning to relate results either to the effect of physical exercise, or rest. Sample size for the study could affect the deviation of measurements. A larger sample study for future research would serve as a benefit to properly measure these tests for the Wheelchair Basketball population.

The participants involved in the study had a wide variety of either congenital or acquired physical disabilities. Regarding this, some participants were no longer able to take part in the study due to disability-specific issues (i.e. pressure sores, overuse injuries of the shoulders and elbows), that prevented them from being involved in the DTE. Due to the span of physical disabilities in the participants, the data used in the study did not isolate or attest for athletic developmental histories, or sport milestones. Although all of the participants were required to have a certain amount of competition and training experience for the study, some of the results may be influenced by past-experience or sport-specific practice. For example, if an athlete acquired an injury later in life (rather than being born with one), they demonstrate later attainment of sport milestones (Dehghansai et al., 2016b). Furthermore, wheelchair basketball athletes demonstrated increased amount of hours of DP when they made a conscious decision to excel their sporting career (which included modified training regimens and non-sports-specific modalities [i.e. strength & conditioning]; Dehghansai et al., 2016b). With this, it could be assumed that athletes with congenital disabilities, how having engaged in more sport-specific practice would have an advantage over athletes who have acquired a physical disability. However, it is demonstrated that athletes with congenital or acquired physical disabilities reach 'key' milestones (i.e. first National or International competition) around the same age (Dehghansai et al., 2016b). This could be further explained by Baker et al., (2003) study on athletes from team-ball sports. Results from the study indicated a negative relationship between accumulated sport-specific training hours, and the number of sports mainstream athletes participated in. This could help to explain how athletes with acquired physical disabilities were able to transfer skills from previous sports to wheelchair basketball (Dehghansai et al., 2016b).

Although we did not collect athletic histories from the participants, we question what the potential implications would have been if we included for previous – potentially transferable – experience (i.e. athletes with congenital physical disabilities coming from

Sledge Hockey, Wheelchair Tennis, or Wheelchair Rugby [i.e. speed progressions, turning, and stopping are similar sport characteristics], or athletes with acquired physical disabilities coming from mainstream Basketball or Soccer [i.e. similar patterns in sport]). In parasport, there is a large variability in the amount of DP an athlete accumulates in order to perform at a high level (Dehghansai et al., 2016b). The amount of accumulated DP between the participants may have affected the results, as some participants may have advantages in either sport-specific cognitive skills or physical performance as a result of different training histories. Therefore, future research should isolate and attest for DP differences in participants, as it may serve as a potential explanation of the current results.

Looking at the potential impacts that MOT performance had on sport-specific physical performance (i.e. ITQMT), we see minute changes in both the positive and negative direction. A limitation in using only pre- and post-test results is that we fail to observe typical trends in physical performance (i.e. non-intervention scores). Future research would benefit from having results or observations of physical performance prior to the start of the study in whole (i.e. using the same 6-month period prior to the start of the study). Having this pre-pre-test information would allow researchers to have prior knowledge of typical trends in performance, and better verify if the observed results are from the intervention itself, or a product of the DTE.

In regards to the 3-Assumptions (see below), the present study falls short of representing this. Although we understand how certain cognitive components can be related to sport performance (i.e. attention, anticipation, decision-making skills, etc.), we failed to confidently measure if these components were trained through the intervention, and finally if they were successfully measureable through performance. Current research (Farrow et al., 2017) says that evidence in use of MOT programs is not compelling. Based on evidence, and current quality of research, we recommend that practitioners exercise a healthy amount of skepticism about the efficacy and utility of programs, and their expectations about the benefits of use.

Future Directions

Given the controversy about general cognitive training programs and the need for more research on this topic (Simons et al., 2016), this research project will contribute to understanding whether these brain training programs have transferable benefits. This would be beneficial for all sports to understand the impact that different types of perceptual-cognitive training has on high performance sports, and athlete development. More broadly, this research will contribute to discussion about the claims of brain training companies. These companies promote the success of their products to a wide variety of different conditions and wanted outcomes (Simons et al., 2016). For example, they claim to help physical, and cognitive related decline such as Turner Syndrome and Age-Related cognitive impairment. As well, promote sport performance, everyday memory, and general cognitive ability in healthy populations (Simons et al., 2016). It is important to note the broader implications of these claims, as companies such as Lumosity, have made without the proper scientific evidence to support them (Federal Trade Commission, 2016a, 2016b). As such, research on brain training games may contribute to better evidence-based practice and consumer awareness.

Going forward, a number of assumptions need to be researched and verified. According to Abernethy and Wood (2001), when performing perceptual-cognitive studies, three key assumptions need to be met. The first assumption is that cognitive performance components (i.e. WM, visual information processing, attention control, etc.), need to be directly related to sport performance. The second assumption is that the above performance components can be trained. Lastly, the third assumption is that training these performance components can have a measureable transfer to sport performance (Abernethy & Wood, 2001; Farrow et al., 2017). Currently, research has not shown these assumptions in regards to training with MOT sessions and level of sport performance (Farrow et al., 2017). Therefore future research is needed to further investigate which proponents of performance are being trained when using MOT programs, and also investigate the potential measurability and transferability of performance components from general-cognitive training to sport-specific performance. Furthermore, the availability and use of a control group in future studies is encouraged to further observe intervention effects.

Future research is needed in the area of perceptual-cognitive training, focusing on athletes with physical disabilities. Future studies would benefit from use of a proper control-group, as well as longer intervention schedules. As there is no sport-specific context when using GCT, methods to improve observations of transfer effects is also needed. Future research would benefit from including more variables in participants (i.e. congenital vs. acquired injury, expert vs. novice comparisons, etc.), and a more rigid intervention/study schedule (see Schapschröer et al., 2016).

In regards to personal characteristics of participants, a potential important variable would be to look at the differences between males and females. In the present study, the females were on average, older than the males. This is a similar outcome to Dehghansai et al., (2017b), paper on training histories of Canadian Wheelchair Basketball players. With this being said, future research could compare male vs. female differences looking at present age, and starting age into sport-specific practice, and if this has an effect on deliberate practice hours between sexes (as older athletes may not have a considerable amount of increased DP compared to younger athletes). Furthermore, this would benefit training curriculums to see if perhaps techniques, such as MOT, are only beneficial for those who are on average younger, or less developed (in sport-specific development), compared to their teammates.

Comparing male vs. female differences would also be beneficial in future research when looking at overall team-performance of perceptual-cognitive skills. Tracking and training perceptual-cognitive skills could potentially give researchers insight to gaze behavior differences in males and females, and also, novices vs. experts. Efficient gaze behaviour and visual attention patterns can be considered an underlying mechanism of expert performance (Mann et al., 2007). Developed gaze control consisting of fewer eye-fixations for a longer period of time are demonstrated to be characteristics of expert performers (Mann et al., 2007). Therefore, testing this type of behaviors in para-athletes may be a good indicator of skills that contribute to expert performance. Specifically using MOT, future directions could target gaze behaviors in para-athletes, and test if using MOT would increase skill and performance. Furthermore, future research could look at eye-movement patterns to look at anticipatory skills of experts, and how this differs from novices in the same cohort. Due to the unique developmental histories inherent to para-athletes, it is important to increase research in this field, and particularly in perceptual-cognitive training.

Research on perceptual-cognitive training is scarce in para-sport populations (Dehghansai et al., 2017). As well, this research is good for collaborations between sport teams, sports centres, and universities to expand further knowledge in an area. As there are significant incentives for high levels of athletic performance and success in different programs, the need for evidence-based research is increasing. Research in high performance sports is highly important for the innovation and development of programs, and athlete preparation into specific sports. Results from this study will be the first step in trying to understand how cognitive training will fit within a broader high performance training schedule.

Expertise in Parasport

While results from this study contributes to the understanding of perceptual-cognitive training in high performance parasport, there are still strides that need to be made when concerning the definition of expertise, and our definition of deliberate practice.

The theory of deliberate practice, as proposed by Ericsson and colleagues (1993), states that the theory fits for healthy individuals, and goes into detail on distinct physical characteristics of elite performers (see pg 394, Ericsson et al., 1993). As such, it is understood that Paralympic athletes do not possess “typical” physical characteristics for the generally defined expertise. However, the embodiment of expert performance is typically seen through support and followings, media attention, and coach and team admiration (Janelle & Hillman, 2003). Furthermore, the visual representation of expert performance is seen at large sporting events (i.e. Olympics, Super Bowl, World Cup, Formula One, etc.; Janelle & Hillman, 2003; Baker, Wattie, & Schorer, 2015). Therefore, it is impeccably hard to define expertise for a population in which expertise has not been explicitly defined.

In the attainment of expertise, the 10-years (Simon & Chase, 1973), and/or 10,000 hours (Ericsson et al. 1993) of practice, have been used as benchmarks for achieving expertise. The 10-year rule originally discussed by Simon & Chase (1973), says that experts typically need more than 10 years of practice to have appropriate skills to succeed at an international level. Similarly, Ericsson and colleagues (1993) reported that expert violinists had achieved over 10,000 hours of practice by age 20. In regards to parasport, the starting age of practice, deliberate practice, and sport-specific practice can occur later in life, specifically for individuals with acquired physical disabilities (Dehghansai, 2016b). Therefore, the framework of 10,000 hours or 10-years should consider physical ability as it relates to expertise, as the timeline of development may not occur in accordance to the previous rules. For example, if an athlete acquired a physical disability and begins to participate in parasport, they may not complete 10,000 hours, or 10-years of DP prior to reaching the highest level of competition. In regards to defining expert performance however, many Paralympians achieve podium results and set world records despite not achieving 10,000 hours or 10-years of training, and represent a large variation of DP (Dehghansai, 2017b). This suggests that there may be a need to redefine mechanisms of expertise, relative to sport domain and the individual participant (for a detailed perspective and taxonomy for skill in sport, see: Baker, Wattie & Schorer, 2015). We see this as a challenge in parasport, when trying to define which athletes are, and are-not experts in their field (as some have engaged in more sport-specific practice earlier in life, compared to others). This is also challenging when looking at personal differences between athletes (i.e. congenital vs. acquired injuries), as previous research has shown that regardless of start time into sport, athletes follow similar patterns and milestones prior to reaching elite level competition status (see Dehghansai et al., 2017b). Therefore, reconsideration on the definitions of DP and expertise are needed in the parasport population, as DP can be considered a *determinant* of expertise, rather than expertise itself.

Furthermore, DP does not consider skill transfer when considering how para-athletes reach expert levels. For example, if an athlete transfers from mainstream basketball to wheelchair basketball as a result of an acquired disability, is there an accumulated amount of practice considered between sports, and is this accumulation considered DP even though it is between sports? From this perspective, the original definition of expertise (i.e. the ability to consistently demonstrate superior athletic performance; Starkes, 1993), and the development of expertise (i.e. DP; Ericsson et al., 1993), is fluid when considering the developmental milestones of athletes with physical disabilities. However, the nature of expertise in parasport raises many questions, as the definition of DP (with the determined 10,000 hour or 10-year rule) does not technically fit with elite performance of individuals with physical disabilities. Future research that focuses on parasport may need to consider alternative criteria and conceptualizations of expertise, as athletes with physical disabilities present unique developmental histories (either through congenital or acquired disabilities), that may not be in accordance with current definitions.

3.8 CONCLUSION

Based on previous research of perceptual-cognitive training in sport performance (Simons et al., 2016; Wentink et al., 2016; Harris, Wilson & Vine, 2018), we hypothesized that having Canadian wheelchair basketball athletes participate in MOT would not effect their sport-performance. Our computed results in t-tests, correlations, moderation (pattern-recall), and mediation support this. One exception to the null is the moderating effect that occurred between pre- and post-test ITQMT scores. From the results, we observe that the strength of the relationship between pre- and post-test ITQMT scores emerged in participants who also had high scores for the MOT intervention. However, we further observed that the relationship from pre- to post-test was not mediated by the MOT intervention (i.e. indirect effect of pre- to post-test). Given the mixed findings and limitations to the current study we can say that participation in the MOT intervention had an inconclusive effect on sport-specific performance.

Implications for High Performance Sport

While more research is needed in this area of focus, we further conclude that participation in GCT programs has no harmful effect in sport training. If coaches or sport-organizations are currently using GCT in their curriculums, it is encouraged to pair training with sport-specific modalities (i.e. dribbling a ball while using GCT) in order to add an aspect of sport-specific context, or motor-control demands. Furthermore, use of GCT in athletes who have no preconceived notion about the effect of training may be more beneficial than athletes who's belief is negative prior to use of GCT – more research is also needed testing the perception of participants who partake in GCT. It is possible that a sort of placebo effect may emerge based on athletes' beliefs about the usefulness of MOT. As such, sport organization will have to balance potential benefits of MOT against the cost of such programs and whether athletes' time would be better spent training on domain-specific tasks or in recovery.

3.9 REFERENCES

Abernethy, B., Baker, J., & Cotê, J. (2005). Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology, 19*(6), 705e718. http://dx.doi.org/10.1002/acp.1102

Abernethy, B., Neal, R. J., & Koning, P. (1994). Visual-perceptual and cognitive differences between expert, intermediate and novice snooker players. *Applied Cognitive Psychology, 8,* 185–211.

Allard, F., Graham, S. and Paarsalu, M. E. (1980). Perception in sport: basketball. *Journal of Sport Psychology, 2,* 14±21.

Allard, F. and Starkes, J. L. (1980). Perception in sport: volleyball. *Journal of Sport Psychology, 2,* 22±23.

Baker, J., Côté, J., & Abernethy, B. (2003). Sport specific practice and the development of expert-decision making in team ball sports. *Journal of Applied Sport Psychology, 15*:1, 12-25. doi:10.1080/10413200305400

Baker, J., & Farrow, D. (2015). *Routledge handbook of sport expertise*. London: Routledge.

Baker, J., Wattie, N., & Schorer, J., (2015). Defining expertise: A taxonomy for researchers in skill acquisition and expertise. In J. Baker, & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pg. 145 – 155). United Kingdom: Routledge.

Brewer-Deluce, D., Wilson, T. D., & Owen, A. M. (2017). Cognitive Function in Varsity Football Athletes is Maintained in the Absence of Concussion. *The FASEB Journal*, *31*(1 Supplement), 745-7.

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science*, *15*(4), 322-331. doi:10.1080/17461391.2014.957727

Bühner, M. (2001). Die Bedeutung von mentaler Operation und Material bei der Erfassung von der Konzentrationstest-Leistung. Ein Beitrag zur Validität von Durchstreichtests [The meaning of mental operation and material in the assessment of concentration performance. A contribution to validity of concentration tests of the cancelling type]. Hamburg: Kovac.

Burkett, B., Mellifont, R., & Mason, B., (2010). The influence of swimming start components for selected Olympic and Paralympic swimmers. *Journal of Applied Biomechanics*, *26*(2), 134-141. Pubmed doi:10.1123/jab.26.2.134

Cambridge Brain Sciences (n.d.) Retrieved from: https://www.cambridgebrainsciences.com/science/tests

Chase, W. G., & Simon, H. A. (1973). The mind’s eye in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215–281). New York: Academic Press

Daly, D. J., Djobova, S. K., Malone, L. A., Vanlandewijck, Y., & Steadward, R. D., (2003). Swimming speed patterns and stroking variables in the Paralympic 100-m freestyle. *Adapted Physical Activity Quarterly, 20*(3), 260 – 278. doi:10.1123/apaq.20.3.260

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017a). A systematic review of influences on development of athletes with disabilities. *Adapted Physical Activity Quarterly, 34(*1), 72-90. doi:10.1123/APAQ.2016-0030

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017b). Training and development of Canadian wheelchair basketball players. *European Journal of Sport Science,17*(5), 511-518. doi:10.1080/17461391.2016.1276636

Duff, K., Beglinger, L. J., Schultz, S. K., Moser, D. J., McCaffrey, R. J., Haase, R. F., Westervelt, H. JK., Langbehn, D. R., Paulsen, J. S., & Huntington's Study Group (2007). Practice effects in the prediction of long-term cognitive outcome in three patient samples: A novel prognostic index. *Archives of Neuropsychology: The Official Journal of the National Academy of Neuropsychologists, 22*(1), 15 – 24. doi:10.1016/j.acn.2006.08.013

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports (Nature Publisher Group), 3,* 1154.

Faubert, J. & Sidebottom, L. (2012). Perceptual-cognitive training of athletes. *Journal of Clinical Sport Psychology, 6,* 85-102. doi:10.1123/jcsp.6.1.85

Faul, F., Erdfelder, E., Lang, A.G., & Buchner, A., (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods, 39*:175-191. doi:10.3758/BF03193146

Ferreira, N., Owen, A., Mohan, A., Corbett, A., & Ballard, C. (2015). Associations between cognitively stimulating leisure activities, cognitive function and age-related cognitive decline. *International Journal of Geriatric Psychiatry, 30*(4), 422-430

Fischer, L., Baker, J., Rienhoff, R., Strauß, B., Tirp, J., Büsch, D., (2016). Perceptual-cognitive expertise of handball coaches in their young and middle adult years. *Journal of Sports Sciences, 34*, 1–6.

Furley, P, & Memmert, D., (2015). Creativity and working memory capacity in sports: Working memory capacity is not a limiting factor in creative decision making amongst skilled performers. *Frontiers in Psychology*, doi:10.3389/fpsyg.2015.00115

Goosey-Tolfrey, V. L., Butterworth, D., & Morriss, C. (2002). Free throw shooting technique of male wheelchair basketball players. *Adapted Physical Activity Quarterly*, 19(2), 238-250.

Gorman, A. D., Abernethy, B., & Farrow, D. (2013). Is the relationship between pattern recall and decisionmaking influenced by anticipatory recall? *The Quarterly Journal of Experimental Psychology*, 66, 2219–2236

Harris, D. J., Wilson, M. R., & Vine, S. J., (2018). A systematic review of commercial cognitive training devices: Implications for use in sport. *Frontiers in Psychology*, 9:709. doi:10.3389/fpsyg.2018.00709

Hayes, A. F., (2012). PROCESS: a versatile computational tool for observed variable mediation, moderation, and conditional process modeling.

Helsen, W., & Pauwels, J. M. (1993a). A cognitive approach to visual search in sport. In D. Brogan, A. Gale and K. Carr K (Eds), *Visual search II* (pp.379±388).

Helsen, W., & Pauwels, J. M. (1993b). The relationship between expertise and visual information processing in sport. In J. Starkes and F. Allard (Eds), *Cognitive issues in motor expertise* (pp.109±134). Amsterdam: North-Holland.

Helsen, W., & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology, 13*, 1-27.

Helsen, W. F., Starkes, J. L., & Hodges, N. J. (1998). Team sports and the theory of deliberate practice. *Journal of Sport and Exercise Psychology, 20*(1), 12

International Wheelchair Basketball Federation. (June 2014). *Official player classification manual.* Retrieved from: https://iwbf.org/wp-content/uploads/2017/09/CLASSIFICATION-MANUAL-2014-2018-ENGLISH-FINAL.pdf

Mandeville Legacy (2014). Retrieved December 10th, 2017, from: http://www.mandevillelegacy.org.uk/category/topics

Mangine, G. T., Hoffman, J. R., Wells, A. J., Gonzalez, A. M, Rogowski, J. P., Townsend, J. R., Jajtner, A. R., Beyer, K. S., Bohner, J. D., Pruna, G. J., Fragala, M. S., & Stout, J. R. (2014). Visual tracking speed is related to basketball-specific measures in NBA players. *Journal of Strength and Conditioning Research, 28*(9), 2406 – 2414.

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: a meta-analysis. *Journal of Sport & Exercise Psychology, 29*(4), 457478.

Marteniuk, R.G. (1976). *Information processing in motor skills*. New York: Holt, Rinehart, and Winston.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., Wager, T. D., (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1): 49 - 100

Murdoch, J., (2012, August 30). London 2012 Paralympic athletes: The full list of competitors and disciplines. *The Guardian*. Retrieved from: http://www.theguardian.com/ news/datablog/2012/aug/30/every-paralympic-athlete-and-their-sport-data

Nanda, B., Balde, J., Manjunatha, S. (2013). The acute effects of a single bout of moderate-intensity aerobic exercise on cognitive functions in healthy adult males. *Journal of Clinical and Diagnostic Research* [serial online], 1883-1885

Nuri, L., Shadmehr, A., Ghotbi, N., & Attarbashi Moghadam, B. (2013). Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport. *European Journal of Science, Vol. 13*, No. 5, 431-436. doi:10.1080/17461391.2012.738712

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S, Howard, R. J., Ballard, C. G. (2010). Putting brain training to the test. *Nature*, *465*(7299), 775–778. http://doi.org/10.1038/nature09042

Paralympics – History of the Movement (n.d.) Retrieved on January 3rd, 2018 from, https://www.paralympic.org/the-ipc/history-of-the-movement

Parsons, B., Magill, T., Boucher, A., Zhang, M., Zogbo, K., Bérubé, S., Scheffer, O., Beauregard, M., & Faubert, J. (2016). Enhancing cognitive function using perceptual-cognitive training. *Clinical EEG and Neuroscience, Vol. 47*(1), 37-47. doi:10.1177/1550059414563746

Perico, C., Tullo, D., Perrotti, K., Faubert, J., & Bertone, A., (2014). The effect of feedback on 3D multiple object tracking performance and its transferability to other attentional tasks [ABSTRACT]. *Journal of Vision, Vol. 14*, 357. doi:10.1167/14.10.357

Pylyshyn, Z.W. and R.W. Storm, (1988). Tracking multiple independent targets: evidence for a parallel tracking mechanism. *Spatial Vision*, *3*(3): p. 1-19.

Rio 2016. (n.d.) Retrieved September 5th, 2017 from, http://paralympic.ca/rio2016

Ripoll, H. (1988). Analysis of visual scanning patterns of volleyball players in a problem solving task. *International Journal of Sport Psychology*, *19*, 9±25.

Romeas, T., Guldner, A., & Faubert, J., (2016). 3D-multiple object tracking training task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise, 22*, 1-9. doi:10.1016/j.psychsport.2015.06.002

Schapschröer, M., Baker, J., & Schorer, J., (2016a). Effects of domain-specific exercise load on speed and accuracy of a domain-specific perceptual-cognitive task. *Human movement science, 48*, 121-131. doi:10.1016/j.humov.2016.05.001

Schapschröer, M., Baker, J., & Schorer, J., (2016b). Exploring the interaction of physical exercise load and pattern recall performance in female handball players. *Experimental Brain Research, 234,* 1713 – 1723. doi:10.1007/s00221-016-4584-x

Simon, H. A., & Chase, W. G. (1973). Skill in chess. American Scientist, 61, 394403.

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., Stine-Morrow, E. A. L. (2016). Do “brain training” programs work? *Psychological Science in the Public Interest, Vol. 17*(3), 103-186. doi:10.1177/1529100616661983

Starkes, J. L. (1987). Skill in field hockey: the nature of the cognitive advantage. *Journal of Sport Psychology, 9,* 146–160.

Tullo, D., Faubert, J., & Bertone, A. (2018). The characterization of attention resource capacity and its’ relationship with fluid reasoning intelligence: A multiple object tracking study. *Intelligence, 69*: 158 – 168.

Vartanian, O., Coady, L., & Blacker, K., (2016). 3D multiple object tracking boosts working memory span: Implications for cognitive training in military populations. *Military Psychology, 28,* No. 5, 353 – 360.

Wentink, M. M., Berger, M. A., de Kloet, A. J., Meesters, J., Band, G. P., Wolterbeek, R., Goossens, P. H., Vliet Vlieland, T. P. (2016). The effects of an 8-week computer-based brain training programme on cognitive functioning, QOL, and self-efficacy after stroke. *Neuropsychological Rehabilitation, 26*(5-6):847-65. doi:10.1080/09602011.2016.1162175.

Williams, A. M. (2000). Perceptual skill in soccer: implications for talent identification and development. *Journal of Sports Sciences*, *18*(9), 737–750.

Williams, A. M., Davids, K., & Williams, J.G. (1999). *Visual Perception and Action in Sport*. London: E & FN Spon

CHAPTER 4: GENERAL DISCUSSION

4.1 THESIS SUMMARY

Considering the increased growth of research completed on mainstream or able-bodied athletes, it is apparent that research on the development of expertise of athletes with a physical disability has not matched the same level of growth (Dehghansai, Lemez, Wattie, & Baker, 2017). The comparatively smaller amount of research completed on athletes with disabilities in parasport stresses the need for future directions and work examining the analysis and training development of athletes with disabilities (Deghgansai et al., 2017). Moreover, research studying perceptual-cognitive training in athletes with physical disabilities is scarce. Among studies completed on mainstream or able-bodied athletes/participants, there is a lack of skill transfer from the practiced task to a real-life task (see Wentink et al., 2016). With this being said, and with support from previous research (see Wentink et al., 2016; Simons et al., 2016), we hypothesized that participating in GCT programs would have no effect on sport-specific performance in elite level athletes with physical disabilities.

We recruited 12 Canadian Wheelchair Basketball players from the Senior high performance program, and National Academy program out of Toronto, Ontario. Athletes participated in a Pre-Test vs. Post-Test, Intervention study design to look at the potential changes/influence of the intervention. Total study time was 6-weeks, with the intervention taking place from Week 2 to Week 5. Week 1 consisted of GEF tasks, sport-specific pattern-recall, and physical on-court performance measures of each participant. Week 2 – Week 5 consisted of 3x week MOT sessions, and Week 6 was a replication of Week 1.

Results from paired t-tests, correlations, moderation and mediation regressions support the presented null hypothesis that participating in a GCT intervention had no conclusive effect on sport-specific performance from pre-test to post-test. Minimal statistically-significant associations were reported on the changes from pre-test to post-test measurements, which supports the notion of negligible effect over the time of the study.

Limitations of the study include sample size, scheduling limitations, and mediators and moderators that would affect anticipation and decision-making skills in sport-performance. Going forward, stronger measurement tools are recommended to encompass if cognitive and physical components of sport are transferred from training interventions. Furthermore, a larger sample size, and true novice vs. expert comparisons would help in validating results.

4.2 FUTURE RESEARCH

Going forward, a number of assumptions need to be researched and verified. According to Abernethy and Wood (2001), when performing perceptual-cognitive studies (especially using GCT programs), three key assumptions need to be met. The first assumption is that cognitive performance components (i.e. WM, visual information processing, attention control, etc.), need to be directly related to sport performance. The second assumption is that the above performance components can be trained. Lastly, the third assumption is that training these performance components can have a measureable transfer to sport performance (Abernethy & Wood, 2001; Farrow et al., 2017). If the first assumption is true, then researchers could expect to see elite or expert performers distinguished from novice counterparts by basic visual function (i.e. expert performers would have greater function, whereas less skilled performers would have greater visual errors; Abernethy & Wood, 2001). However, previous research (see Starkes & Deakin, 1984; Abernethy, 1987) has demonstrated that expert vs. novice cohorts are not set apart by visual function. Therefore, visual function is not as necessary to expert development as originally thought (Abernethy & Wood, 2001).

The second assumption that says components of cognition or visual performance can be trained, needs to be further researched on athletes. Reasoning for this is that GCT programs are highly similar to tools that both train and test visual function. Therefore, it is difficult to conclude if pre- vs. post-test differences are attributed to actual improvements in function, or simply, to learner effects (Abernethy & Wood, 2001).

Finally, the third assumption that says that cognitive components, or visual function can be automatically transferred to sport performance, is significantly under tested. The assumption of the transferable relationship between basic visual or cognitive capacities is one of the main issues in the utility and efficacy of GCT programs (Abernethy & Wood, 2001). This is based on variables that are not associated with the linear relationship of visual/cognitive function vs. sport performance (i.e. self-efficacy, confidence in task, perception of cognitive training task; Abernethy & Wood, 2001). Furthermore, the third assumption violates one of the oldest and rudimentary principles of skill acquisition – that specific aspects of expert development can emerge from general training (Abernethy & Wood, 2001). In summary, if one of the assumptions is incorrect, then the GCT program used will not benefit sport performance (Abernethy & Wood, 2001). Currently, research has not shown these assumptions in regards to training with MOT sessions and level of sport performance (Farrow et al., 2017). The current study also found that there was inconclusive results in regards to these assumptions.

In conjunction with the 3-Assumptions, results can also be interpreted though the theoretical lens of the expert performance approach (see Chapter 2.5). Results from the present study suggest that MOT training is not sufficient to identify mechanisms that lead to expert performance. Furthermore, this tool was not deemed useful as a training intervention to improve sport-specific performance or underlying mechanisms for expert development. A visual representation of this relationship can be seen in Figure 1

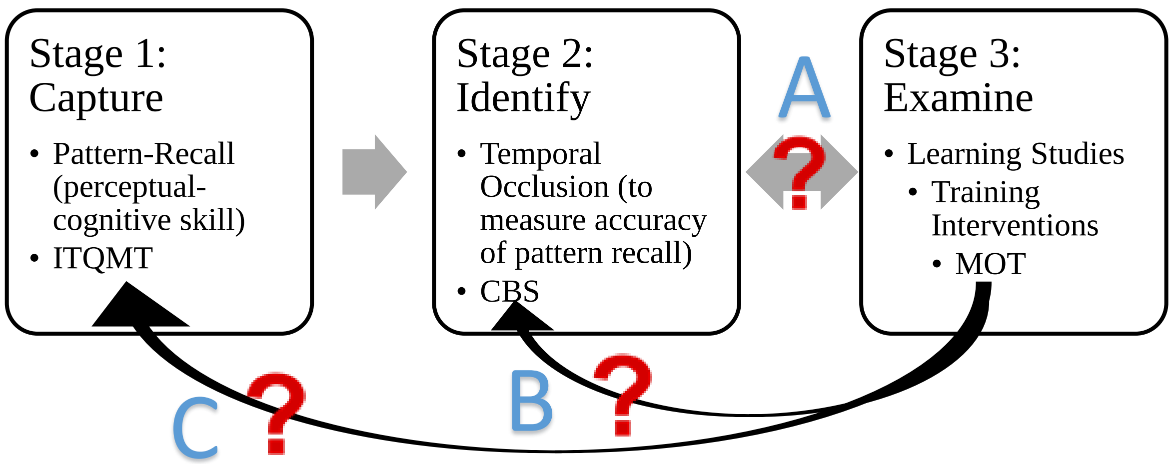


Figure 1. Representativeness of MOT intervention for the Expert Performance Approach in Stage 1, Stage 2, and Stage 3.

Evidence from the present study on MOT impact is not consistent with each stage of the Expert Performance Approach (developed by Ericsson & Smith, 1991). This can be seen in the results that MOT was not a sufficient tool to demonstrate implications for development (i.e. Stage 3; see relationship A), it failed to identify underlying mechanisms for expert performance (i.e. Stage 2; see relationship A & B), and lastly, was inconclusive in demonstrating improved effects on actual in-game performance (i.e. Stage 1; see relationship C).

In the previously mentioned experimental investigation by Abernethy and Wood (2001), on general visual training programs for sport performance, the authors' noted:

“Despite their growing use, and the strong claims made by proponents of visual training regarding their effectiveness, the evidence to demonstrate that such programmes can improve both vision in general, and sports performance in particular, is almost entirely anecdotal and, consequently, subject to bias and expectancy effects.” (pg 203; Abernethy & Wood, 2001). Therefore, future research is needed to further investigate which proponents of performance are being trained when using MOT programs, and also investigate the potential measurability and transferability of performance components from general-cognitive training to sport-specific performance. Authors also noted, “In conclusion… (results) suggest that generalized visual training programmes of the type advocated by sports optometrists should be use with caution by athletes and coaches. These programmes do not appear to provide the improvements in either basic visual function or motor performance relevant to sport that they claim to produce” (pg. 220; Abernethy & Wood, 2001). With this, the availability and use of a control group in future studies is encouraged to further observe intervention effects. This would create opportunity to investigate the differences between experts and non-experts (rather than just experts within experts of a similar group), and furthermore, allow researchers to see if dosage vs. placebo (or no intervention), has an effect on performance.

Aside from measuring the 3-Assumptions (see above), there are still many questions about the development, and perceptual-cognitive skill of athletes with physical disabilities. In regards to research, studies completed on athletes with a physical disability (at either the grassroots level, or elite level – Paralympics) are not as numerous as the literature on mainstream (i.e. able-bodied) counterparts (Dehghansai et al., 2017b). As such, it is important to continuously conduct research on this population to give us a better understanding of athlete development, and how this could perhaps effect perceptual-cognitive skill, and skill development. Athletes with physical disabilities demonstrate unique developmental histories (Dehghansai et al., 2017b), and therefore, it may be useful to consider these unique constraints on perceptual-cognitive skill development. For example, athletes can have a variety of physical disabilities, which can be either acquired or congenital. Research suggests that there is variability in and how much each athlete trained prior to elite level status (Dehghansai et al., 2017b). It is not clear how this variability in DP influences development of perceptual-cognitive skill. Furthermore, currently, it is not known how, or if, experience in sport prior to acquired physical disability influences transfer of perceptual cognitive skills – decision making and anticipation – to parasport. For example, if an athlete had previously played stand-up basketball and acquires a physical disability then transfers to wheelchair basketball. Furthermore, we have limited information on the perceptual-cognitive skill sets that each athlete has, and if type of injury affects this. Although specific to each sport, physical ability is categorized into classifications. Research that is currently missing is information on how perceptual-cognitive skills vary based on athlete classification (for more information on classification, see: International Wheelchair Basketball Federation [IWBF], 2014; "Classification", n.d.; "2007 IPC Classification Code", n.d.). Continued research investigating this may further assist in training curriculums, as it would allow personalization of perceptual-cognitive training programs.

These questions demonstrate how little we know about parasport and athletes with physical disabilities. More specifically, we have little evidence to explain the influence of perceptual-cognitive training based on injury. We know that there is a significant amount of variation in regards to accumulated hours of DP, as well as athlete debut into high performance sport (based on physical ability and/or time and type of injury; Dehghansai et al., 2017a,b). Future research would create additional information, and perhaps answers to the previous questions about athlete development. Furthermore, this research would make a growing impact on information of perceptual-cognitive skills in athletes with physical disabilities, as this information that is scarce (Dehghansai et al., 2017a). This information would inform athlete participation in perceptual-cognitive training programs, allow more information to shape the daily training environment for athletes, and create a greater understanding of how perceptual-cognitive skills are developed in athletes with physical disabilities.

4.3 IMPLICATIONS

Results from this study have important implications for perceptual-cognitive training prescriptions and usage in high performance sport. Previous research has shown that expert to non-expert skill differences exist when the task is specific to the domain of the participant (Helsen & Starkes, 1999; Schapschröer et al., 2016a, 2016b). Furthermore, it is known that MOT training includes no sport-specific context, or motor control demands (Faubert, 2013). Regardless of this, it is said that training with MOT requires high levels of working memory (WM), visual information processing speeds, and attention allocation/control (Romeas, Guldner, & Faubert, 2016). Current research is scarce in showing the effect of such interventions in the transfer of cognitive skill to on-field performance, and more research is needed to show if cognitive capacities (i.e., WM) can influence sport performance (Farrow et al., 2017). Based on these arguments, the findings from the present study provide additional support to suggest that there is no transfer effect of GCT to domain-specific performance.

Based on previous methodology, and results of MOT training on sport-performance, it is not recommended that sport organizations invest in such programs, or use them as assessment tools for Talent Identification (Farrow et al., 2017). Results from the present study create a good starting point into the use of MOT training in sport-curriculum development. Furthermore, the present study is the first to be completed on the Para-sport population, therefore this is beneficial for future research to test the differences (if any) between para-sport, and able-bodied populations.

Overall, results from this study have important implications for developing research in perceptual-cognitive training, research in Para-sport populations, and sport-curriculum development. This study may contribute to the creation of specific and informed perceptual-cognitive training guidelines and prescription for this population.

4.4 REFERENCES

2007 IPC Classification Code, (n.d.). Retrived on July 3rd, 2018. From: https://www.paralympic.org/2007-classification-code

Abernethy, B., (1987). Selective attention in fast ball sports. II. Expert-novice differences. *Australian Journal of Science and Medicine in Sport, 19*, 7-16.

Abernethy, B., & Wood, J., (2001). Do generalized visual training programmes for sport really work? An experimental investigation. *Journal of Sport Sciences, 19*, 203-222. doi:10.1080/026404101750095376

Classification, (n.d.). Retrieved on July 3rd, 2018. From: http://paralympic.ca/classification

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017a). A systematic review of influences on development of athletes with disabilities. *Adapted Physical Activity Quarterly, 34*(1), 72-90. doi:10.1123/APAQ.2016-0030

Dehghansai, N., Lemez, S., Wattie, N., & Baker, J. (2017b). Training and development of Canadian wheelchair basketball players. *European Journal of Sport Science,17*(5), 511-518. doi:10.1080/17461391.2016.1276636

Ericsson, K.A. and Smith, J., (1991). Prospects and Limits of the Empirical Study of Expertise: An Introduction, in: Ericsson, K.A. and Smith, J., eds., *Toward a General Theory of Expertise: Prospects and Limits*, Cambridge University Press, New York, 1991, 1-38

Farrow, D., Reid, M., Buszard, T., & Kovalchik, S., (2017). Charting the development of sport expertise: challenges and opportunities. *International Review of Sport and Exercise Psychology*. doi:10.1080/1750984X.2017.1290817

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific Reports (Nature Publisher Group), 3*, 1154.

Federal Trade Commission (2016a). [Press release] https://www.ftc.gov/news-events/press-releases/2016/01/lumosity-pay-2-million-settle-ftc-deceptive-advertising-charges

Federal Trade Commission. (2016b). Settlement with Lumos Labs. Retrieved from https://www.ftc.gov/system/files/documents/cases/160105lumoslabsstip.pdf

Green CS, Bavelier D (2003) Action video game modifies visual selective attention. *Nature 423*: 534–537.

Green CS, Bavelier D (2006) Enumeration versus multiple object tracking: the case of action video game players. *Cognition 101:* 217–245.

Green CS, Bavelier D (2007) Action-video-game experience alters the spatial resolution of vision. *Psychol Sci 18*: 88–94.

Helsen, W., & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology*, *13*, 1-27.

Hills, S. P., & Russell, M. (2018). Carbohydrates for soccer: A focus on skilled actions and half-time practices. *Nutrients*, *10*(1), 22.

International Wheelchair Basketball Federation. (June 2014). *Official player classification manual.* Retrieved from: https://iwbf.org/wp-content/uploads/2017/09/CLASSIFICATION-MANUAL-2014-2018-ENGLISH-FINAL.pdf

Li R, Polat U, Makous W, Bavelier D (2009) Enhancing the contrast sensitivity function through action video game training. *Nat Neurosci 12*: 549–551.

McMorris, T., & Graydon, J., (1997). The effect of exercise on cognitive performance in soccer-specific tests. *Journal of Sport Sciences*, *15*(5): 495-468. doi:10.1080/026404197367092

Romeas, T., Guldner, A., & Faubert, J., (2016). 3D-multiple object tracking training task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise, 22*, 1-9. doi:10.1016/j.psychsport.2015.06.002

Schapschröer, M., Baker, J., & Schorer, J. (2016a). Effects of domain-specific exercise load on speed and accuracy of a domain-specific perceptual-cognitive task. *Human movement science*, 48, 121-131. doi:10.1016/j.humov.2016.05.001

Schapschröer, M., Baker, J., & Schorer, J. (2016b). Exploring the interaction of physical exercise load and pattern recall performance in female handball players. *Experimental Brain Research, 234*, 1713-1723. doi:10.1007/s00221-016-4584-x

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., Stine-Morrow, E. A. L. (2016). Do “brain training” programs work? *Psychological Science in the Public Interest, Vol. 17*(3), 103-186. doi:10.1177/1529100616661983

Starkes, J. L., & Deakin, J., (1984). Perception in sport: A cognitive approach to skilled performance. In *Cognitive Sport Psychology* (edited by W. F. Straub and J. M. Williams), pp. 115-128. Lansing, NY: Sport Science Associates

Wentink, M. M., Berger, M. A., de Kloet, A. J., Meesters, J., Band, G. P., Wolterbeek, R., Goossens, P. H., Vliet Vlieland, T. P. (2016). The effects of an 8-week computer-based brain training programme on cognitive functioning, QOL, and self-efficacy after stroke. *Neuropsychological Rehabilitation, 26*(5-6):847-65. doi:10.1080/09602011.2016.1162175

APPENDICIES

APPENDIX 1: LETTER OF PERMISSION/APPROVAL FROM WHEELCHAIR BASKETBALL CANADA

WHEELCHAIR
BASKETBALL
CANADA

December 1, 2016

Dear Ms. Pietroniro;

It is my pleasure as National Academy Director to write a letter of support for the proposed, "Influence of General Cognitive Training on Sport-Specific Performance in Wheelchair Basketball", being conducted by yourself, with the supervision of Dr. Nick Wattie.

Wheelchair Basketball Canada will always be supportive of research in Para-populations. You have our full permission to recruit the Senior and Academy athletes for your study, and use the National Training Center as part of your lab to collect data.

I fully support this endeavor and the efforts of yourself and Dr. Nick Wattie as you try to fill a void that exists in current research being conducted on para-athletes. We are excited to see you results for this study, and are here if you need any guidance or help.

Sincerely,

Michael Frogley
National Academy Director
Wheelchair Basketball Canada

REAL LIFE. REAL SPORT.

Wheelchair Basketball Canada

wheelchairbasketball.ca
6 Antares Drive, Phase 1, Unit 8, Ottawa, Ontario K2E 8A9
T: 613-260-1296 F: 613-260-1456

APPENDIX 2: REB APPROVAL FROM THE CANADIAN SPORT INSTITUTE OF ONTARIO (CSIO)

CANADIAN SPORT INSTITUTE INSTITUT CANADIEN DU SPORT

CSIO Research Ethics Board

MEMORANDUM

DATE:	April 25, 2017
TO:	Annie Pietroniro, Principle Investigator
FROM:	Dr. Heather Sprenger, Lead of Physiology, Research & Innovation
REB #:	2017-02
Title:	The influence of General Cognitive Training on Sport-Specific Performance in Canadian Wheelchair Basketball players

The Canadian Sport Institute Research Ethics Board (REB) has reviewed the revisions made to project submission REB 2017-02 and has granted your project approval. Please refer to your project REB number for future correspondence.

If this project changes in anyway, **you have the explicit responsibility to notify the Lead of Research & Innovation at that time in writing.**

Research records must be retained for a minimum of 3 years after completion of the research; if the study involves medical treatment, it is recommended that the results are retained for 5 years.

You are responsible for notifying all parties about the approval of this project, including your co-investigators, PSO/NSO coaches, and management. Please be advised that you will need to submit a progress report every 6 months until the study is completed and a final report outlining the key findings of the study.

Good luck with your research pursuits,

Dr. Heather (Logan) Sprenger, PhD

CSIO Research Ethics Board Co-Chair

APPENDIX 3: REB APPROVAL FROM THE UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY (UOIT)

Approval Notice - REB File #14439

researchethics@uoit.ca <researchethics@uoit.ca> 29 September 2017 at 12:00
To: "Dr. Nick Wattie (Primary Investigator)" <nick.wattie@uoit.ca>
Cc: "Ms. Annie Pietroniro (Student Lead/Post-Doctoral Lead)" <annie.pietroniro@uoit.net>, researchethics@uoit.ca

Date:	*September 29, 2017*
To:	*Nick Wattie*
From:	*Shirley Van Nuland, REB Chair*
File # & Title:	*14439 - The influence of General Cognitive Training on Sport-Specific Performance in Canadian Wheelchair Basketball players.*
Status:	***FULL REB APPROVED (conditions outlined in June 22, 2017 letter have been satisfied)***
Current Expiry:	***June 01, 2018***

Notwithstanding this approval, you are required to obtain/submit, to UOIT's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The University of Ontario, Institute of Technology Research Ethics Board (REB) has reviewed and approved the research proposal cited above. This application has been reviewed to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 (2014)) and the UOIT Research Ethics Policy and Procedures. You are required to adhere to the protocol as last reviewed and approved by the REB.

Continuing Review Requirements (all forms are accessible from the IRIS research portal):

- **Renewal Request Form**: All approved projects are subject to an annual renewal process. Projects must be renewed or closed by the expiry date indicated above ("Current Expiry"). Projects not renewed 30 days post expiry date will be automatically suspended by the REB; projects not renewed 60 days post expiry date will be automatically closed by the REB. Once your file has been formally closed, a new submission will be required to open a new file.
- **Change Request Form**: Any changes or modifications (e.g. adding a Co-PI or a change in methodology) must be approved by the REB through the completion of a change request form before implemented.
- **Adverse or Unexpected Events Form**: Events must be reported to the REB within 72 hours after the event occurred with an indication of how these events affect (in the view of the Principal Investigator) the safety of the participants and the continuation of the protocol (i.e. un-anticipated or un-mitigated physical, social or psychological harm to a participant).
- **Research Project Completion Form**: This form must be completed when the research study is concluded.

Always quote your REB file number (**14439**) on future correspondence. We wish you success with your study.

Dr. Shirley Van Nuland	Janice Moseley
REB Chair	Research Ethics Coordinator
shirley.vannuland@uoit.ca	researchethics@uoit.ca

APPENDIX 4: INFORMED CONSENT

Informed Consent – Influence of General Cognitive Training and Sport-Specific Performance

This consent form is only part of the process of informed consent. This should give you a basic idea and understanding of what the study, and your participation entails. If you would like more information on anything you see here, or information not-included, please do not hesitate to get in contact with Annie Pietroniro, Dr. Nick Wattie, or Dr. Joe Baker. Please take the time to read this form carefully, and to understand following information.

Study Name:
The influence of General Cognitive Training and Sport-Specific Performance in Canadian Wheelchair Basketball Players

Researchers:

Ms. Annie Pietroniro, BHSc

MHSc (Candidate)

Faculty of Health Sciences

University of Ontario Institute of Technology

annie.pietroniro@uoit.ca

Dr. Nick Wattie, PhD

Assistant Professor

Faculty of Health Sciences

University of Ontario Institute of Technology

nick.wattie@uoit.ca

Dr. Joseph Baker, PhD

Professor

School of Kinesiology and Health Science

York University

bakerj@yorku.ca

Purpose of Research:
Brain Training Programs such as The Neurotracker, advocate that skills learned and retained from general brain training activities are transferable across specific domains. Using Multiple Object Tracking, 3D visual frames and speed thresholds, The Neurotracker aims to improve athletic performance by widening an athlete's visual field, as well as increase their attention and memory capacity during performance. The purpose of this study is to test the relation between performance of The Neurotracker, and performance on-court and through pattern recall tasks in athletes.

Study Information:
In order to test the influence that general cognitive training programs have on sport-specific performance, the following methods will be performed:

Participants will be required to complete 3 x 20 trials of The Neurotracker, per week, over a 4 week period. Study design will be a pre-post design. Prior to trials, athletes will complete basic demographic questionnaire. They will also complete a baseline assessment of general cognitive skills (i.e. executive function) and sport-specific perceptual cognitive skills (using a pattern recall test).

Inclusion and participation in this study requires your consent to release current and future ITQMT scores for pre and post measures of data. All personal identifiers will be removed from ITQMT scores when dealing with peer-reviewed publications, abstracts, and conference presentations. By signing this consent form, you agree to release personal ITQMT data for the purpose of this study.

Risks and discomforts:
There are no risks associated with the methods of study, or possible outcomes.

Benefits of Research and Benefits to you:
Due to the nature of the Neurotracker program, the athletes will be subject to spanning their attention over multiple objects in a short amount of time. As wheelchair basketball is a fast sport, this may result in improved ability to track information more efficiently throughout the court, where their opponents are, and ultimately improve athletes' ability to better execute decisions. Results from this study will be the first step in trying to understand how cognitive training will fit within a broader high performance training schedule.

Research in high performance sports is highly important for the innovation and development of programs, and athlete preparation into specific sports. As well, this research is good for collaborations between sport teams, sports centres, and universities to expand further knowledge in an area. As there are significant incentives for high levels of athletic performance and success in different programs, the need for evidence-based research is increasing. Research on perceptual-cognitive training is scarce in parasport populations.

Voluntary Participation:
Your participation in the research is completely voluntary and that participants may choose to stop participating at any time. The participant should note, that if he/she chooses to not participate, this will not affect their relationship, or the nature of their relationship with the researchers or with staff at University of Ontario Institute of Technology, or York University either now or in the future.

Withdrawal from the study:
You may stop participating in the study at any time, for any reason, if you so decide. Your decision to stop participating in the study, or refusal to answer particular questions will not affect your relationship with the Principal Investigator, Co-Investigators, the University of Ontario Institute of Technology, York University, Canadian Sport Institute of Ontario, or Wheelchair Basketball Canada. In the case of withdrawal, all participant data will be immediately destroyed and removed. There is no consequence from withdrawing from the study.

Confidentiality:
All data collected and contained in the study will be treated as confidential. For this data set, all personal identifiers will be removed from the data set, and the subjects will be organized by number rather than names. Consistent with Statistics Canada guidelines for ensuring confidentiality in data, no cell sizes less than 5 will be reported or used in the description and analysis of the data. This practice ensures that it is impossible to trace any data back to a specific individual. Participants consent to have their data used for the purpose of research in the form of a thesis, as well as academic outputs such as: presentations, conferences, and peer reviewed publications. All results of the study will be presented as aggregate data, and no individual will ever be presented. All qualitative and quantitative data will be compiled and stored on secure serves, and password protected computers and files that only the principle investigator – Ms. Annie Pietroniro, and co-investigators – Dr. Nick Wattie and Dr. Joseph Baker, will have access to. No individual data will be presented during the dissemination of the results. Data will be stored for up to 5 years, after which point data will be destroyed. For the purpose of Individual Performance Plan (IPP) reviews, Head Coaches as well as IST staff will have access to athlete's raw data and results from the study, by the end of the study process. Athletes will only have access to their individual data once the study has finished.

Confidentiality will be provided to the fullest extent possible by law.

Participants Concerns and Reporting:
If you have any questions concerning the research study or experience any discomfort related to the study, please contact the researcher Annie Pietroniro at 647-767-6862 or annie.pietroniro@uoit.net.

Any questions regarding your rights as a participant, complaints, or adverse events may be addressed to Research Ethics Board through the Research Ethics Coordinator – researchethics@uoit.ca or 905.721.8668 x. 3693.

This study has been approved by the UOIT Research Ethics Board REB [REB # 11671] on June 2nd, 2017, and CSIO Research Ethics Board [REB #2017-02].

This research has been reviewed conforms to the standards of the Canadian Tri-Council Research Ethics guidelines.

Legal Rights and Signatures:

Option 1:

I ___________________________________, consent to participate in *The Influence of General Cognitive Training and Sport-Specific Performance in Canadian Wheelchair Basketball Players* research project conducted by Annie Pietroniro. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

Option 2:

I ___________________________________, consent to participate in *The Influence of General Cognitive Training and Sport-Specific Performance in Canadian Wheelchair Basketball Players* research project conducted by Annie Pietroniro. I have understood the nature of this project and wish to participate. I **do not** wish to have my results shared with Coaches, IST, or other Support Staff of Wheelchair Basketball Canada, during, or after the conclusion of data collection. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

Signature____________________________

Date:____________________

Participant:

Signature

Date:____________________

Principal Investigator: Annie Pietroniro

APPENDIX 5: INDIVIDUAL TECHNICAL QUALITY MEASUREMENT TOOL (ITQMT) RUBRIC

Wheelchair Basketball Canada National Academy

Individual Technical Quality Measure Legend as of 7/16

Skill	Score 0	1	2	3
General				
Communication	No talking	Information	Actions	The Plan
Seeing	Head down	Sees ball	Sees ball and players	Sees ball, players, and space
Pushing	Trunk up, hands forward, head down	Trunk Leaning	Trunk Leaning, hands at 12 o'clock	Leaning, 12 O'Clock, head up
Basketball IQ	No reaction/wrong reaction	Reacting	Anticipating	Equality inequality
Style of Play	None	Defensive position	Offensive position	Whistles (3 second violation/fouls)
Offense				
Ball Handling/Dribbling	Turnover	Wrong hand, head down	Correct hand, head down, or visa versa	Correct hand, head up, with contact
Passing/Catching	Turnover	Wrong hand to wrong hand	Correct hand to wrong hand, or visa versa	Correct hand to correct hand
Shooting	Turnover	Bad mechanics, no balance, no follow through, head down	Good mechanics, contested, outside key	Good mechanics, open outside key
1 on 1 w/o Ball	No attack	Space and movement	Change of pace	Fake/Attacks front
1 on 1 w/ Ball	Not a threat	Threat, no space	Space, head down	Space, head up, attacks front
2 on 2 w/ Ball (Picking)	No pick	Bad Pick (no fake, pace, footplate, wrong caster)	Good pick, releases with no space	Good pick, holds
No pick	No pick	Turns defenders back	Turns and holds back	Turns, holds, and explodes to space (2 pushes)
Defense				
1 on 1 off Ball	Not guarding	In-between player and basket, lots of space	Axel to caster	Axel on a caster
1 on 1 on Ball	Not guarding	In-between player and basket, lots of space	Axel to caster	Axel on a caster
2 on 2	Stuck guarding 1 on 1	Have your player and seeing the other players	Seeing the other players and anticipating	Seeing, taking away 1 on 1 cuts, communicating
Rebounding	Nothing	Sees	Sees and calls box out	Sees, calls, and bumps
Jump	No jump	Jumping square	Jumping on a curve	Jumping to the correct side
Recover	Wrong recovery	Sag, not seeing	Sag and seeing	Sag, seeing, ready to push