ASSESSING COGNITIVE-MOTOR INTEGRATION IN MIDDLE-AGED ATHLETES: THE EFFECTS OF DEMENTIA RISK & CONCUSSION

Andrea V. Cavaliere

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Abstract

We investigated the relationship between dementia risk and concussion history in a physically active, middle-aged adult population (between the ages of 30 and 65). These participants either had one of the following: a family history of Alzheimer's disease, a history of concussion(s), both histories, or no histories. We know from previous work in our lab that those with dementia or concussion history performed poorly when asked to make skilled movements when having to think simultaneously (cognitive-motor integration, CMI). Here we conducted a cognitive-motor assessment on middle-aged recreational athletes (male and female) using a computer tablet-based task. Data collected included kinematics such as reaction and movement time, path length, accuracy, precision. We predicted that those who either have a concussion history and/or family history of dementia will perform poorly when compared to controls, and that this effect will be exacerbated in those individuals with both factors. On an exploratory basis, these data will provide insight into lifestyle factors that may affect cognitive-motor integration in middle-aged adults, an ability often important for functioning safely at work and sport. We found that those with both histories have impairments in movement pathlength when compared to those with only concussion history and no histories, suggesting an additive effect of both histories on CMI performance. But activity level does not seem to be protective with regards to CMI decline in those with brain health issues. The data collected will expand current research on rule-based skill assessment that can identify functional CMI impairments before current clinical signs of dementia are observed (or after current signs of concussion resolution are observed).

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No, getting a master's degree does not mean I'm a doctor.

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Abbreviations

AE – Absolute Error

APOE – Apolipoprotein E

CDHX – Concussion and family history of dementia

CHX – Concussion history

CMI – Cognitive-Motor Integration

DHX – Family history of dementia

HR – Horizontal-Rotated task condition

MTb – Ballistic movement time

MTf – Full movement time

PLb –Ballistic pathlength

PLf – Full pathlength

RT – Reaction time

V – Vertical task condition

VE – Variable Error

Introduction

Transforming sensory and cognitive information into a desired action

From the time we wake up in the morning to the time we retire to bed, we interact and reach for a plethora of objects such as a pencil, a smart phone or another human hand. Something as simple as reaching for a delicious cupcake seems so intuitive to us but the neural networks responsible for planning and executing such actions are quite intricate (Gorbet & Sergio, 2016; Granek & Sergio, 2015; Hawkins, Sayegh, Yan, Crawford, & Sergio, 2013; Henriques, Medendorp, Khan, & Crawford, 2002; Sayegh, Gorbet, Hawkins, Hoffman, & Sergio, 2017). To reach and devour that cupcake, we must be able to transform the visual information of its characteristics (such as its size, shape and location on table) into motor output (Atkinson & Braddick, 2011; Henriques et al., 2002). This process is known as visuomotor transformation, which requires longitudinal white matter tracts between the parietal (sensory integration) and frontal (executive function, motor planning & sequencing) lobes; frontoparietal network (Gorbet, Vesia, & Sergio, 2003; Hawkins, Goyal, & Sergio, 2014; Hawkins, Sayegh, Yan, Crawford, & Sergio, 2012; Sayegh et al., 2017).

According to Wise et al (1996), reaching can be either *standard* or *non-standard*. In standard transformations or *mappings*, you can directly interact with an object such as a barbell on the ground; you shift your gaze to a near by bar and you maintain that gaze until the bar is grasped. Neurologically, this kind of transformation is regarded as the *default network*, controlled by various frontoparietal regions important for sensory integration, planning and execution (Gorbet & Sergio, 2016; Hawkins & Sergio, 2014). This network includes activation in the primary motor cortex, medial motor areas, lateral premotor cortex and the superior parietal lobule (Gorbet, Staines, & Sergio, 2004).

The other type of mapping, non-standard, is not as straightforward as standard mappings are. These mappings occur when gaze and arm movement are *dissociated*, compared to standard mappings where gaze and arm movements are *closely associated* (Gorbet & Sergio, 2016; Henriques, Klier, Smith, Lowy, & Crawford, 1998; Prablanc, Echallier, Komilis, & Jeannerod, 1979; Scherberger, Goodale, & Andersen, 2003). An example of this would be using a computer mouse because you are looking at the screen but controlling the cursor with you arm; thus, your gaze and arm are dissociated since you would not normally stare at your mouse whilst shopping online. Gorbet and collegues (2004), using BOLD fMRI, found that tasks that required the dissociation between eye and hand (non-standard) do *not* activate the default network the same way a standard task did. They expected to see increased activity in the default network with non-standard tasks, but they witnessed decreased activity instead. This is perhaps due to the brain's attempt to hinder the network's role in coupling the eyes and hand in direct interactions because non-standard transformations require a *decoupling* of gaze and arm movement.

Non-standard mappings can be categorized as either *arbitrary* or *transformational* (Wise et al., 1996). Arbitrary transformations occur when the rule between visual stimulus and motor output are, well… arbitrary. An example includes stepping on the accelerator when a traffic light turns from red to green. The colours used are completely arbitrary as they could be any colour to elicit an appropriate motor response. However, transformational mappings are more spatial in nature. Since the gaze and movement are dissociated, the dissociation can occur in different spatial planes (i.e. horizontal and vertical). An example would be performing laparoscopic surgery because the surgeon will be gazing at a monitor on the horizontal plane and utilizing tools in the vertical plane; the computer mouse example used earlier is also considered transformational. To add to this, these

transformations require the frontoparietal network, thus one can simplify that we are essentially *thinking and moving at the same time*; a phenomenon know as *cognitive-motor integration (CMI).* CMI is the integration of a cognitive rule in order to execute a desired motor output (Gorbet & Sergio, 2009, 2016; Wise et al., 1996).

If we consider lesion studies, they give valuable insight into human behaviour and can support the claim that CMI requires robust white matter connections between frontal and parietal areas. The role of the posterior parietal cortex in CMI is pivotal, it is responsible for integration of visual information into motor plans specific for reaching; visually guided movements (Blangero, Menz, McNamara, & Binkofski, 2009; Hwang, Hauschild, Wilke, & Andersen, 2012; Snyder, Batista, & Andersen, 2000). Unfortunately for patient IG, damage was sustained in IG's posterior parietal cortex, specifically the caudal superior parietal area. This resulted in optic ataxia, meaning IG's visually guided reaching was significantly impaired but was still able to recognize objects (a function reserved for the inferior temporal lobule) (Blangero et al., 2009; Hwang et al., 2012; Karnath & Perenin, 2005; Pisella et al., 2009).

Feedback & Feedforward Models of Reaching

With any sort of reach with the arm, our central nervous system must be able to estimate a motor command to achieve a goal and to predict possible consequences of a motor action. Over the years two models have been proposed and there is disagreement around which one can define the psychophysical underpinnings of limb dynamics. The *feedforward* model proposes that a motor plan is predetermined or defined well before motor execution; that is, a series of muscles are selected in the arm to be integrated into a motor plan before arm displacement towards a visual target (Desmurget & Grafton, 2000; Sabes, 2000). However, this model suggests that online feedback loops are only applied to the end of an arm trajectory, therefore this model is best used to describe quick and stable goal-directed arm movements (Jeannerod, 1988; Keele, 1981). *Feedback* models counter this view, stating that the series of muscle activation necessary to reach for a target are not predetermined before the onset of arm movement, only during arm displacement does this occur. Since no prior motor plan is established, the motor command is created during arm displacement while an error signal compares location of the current system (i.e. arm) to a reference state (i.e. target position) (Desmurget & Grafton, 2000; Hinton, 1983; Sabes, 2000). However, it is worth noting that this model is associated with long visual and proprioceptive delays (Cordo & Flanders, 1989; Keele, 1981; Petersen, Christensen, Morita, Sinkjær, & Nielsen, 1998). So, it seems that both models have their merits and apparent drawbacks. It is with this association that a *hybrid* model has been proposed. As the name implies, hybrid models are an amalgamation of both feedforward and feedback attributes. A preliminary, unpolished motor plan is established before arm displacement (Pélisson, Prablanc, Goodale, & Jeannerod, 1986)

then the plan is refined following motor execution with online feedback loops (Desmurget & Grafton, 2000).

In sum, feedforward models help explain why learned behaviours are executed quickly (e.g. playing piano for decades) and feedback models explain why novel movements and behaviours take time and correction to perfect and retain (Crawford, Medendorp, & Marotta, 2004).

Cognitive-Motor Integration Dysfunction: Dementia Risk & Concussion

The frontoparietal network is essential for visuomotor transformations or CMI. However, in certain circumstances CMI performance can be impaired. One such circumstance is the increased risk of developing dementia. Dementia is an age-related gradual decline in cognitive functioning. Impairments or abnormalities are seen in memory, executive functioning, motor control, mood and motivation. These characteristics tend to interfere with relationships and work, and dependency on family and health care increases (Cerejeira, Lagarto, & Mukaetova-Ladinska, 2012; Robillard, 2007). Nonetheless, is dementia inevitable as we age? That may be the case, since populations around the world continue to live longer and experience progressive cognitive decline (Gauthier et al., 2006; Lindsay et al., 2002; Morris, 2005; Robillard, 2007; Scheltens et al., 2016). However, it is possible to identify variables and biomarkers that may influence dementia risk. The APOE e4 gene variant is known to be linked with an increased risk of developing dementia later in life (Farrer et al., 1997; Hawkins & Sergio, 2016; Hawkins, Goyal, & Sergio, 2015; Hawkins & Sergio, 2014; Riedel, Thompson, & Brinton, 2016; Roses, 1996); since it is a genetic factor, it can be passed down to children and, if genetic testing is not available, the only way to conclude if one is

at risk for developing dementia, is to wait until parent(s) reaches age of onset. In addition, the APOE e4 variant is associated with abnormal grey and white matter level in the brain (Hawkins, Goyal, & Sergio, 2014; Kara M. Hawkins & Sergio, 2016; Honea, Swerdlow, Vidoni, Goodwin, & Burns, 2010; Persson et al., 2006; Podewils et al., 2005; Riedel, Thompson, & Brinton, 2016). Thus, there is a strong association between white/grey matter integrity and processing the APOE e4 variant, and this abnormality in neural tissue can translate into numerous deficits in behaviour; such as CMI performance. Hawkins and colleagues found that older adults who were at risk for developing dementia performed poorly on non-standard CMI task while showing, via diffusion tensor imaging, decreased white matter integrity in the frontoparietal network associated with CMI (Hawkins & Sergio, 2014; Hawkins, Goyal, & Sergio, 2015b; Salek, Anderson, & Sergio, 2011). What is more striking is deficits in CMI in those with dementia risk may be indicative of early stage dementia (W.J. Tippett & Sergio, 2006; Verheij et al., 2012).

Let us shift attention to concussions; another phenomenon that afflicts thousands to millions of people, especially athletes, every year. A popular definition states that concussion "is a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (Signoretti et al., 2011). To expand on this, the current consensus statement on concussion in sport states that a sport-related concussion: may be caused by a direct blow to the head, face, neck or body with a force transmitted to the head; usually results in rapid onset of short-term impairment of neurological function, typically functional issues rather than structural; may result in neuropathological changes,

and may or may not include a loss of consciousness (McCrory et al., 2017). Symptoms that may occur when one sustains a concussion include physical, cognitive, emotional and sleep disturbances (Brown, Elsass, Miller, Reed, & Reneker, 2015; McKee et al., 2009) along with neurological changes such as, again, altered white and grey matter (Lipton et al., 2013; McKee & Robinson, 2014; Sussman et al., 2017). As such, when there is altered white and grey matter, behavioural anomalies ensue. Studies on youth sports players displayed consistent data proposing that players with a history of concussion perform poorly on behavioural tests where CMI is required (Brown, Dalecki, Hughes, Macpherson, & Sergio, 2015; Dalecki, Albines, Macpherson, & Sergio, 2016; Hurtubise, Gorbet, Hamandi, Macpherson, & Sergio, 2016). These deficits are not isolated in youth but there are impairments in older adults as well. A study done by Guskiewicz and colleagues (2005) conducted a battery of tests on 2552 retired professional football players and concluded that symptoms related to dementia may be due to multiple concussions sustained during a retired athlete's professional career and that these symptoms occur early in the retirees when compared to the general population. To link this to dementia, they also found an association between the APOE e4 variant and concussion history and found those with both were more susceptible to symptoms of dementia; the allele is strongly associated with increased severity of neurological impairments (Brichtová & Kozák, 2008; Graham, Horsburgh, Nicoll, & Teasdale, 1999; Jordan et al., 1997; Mahley & Huang, 2012; Saunders et al., 1993). Consequently, one can conclude that dementia-like signs and symptoms are induced by have sustained concussions during youth or adulthood in which severity in brain dysconnectivity can be influenced by the APOE e4 allele.

Briefly, there seems to be a relationship between the APOE e4 gene variant, neurodegeneration, and deficiencies in CMI. It known that those with sustained concussions and those with dementia suffer from poor CMI performance; thus, it is conceivable to consider using CMI to detect (non-invasively) these functional deficits in at-risk populations (i.e. sport players, ageing populations). Building on that premise, would those with both concussion history and dementia risk display much poorer CMI performance than those with either alone? Would their functional living be significantly hindered because of it?

Physical Activity & the Brain

Being physically active regularly has pronounced health benefits, engaging in activities that tax the cardiorespiratory system can lead to increased stroke volume, decreased resting heart rate, increased mitochondria proliferation, increased muscular hypertrophy and endurance, etc (Miller, Balady, & Fletcher, 1997; Warburton, Nicol, & Bredin, 2006; Yan, Okutsu, Akhtar, & Lira, 2011). Neurological and psychological benefits of physical activity are also apparent which include increased white/grey matter integrity, decreased anxiety and depression, and decreased risk of developing dementia (Boraxbekk, Salami, Wåhlin, & Nyberg, 2016; Kirk I Erickson, Hillman, & Kramer, 2015; Gons et al., 2013; Gow et al., 2012; Kalaria, 2010). However, the definition of "physical activity" is open to interpretation in contemporary research. For simplicity sake, we will subscribe to Caspersen, Powell, & Christenson's (1985) definition of "physical activity" and "exercise". Physical activities are movements caused by skeletal

muscles that expend energy, energy expenditure that varies from low to high. Exercise is similar to physical activity, but movements and actions are planned, structure and repetitive with a goal of achieving a certain level of physical fitness. This leads to the definition of physical fitness: A set of characteristics that individuals inherently have or achieve that relates to the ability to perform physical activity. These characteristics include cardiorespiratory endurance, muscular endurance and strength, flexibility and mobility, agility, coordination, speed, power, reaction time, and body composition (Monyeki et al., 2005; Vaara et al., 2012). These qualities can be attributed to athletic ability but Araújo & Scharhag (2016) believe an athlete must obtain said qualities while devoting most of his or her time to sport and training and be registered in regional or national sport federations. Though this is more of a contemporary definition of an athlete, we will continue to use Caspersen, Powell, & Christenson's (1985) definition of physical fitness as athletic ability.

In children, diffusion tensor imaging display strong white (uncinate fasciculus, superior longitudinal fasciculus) and grey (basal ganglia, hippocampi) matter integrity in participants who went through an exercise intervention than controls, making neural areas known for memory and abstract thought more robust in active children (Chaddock-Heyman et al., 2014; Chaddock, Erickson, Prakash, Kim, et al., 2010; Chaddock, Erickson, Prakash, Vanpatter, et al., 2010; K. I. Erickson et al., 2011). In older adults, atrophy of various brain areas are inevitable with increasing age (K. M. Hawkins & Sergio, 2014, 2016). Fortunately, physical exercise has been linked to higher grey matter volumes in the frontal cortex, hippocampi and caudate nucleus, this increase in grey matter is also associated with decreased risk of developing dementia (K. I. Erickson et al., 2010; Voss et al., 2016). Exercise also strengthens neural networks, compared to controls, engaging in cardiorespiratory exercise is linked to increased white matter

integrity in the brain (i.e. temporal region) while a sedentary lifestyle was associated with lower white matter integrity in the parahippocampal regions (Burzynska et al., 2014; K. I. Erickson et al., 2015). In addition, these adults are able to perform better than sedentary adults when tasked with complex cognitive tests that can be attributed to increased white matter connectivity between prefrontal, hippocampal, parietal and cingulate areas (Burdette et al., 2010; Voss et al., 2010). Thus, being physical active can have neurological (strong white and grey matter integrity) and behavioural (preserved cognitive/executive functioning) implications.

Woodard and collegues (2012) investigated the effects of self-reported physical activity and cognitively stimulating activities in healthy adults with and without the APOE e4 allele. They self-reported cognitively stimulating activities a good predicator of cognitive decline in the participants. But there was an interaction between self-reported physical activity and APOE e4 possession, where those who are carriers but also active had reduced risk of cognitive impairments which the authors say may be attributed to increased functional and structural integrity in hippocampal regions in these participants. In addition, Smith and collegues (2011) demonstrated that participants who are carriers of the APOE e4 allele and physically active had better semantic memory-related activation compared to inactive carriers. In fact those who are carriers and inactive are predicted to have greater cognitive declines and hippocampal atrophy over an 18-month period (J. L. Woodard et al., 2012; Smith et al., 2014).

Athletes playing a sport for a long period of time are known to have quicker reaction times, coordination and are more efficient compared to non-athletes or new athletes. Expert tennis players are able to predict and anticipate situations better than novices, displaying stronger activation in areas linked to reaching (i.e. superior parietal lobe), prediction (i.e. frontal cortex), coordination and error detection (i.e. cerebellum); due to years of training, expert athletes are able to use more fine motor representations than novice athletes (Balser et al., 2014). Athletes also seem to have efficient neural networks, displaying lower activation in task-related neural networks than non-athletes, suggesting that athletes are able to activate neural areas necessary for their sport but use less energy to do so (Guo, Li, & Yu, 2017). Having athletic ability (physical fitness) is positively linked to preserve brain function in ageing individuals. In one study, white matter integrity was assessed in Masters athletes and sedentary older adults using MRI fluid attenuated inversion recovery and diffusion tensor imaging. It was found that Masters athletes had more preserved white matter tracts than sedentary participants and discussed the very possibility of physical fitness as having protective effects against age-related neural atrophy and dementia (McKee, Daneshvar, Alvarez, & Stein, 2014; Tseng et al., 2013).

Purpose & Hypotheses

In this study, we examine in a middle-aged and active population (i.e. between the years of 30 and 65) the effects of dementia risk and concussion on the middle-aged CMI network. We believe it is vital to study and analyse this population because they currently make up most of the workforce in Canada and North America, therefore their functional

living and quality of life is central for a strong and robust society. Also, once middle-aged, most of these individuals will know if their parents, grandparents, aunts or uncles have or are developing dementia, facilitating the task of recognizing dementia in the family.

We hypothesize that when comparing data collected from middle-aged participants to data collected from our lab previously (youth and older adults), the middle-aged participants will perform just as poorly as concussed youth and dementia-risk seniors on a non-standard CMI task (Dalecki et al., 2016; Kara M Hawkins & Sergio, 2014; Hurtubise et al., 2016; William J. Tippett, Sergio, & Black, 2012). We also believe middle-aged participants with both concussion and dementia risk will perform worse on a CMI task than those with either alone. We will also investigate physical activity as a mitigative factor against CMI decline in those with concussion and/or dementia risk; this will be an exploratory measure.

Methods & Materials

This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines, all participants signed a written consent form beforehand.

Participants

Participants (men and women) who were actively engaging in recreational sports and participants who were sedentary were recruited from various rec teams in the Greater Toronto Area; these participants were between the ages of 30 and 65 years.

Questionnaires are given initially, were the participant self-reported demographic data like age, dementia/concussion history, fitness level, video game use, etc (***see Appendix 1)***. To be considered to have a history of concussion, one must have had at least one incident of a sustained concussion in their past or one during their current condition when answering the questionnaire. To be considered to have a familial history of dementia, the participant must have had: a maternal history of dementia (at least one close relative) or have multiple close relatives with dementia (maternal and/or paternal). To be considered having had a concussion(s), the participant must have previously sustained a blow to the head which may have resulted in headaches, loss of consciousness, confusion, amnesia, dizziness, nausea. To be considered active, the participant must have reached a certain score when answering questions that are based on physical activity engaged in during a typical week (i.e. involvement in recreational sport, involvement in competitive sport, running, walking, jogging, labour work, exercising at a gym).

When concussion or dementia risk histories are known, each participant was placed in one of four groups: Healthy, concussion group (CHX), dementia risk (DHX) or

both (CDHX). When activity level is known, each participant will be placed in one of three groups: Sedentary, mildly active or moderately/highly active.

Predictor Variables

In our questionnaire, we asked the participant to disclose various information. Numerical data that is collected included: age, number of previous concussions, period of unconsciousness, time to return to play, timeframe of sport(s) played, and frequency of smoking.

Categorical data included: sex, dominant hand used, level of education, ethnicity, occupation, state of employment (full-time, part-time, and unemployed), sport(s) played, if they currently have a concussion, if they sustained a concussion(s) in the past (i.e. yes/no), smoking history (i.e. cigarettes, cannabis, both or other), if currently sustained a non-head related injury (if it kept participant from play longer than 48 hours or 3 weeks), if diagnosed with a neurological disorder, if they use a computer/tablet and frequency of use (i.e. rarely, sometimes, often and all the time), if they play puzzles and at what frequency, if they play video games and what kind (i.e. action or non-action) and how they rate their gaming skills when compared to their peers (i.e. low, intermediate, high) and lastly if they have anyone in their family with dementia and their relationship to the participant. If the participant is female, they will also answer if they are pre-menopausal, peri-menopausal or post-menopausal.

Ordinal data included a list of activities in which participants rate each activity on weekly frequency (i.e. never, rarely [1day/week], sometimes [2 days/week], often [3-4 days/week] and quite often [5-7 days/week]. These activities include: watching television

or movies, reading, socializing (e.g. playing cards, talking to friends, etc.), playing recreational sports, playing competitive sports, playing video/computer games, walking (at least 25 minutes), listening to music, exercising at a gym, doing non-labour work (paid or volunteer), doing labour work (e.g. landscaping, shoveling, painting, etc.; paid or volunteer), running or jogging and lastly doing puzzle, arts and crafts (e.g. knitting, crosswords, etc.). An activity score was quantified using data from: playing recreational sports, playing competitive sports, walking, exercising at a gym, doing labour work running, and jogging. Where "never" gave a score of 0, "rarely" gave a score of 1, "sometimes" gave a score of 2, "often" gave a score of 3 and "quite often" gave a score of 4. A cumulative score between 0 and 6 prompted inclusion to the *sedentary* group, a score between 7 and 12 prompted inclusion to the *mildly active* group, a score of 13 to 18 prompted inclusion to the *moderately active* group and finally a score between 19 to 24 prompted inclusion to the *highly active* group. The quite active group only had two participants in which case we decided to include them into the moderately active group, creating the *moderately/highly active* group.

We defined a concussion as having previously sustained a blow to the head which may have resulted in headaches, loss of consciousness, confusion, amnesia, dizziness, nausea (*Appendix 2)*. We also defined dementia risk as having a maternal history of dementia (at least one close relative) or having two or more close relatives (maternal or paternal) with dementia. Studies showed that women with a family history of dementia or have obtained the APOE e4 allele display an increased risk of developing dementia later in life (Farrer et al., 1997; Kara M Hawkins, Goyal, & Sergio, 2015a; Paganini-Hill & Henderson, 1994; Riedel et al., 2016; Tang et al., 1996; Hawkins, Goyal, & Sergio, 2015b).

Outcome Variables

As mentioned earlier, all participants were subject to a visuomotor task using a tablet computer (Asus Transformer Book T100TAF; vertical screen) and a Keytec Magic Touch touchscreen (KTMT series; horizontal screen), as they were instructed to slide their index finger towards a peripheral, circular target (***see figure 2)*** in two conditions. Variables collected and focused on are performance time, path length, velocity, precision and accuracy.

Performance Time

Between multiple trials, the time between the vanished central target and movement initiation is calculated as mean reaction time (RT) (msecs); RT for the V condition and RT for the HR condition were calculated. Full movement time (MTf; in msecs) was calculated from the movement initiation to endpoint, such as reaching for and ending the movement by touching the target; MTf for V and MTf for HR were calculated. Ballistic movement time (MTb) (msecs) was time between start (surpassing 10% of peak velocity) to first stopping point (dropping below 10%) in cursor movement; MTb for V and MTb for HR were calculated.

Pathlength

The full pathlength (PLf) (mm) was the distance between start position and end position of cursor movement; PLf for V and PLf for HR were calculated. The ballistic

pathlength (PLb) (mm) was the distance between the start to first stopping point in cursor movement; PLb for V and PLb for HR were calculated.

Precision & Accuracy

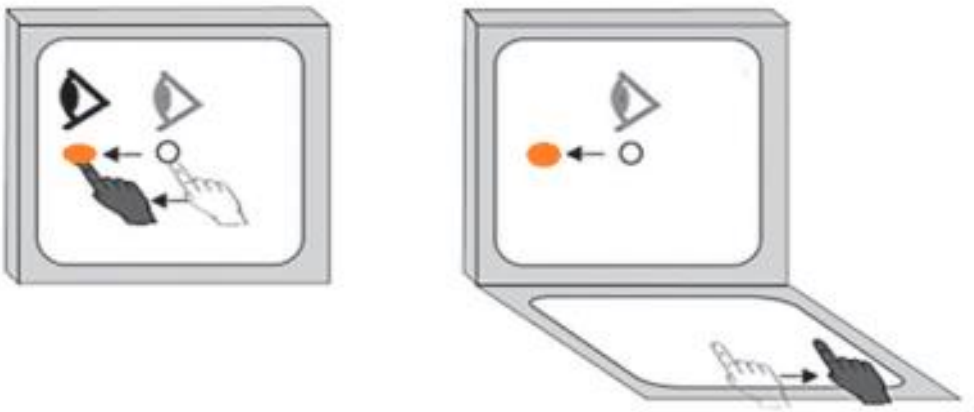
The absolute error (AE) or endpoint accuracy (mm) was calculated as the distance between mean movement endpoint for each target location and the actual target location; as such the variables, AE for V and AE for HR were calculated. The variable error (VE) or endpoint precision (mm) was the distance between endpoints of the movements from their mean movements; the variables VE for V and VE for HR were calculated.

Procedures

Similar to the works of Brown & collegues (2015) and Salek, Anderson, & Sergio (2011) each participant was subject to a brief questionnaire, a consent form and two visuomotor task conditions, *vertical and horizontal reversal*, that occurred in a randomized order on a tablet computer (Asus Transformer Book T100TAF; vertical screen) and a Keytec Magic Touch touchscreen (KTMT series; horizontal screen). A schematic drawing of the equipment and the basic task are illustrated in ***Figure 1***. In the vertical (V) task, the participant utilized the top (vertical plane) screen only and use their dominant arm to move the cursor toward the peripheral and central circular targets using their index finger; the participant's gaze and finger directly interacted with the targets. The horizontal reversal condition (HR) was a non-standard CMI task, where the

participant interacted with both screens (tablet and touchscreen) on vertical and horizontal planes, creating two levels of decoupling for both visual and motor systems. Peripheral and central targets appeared on the vertical screen, but participants controlled the cursor with the horizontal (bottom) screen. However, in the horizontal screen there was a feedback reversal of 180°, thus the participant had to move their finger in the opposite direction to move the cursor toward a target. For example, to reach a peripheral target on the top side of the vertical screen the participant must move the cursor downwards on the horizontal screen. Participants sat on a chair with the BrDI device on a desk where the distance between the laptop and participant are at a comfortable length when stretching out their dominant arm.

A.



B.

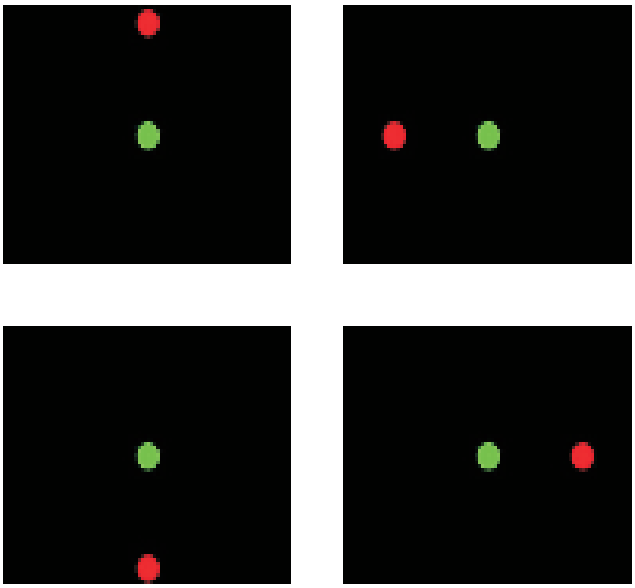


Figure 1: *Testing Apparatus and target display. A. Design for standard vertical (direct interaction) & non-standard horizontal rotated (cognitive-motor integration) conditions, respectively. Starting point of the central target is represented as light grey eye, finger & cursor while dark grey denotes movement of eye & finger. The orange circles represent peripheral targets and the grey circles represent central position of finger prior to initial movement. B. Visual peripheral stimuli presented in the four locations on the screen.*

As mentioned before, both conditions occurred in a randomized order. Within the task, the targets on the vertical touch screen are circular and 20 mm in diameter. The distance between central (centre screen) and peripheral targets was 55 mm as the task itself was displayed on a 125 x 125 mm black square with the surrounding background coloured grey, to maintain a constant visual border. In each condition, there was 20 trials (5 trials to each of the 4 peripheral targets); 40 trials in total for each participant.

As for the timing and target response in both conditions, a trial began with a central yellow target. Once the participant moved the cursor to the yellow target, with their index finger on their dominant hand, the central target turned green and after the finger is held for 4000 msecs the target disappeared, and a red peripheral target appeared. Once the peripheral target is reached and held for 500 msecs the target disappeared, then centre target reappeared in which the participants moved back to the centre; this counted as one trial. The next trial is followed with a green central target after an inter-trial interval of 2000 msecs.

Each participant had full view of their hand and fingers. Each participant was prompted to move the cursor toward each target as accurately and as quickly as possible and to minimally attend to external distractions when performing. The experimenter examined and monitored each participant's trials and movements to distinguish error trials for each task (i.e. if they went in the wrong direction or the tablet had technical difficulties such as not responding to touch). Error trials (which will be discussed in *Data Processing*) are automatically removed during data analysis.

Lastly, the researcher was blind to the participant's questionnaire responses. Only initials are given and once the questionnaire is completed, the participant folded the questionnaire and as given to the researcher. The blind was broken once the participant's kinematic (outcome) data is entered and analyzed via MATLAB (Mathworks, Inc., Natick MA). Afterwards, the predictor variables from the questionnaires were collected and analyzed.

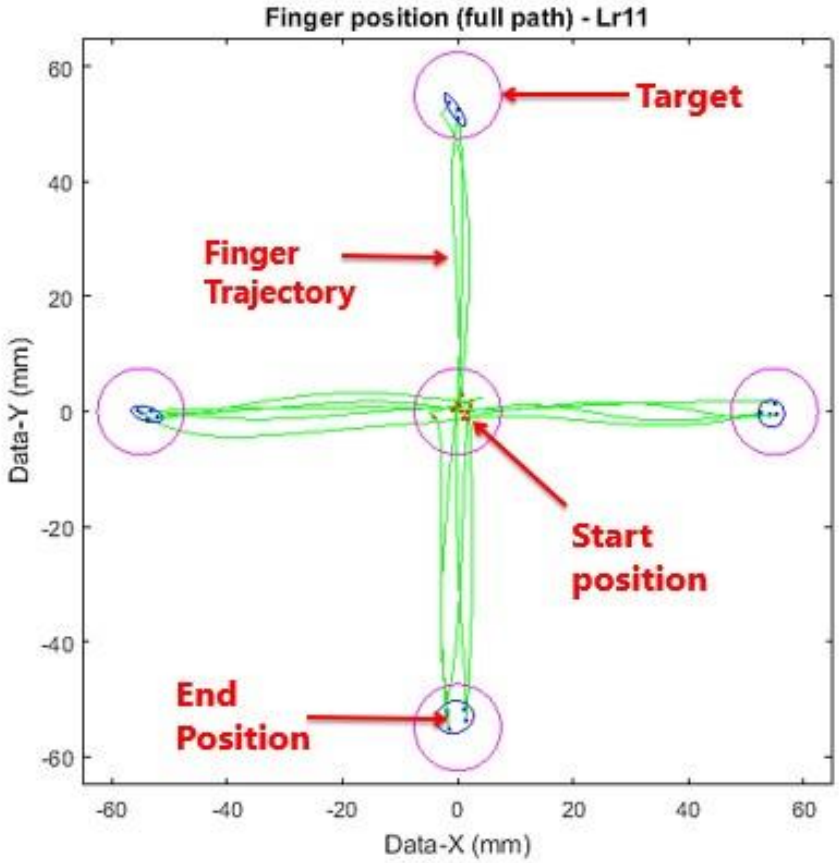


***Figure 2**: A trajectory output via MATLAB. The purple circles indicate the peripheral targets, the green lines indicate actual finger trajectory, the red dots indicate the start position of the finger and the blue dots indicate the end position. Each green line indicates the finger path of one trial. From this output we were able to utilize multiple variables.*

Error Trials

Error trials included: 1) cursor leaving the central target too early (< 4000 msecs), 2) reaction time was too short (< 150 msecs) or 3) too long (> 8000 msecs), or 4) if movement time was too long (> 10000 msecs) and 5) if the first ballistic movement exited the boundaries of the central target in the wrong direction (i.e. finger movement is greater than 90° from a straight line to the target; output quantified as percentage of trials with direction reversals).

Data Processing and Scoring

The task on the Asus™ tablet was conducted using the BrDI™ program. Finger positioning (x, y coordinates; at 60 Hz sampling rate), response times and error data were recorded during each trial. Saved raw data were converted into MATLAB readable format using a custom C++ application. Individual movement paths derived from the cursor position were filtered (low-pass Butterworth) at 10 Hz (filfilt function, MATLAB, Mathworks Inc.). Each individual trial for each participant was scored using custom software (MATLAB). Velocity and displacement (*x* and *y path*) for each trial were displayed for visual verification of automated movement onset and offset scoring of the filtered data. Movement initiation and ballistic movement endpoints (i.e. the initial muscular impulse before movement path corrections) were automatically scored as 10% of peak velocity. The processed data were then sent to a second custom-written analysis program to compute movement timing and execution outcome measurements. Individual

trials that exceeded 2.5 standard deviations from the mean for each outcome variable were eliminated.

Statistical Analysis

A paired T-test was conducted for the outcome variables for the V and HR conditions respectively. A one-way MANCOVA (parametric) with age as a covariate and Group as a fixed factor (Healthy/sedentary, healthy/active, brain health issue/sedentary & brain health issue/active) was conducted with all outcome variables for the V condition. A second MANCOVA was conducted with all outcome variables for the HR condition. The variable "***Neuro/Activity Status***" was compiled due to the lack of power and missing data in certain variables to see if interactions occurred (i.e. no participants with CDHX and sedentary lifestyle), thus we grouped participants as either *healthy/sedentary, healthy/active, brain issue/sedentary* or *brain issue/active*. Post hoc analyses (Sidak) followed.

Variables that were positively skewed (with a Shapiro-Wilks value of $p \leq .001$, and skewness >1: Reaction time for V and HR conditions, Absolute error for HR, Variable error for HR and Full pathlength for HR) were analyzed using a log function (ANCOVA) to shift their distributions to the right (Altman & Bland, 1996).

Since the "Neuro/Activity Status" variable essentially tested for interactions between activity level and brain health histories, we then looked at "Activity level" (sedentary, mildly active, and moderately/highly active) and "Neurological status" (no history [Healthy], concussion history [CHX], dementia risk [DHX], and both [CDHX]) separately in two one-way (parametric) MANOVAs to test for main effects of each. A

post hoc analyses (Sidak) followed. Effect of sex could not be extrapolated from our data due to low power in certain groups. Statistical significance levels are set to $\alpha = .05$; all analyses were performed using SPSS statistical software (IBM, Inc).

Lastly, to support possible findings on additive effects of having both concussion and family history of dementia, performance variability was observed as well. Between-subject variability in the Neurological group with significant HR outcomes was analyzed via Levene's Test (age-adjusted means) to examine "noise" between these groups; a procedure previously conducted in our lab (W.J. Tippett, Alexander, Rizkalla, Sergio, & Black, 2013).

Results

Thirty-five participants (***see table 1)*** were recruited (17 females; M_{age}= 42.4 years old ± 10.7). Regarding neurological status, 16 of the participants were healthy (8 females; M_{age}= 44 ± 13.1), 10 had concussion history (2 females; M_{age}= 38.9 ± 5.8), 5 had dementia risk (3 females; M_{age}= 44.6 ± 10.6) and 4 had both histories (all female; M_{age}= 42.5 ± 10.6).

Regarding activity level, 9 were sedentary (7 females; M_{age}= 55 ± 10.2), 11 were mildly active (5 females; M_{age}= 35.9 ± 6.3) and 15 were moderately/highly active (5 females; M_{age}= 38 ± 6.08).

In terms of Neuro/Activity status, 5 were in the healthy/sedentary group (4 females; M_{age}= 60.8 ± 4.02), 10 were healthy/active (3 females; M_{age}= 37.7 ± 7.7), 4 were

brain issue/sedentary (3 females; M_{age}= 47.7 ± 11.5) and 16 were brain issue/ (7 females; M_{age}= 36.7 ± 11.3).

In a paired T-test, each outcome variable for both V and HR conditions were significantly different from each other ($p < .002$). Thus, on timing and trajectory, all participants had more difficulty on the HR condition than the V condition, as expected.

Neuro/Activity Status

All of the following results were adjusted for age (***see Table 2)***. Looking at the effect of **neuro/activity status** for all **V** condition outcomes, between-subjects analysis found a difference between neuro/activity status and ***MTf*** ($F(3,31)= 6.130$, $p= .002$, $\eta p2= .380$). A pairwise analysis found that the ***MTf*** (**see *figure* 3**) for brain issue/active participants (Adj. M= 377.04 msecs, SE= 29.44) to be shorter than brain issue/sedentary ($p= .002$; Adj. M= 643.70 msecs, SE= 57.54)**.** Hence, those participants with sedentary lifestyles having dementia risk and/or concussion history demonstrated significantly slower movement times compared to those with more active lifestyles, on the basic eye-hand movement task.

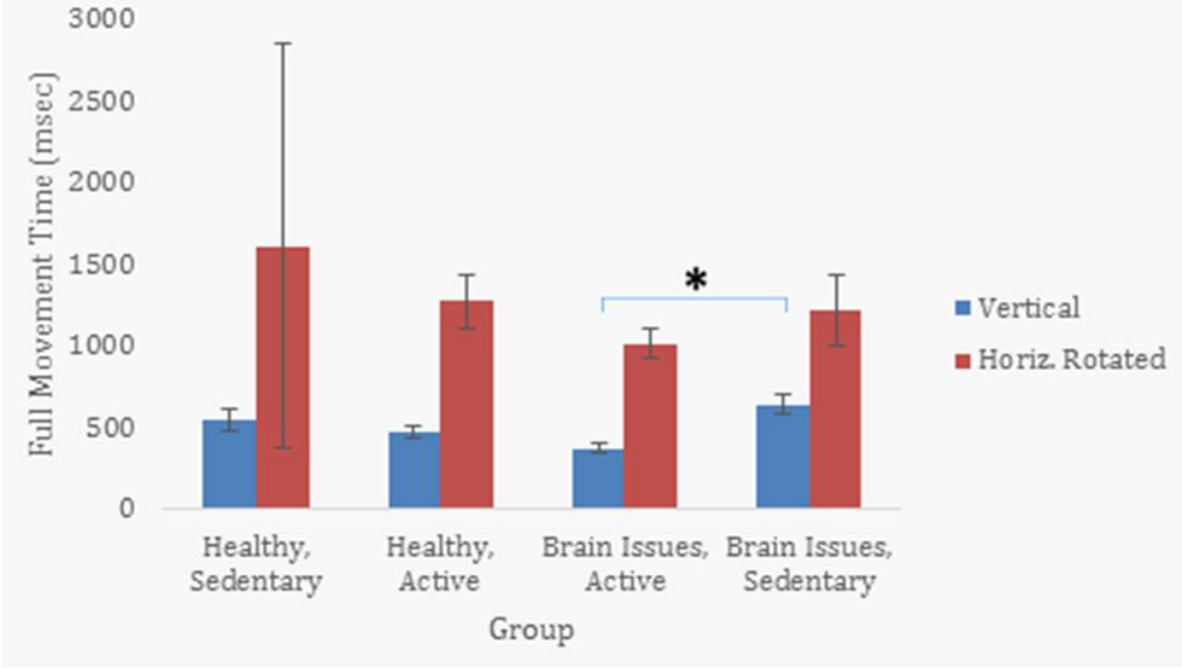


***Figure 3**: The full movement time (msec) (the length of the trajectory from onset to endpoint) means for neuro/activity groups; controlled for age. *p < 0.05. Error bars represent standard error of the mean; adjusted means displayed.*

The effect of **neuro/activity status** for all **HR** condition outcomes, between-subjects analysis (Sidak, parametric) found significance between status and ***MTb*** ($F(3,30)= 4.53$, $p= .010$, $\eta p2= .312$). In a pairwise analysis, ***MTb*** in brain health issue/active participants (Adj M= 672.57 msecs, SE= 57.87 msecs) was significantly shorter ($p= .009$, **see *figure 4***) than healthy/active ones (Adj M= 968.47 msecs, SE= 113.12 msecs). Using an ANCOVA log function for skewed V/HR outcomes, there was no significance ($p> .05$) between neuro/activity status and V/HR outcomes. Hence, participants who are active with brain health issues performed shorter ballistic movement times toward a peripheral target compared to active, healthy participants.

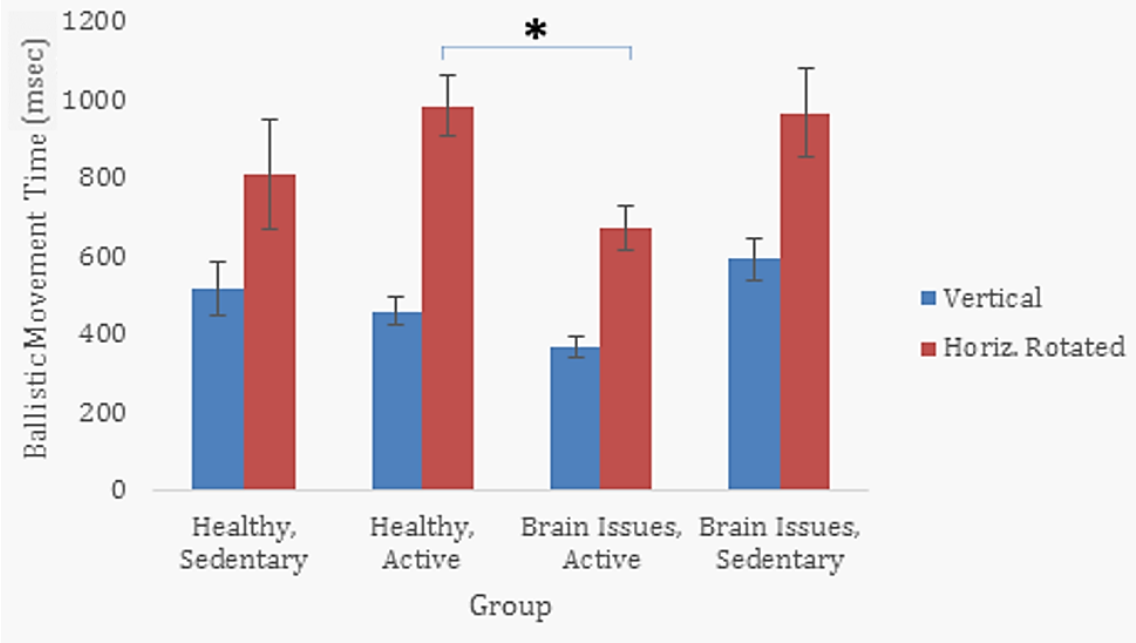


***Figure 4**: Ballistic movement time (msec) (the length of the trajectory from onset to endpoint) means for neuro/activity groups; controlled for age. *p < 0.05. Error bars represent standard error of the mean; adjusted means displayed.*

Activity Level

For effect of **activity level** for all **V** condition outcomes, between-subjects (parametric, Sidak) analysis found Activity score significant for ***MTb*** ($F(2,31)= 4.23$, $p= .024$, $\eta p2= .215$), ***MTf*** ($F(2,31)= 5.42$, $p= .010$, $\eta p2= .259$), and ***PLb*** ($F(2,31)= 3.90$, $p= .031$, $\eta p2= .201$). Pairwise analysis found that ***MTb*** in sedentary participants (Adj. M= 574.26 msecs, SE= 49.43 msecs) was longer ($p= .021$) than moderately/highly active participants (Adj. M= 388.70 msecs, SE= 31.38 msecs). For ***MTf*** (**see *figure 5***), Sedentary participants (Adj. M= 618.08 msecs, SE= 52.16 msecs) were slower than mildly active ($p= .026$) (Adj M= 422. 57 msecs, SE= 37.76 msecs) and moderately/highly active ($p= .008$) (Adj. M= 396.53 msecs, SE= 33.11 msecs) participants. ***PLb*** did not survive pairwise analysis. Using an ANCOVA log function for skewed V outcomes found no significance ($p> .05$) between activity level and V outcomes. Thus, sedentary participants had longer ballistic movement times and slower full movement times toward peripheral targets than mildly and moderately/highly active participants.

For effect of **activity level** for all **HR** condition outcomes, between-subjects (parametric, Sidak) analysis found no significance between activity level and any outcome ($p> .05$). Using an ANCOVA log function for skewed HR outcomes (**see *figure 5***), ***MTf*** was significantly slower for mildly active participants (Adj. M= 1315.96 msecs, SE= 134.97 msecs) ($p= .018$; Overall: Wald Chi-Square= 8.73, df= 2, $p= .013$) versus moderately/highly active participants (Adj. M= 878.86 msecs, SE= 83.41). Thus, those who were considered mildly active had slower movement times toward peripheral targets than those considered to be moderately/highly active, whom which had quicker movement times.

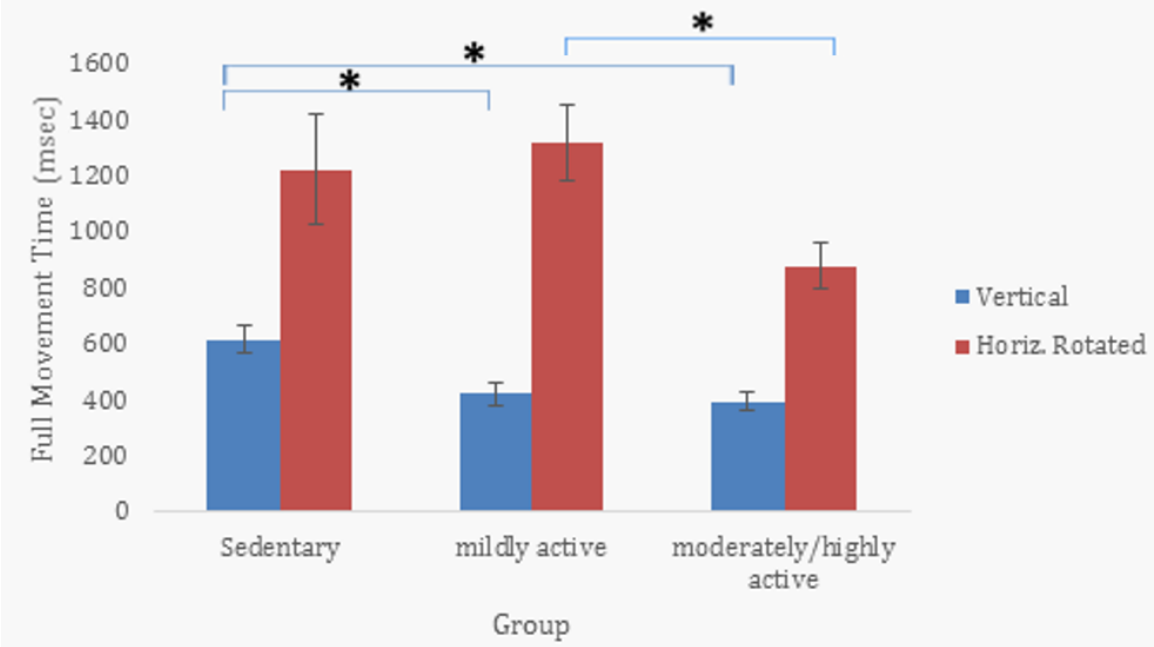


***Figure 5**: The full movement time (msec) (the length of the trajectory from onset to endpoint) means for activity level groups; controlled for age. *p < 0.05. Error bars represent standard error of the mean; adjusted means displayed.*

Neurological Status

For effect of **neurological status** for all **V** condition outcomes, between-subjects (parametric, Sidak) analysis found no significant differences ($p > .05$) between status and V outcomes.

For effect of **neurological status** for all **HR** condition outcomes, between-subjects (parametric, Sidak) analysis found neurological status is significant with ***PLb*** ($F(3,35) = 4.29$, $p = .012$, $\eta p2 = .301$). In a pairwise analysis (**see *figure 6***), CDHX (Adj. M= 45.60 mm, SE= 1.53 mm) participant's ***PLb*** was significantly shorter than in healthy ($p = .008$; Adj. M= 51.62 mm, SE= .76 mm) and CHX participants ($p = .031$; Adj. M= 51.09 mm, SE= .984 mm). Hence, those with both histories (CDHX) had shorter ballistic trajectories toward peripheral targets than healthy and concussed (CHX) participants. A Levene's test revealed that only the variances between healthy and CDHX ***PLb*** means are significant ($F(1,18) = 8.44$, $p = .009$). Thus, the CDHX group (SD= 5.43) had more variation than healthy participants (SD= 2.96).

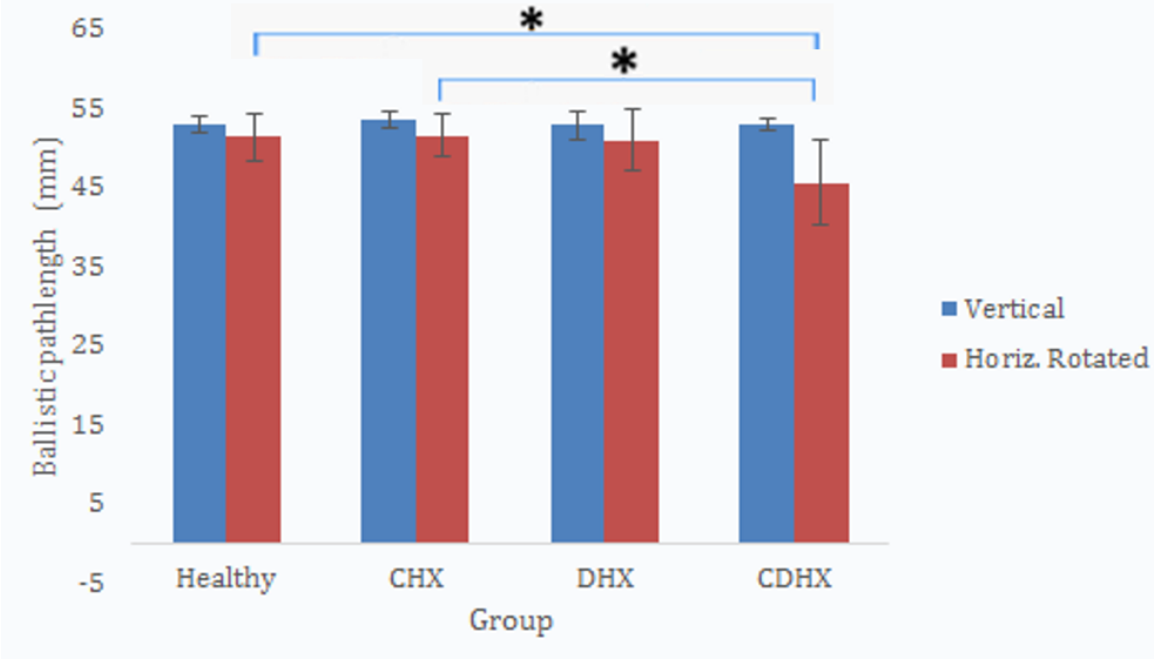


Figure 6: *The ballistic path length (mm) (the length of the trajectory from onset to first stopping point) means for neurological status groups; controlled for age. *p < 0.05. Error bars represent standard error of the mean; adjusted means displayed.*

***Table 1**: Demographic data of participants in each group*

Group	N, *n*	Age (*M* ± *SD*)	Sex *(Female, male)*
Neuro/Activity Status	N= 35		
	Healthy/sedentary, *n= 5*	60.8 ± 4.02	4, 1
	Healthy/active, *n= 10*	37.7 ± 7.7	3, 7
	Brain issue/sedentary, *n= 4*	47.7 ± 11.5	3, 1
	Brain issue/active, *n= 16*	36.7 ± 11.3	7, 9
Activity Level	N= 35		
	Sedentary, *n= 9*	55 ± 10.2	7, 2
	Mildly active, *n= 11*	35.9 ± 6.3	5, 6
	Moderately/Highly active, *n= 15*	38 ± 6.08	5, 10
Neurological Status	N= 35		
	Healthy, *n= 16*	42.4 ± 10.7	8, 8
	CHX, *n= 10*	38.9 ± 5.8	2, 8
	DHX, *n= 5*	44.6 ± 10.6	3, 2
	CDHX, *n= 4*	42.5 ± 10.6	4, 0

Table 2: *Between-Subjects Analysis*

Outcome Variable	Activity Level (V / HR)	Neurological Status (V / HR)	Neuro/activity status (V / HR)
Ballistic Movement Time (MTb)	***p= .024** / *p= .46	*p= .35 / *p=. 25	*p= .077 / ***p= .010**
Full Movement Time (MTf)	***p= .010** / **†p= .013**	*p= .35 / †p= .40	***p= .002** / †p= .46
Ballistic Pathlength (PLb)	***p= .031** / *p= .19	*p= .74 / ***p= .012**	*p= .63 / *p= .10

*P-values for multivariate between-subjects analysis (α= .05). V; vertical condition, HR; horizontal-rotated condition. *Asterisks denote parametric MANCOVA analysis. †Crosses denote non-parametric log-function ANCOVA. Significant values are bolded.*

Discussion

In this study, we wanted to elucidate the effects of concussion history and dementia (familial history) risk on CMI performance; we wished to observe if having both histories exacerbated CMI decline relative to healthy, CHX and DHX participants. We also wished to see if physical activity can mitigate CMI decline in those with brain health issues relative to those without issues. Importantly, we wished to, for the first time in our laboratory, look at cognitive-motor integration performance and brain health in the under-studied working age population. Using a dual-screen device, an eye-hand coordination (visuo-motor transformation) task was used to assess CMI ability in two conditions: vertical (V) and horizontal-rotated. A paired t-test of all V and HR outcomes showed that participants all struggled through the HR condition (***see figure 7)***. This was to be expected as we have found in our lab numerous times with youth and older adults; a task that requires CMI (decoupling) will tax the fronto-parietal network more than a task where one's gaze and hand are closely coupled (Dalecki et al., 2016; K. M. Hawkins & Sergio, 2014; Hurtubise et al., 2016; Tippett, Sergio, & Black, 2012). Thus, this supports our first hypothesis of middle-aged participants performing poorly in a CMI task similar to that observed for concussed youth and dementia-risk seniors in previous studies.

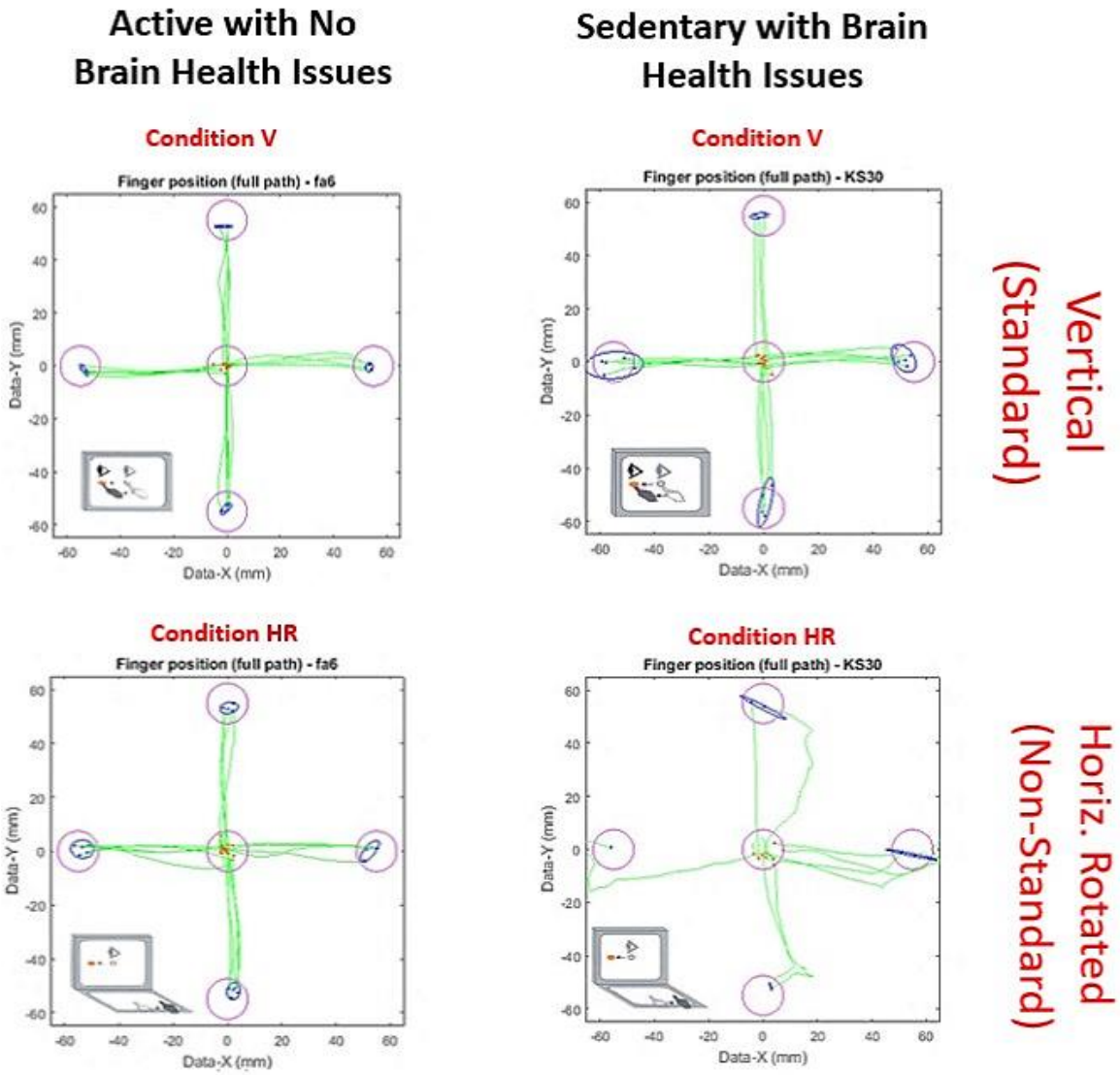


Figure 7: *Finger path data of a participant with an Active lifestyle with no brain health issues (LEFT) and a participant with a sedentary lifestyle with brain health issue(s) (RIGHT). Green lines represent the path taken by the finger sliding on the touchscreen from a central to peripheral targets (purple circles). Red and blue dots show start and end points, respectively. The blue circle denotes the 95% CI for the endpoints. Note the poorer performance in condition HR compared to V for both subjects, and the poorer performance in HR of the participant who is sedentary with a history of brain health issue(s).*

If we look at the data from the neuro/activity status groups, we see something interesting. In the V condition requiring only direct interaction, brain issue/active participants performed better than brain issue/sedentary participants. When engaging in a task that couples one's gaze and hand, it seems that those with have concussion and/or dementia risk and active can reach the target faster (***MTf***) than those with brain health issues and sedentary. Although not directly related to our hypothesis, brain issue/active participants appear to have a robust "default motor skill network" and are efficiently quicker in standard visual-motor mappings (Balser et al., 2014; D. Gorbet & Sergio, 2016; Guo et al., 2017) compared to their sedentary counterparts. But in the HR condition, compared to healthy/active participants, brain issue/active participants demonstrated shorter initial ballistic movement times (***MTb***). If we compare the ballistic data (***MTb***) to their respective full movement times (**MTf)**, we see that the ballistic times for the healthy/active group covers 77.01% of their full movement time (***MTf***) whereas the brain issue/active group's covers only 66.28% of their total movement time. If ***MTb*** are equal to or is close to ***MTf*** times, then little corrections were done by participants, but if not, we assume that more correction were done to reach peripheral targets. Thus, the brain issue/active group needed stop earlier in their trajectory to make a correction compared to the healthy/active participants (i.e. cursor movement of off at an angle when reaching for the peripheral target; trajectory was not a straight line). Therefore, it seems although these individuals have a preserved default network, they have difficulty with CMI tasks since the fronto-parietal network is more burdened while having their brains inflicted with concussions and/or dementia risk, making them more vulnerable to CMI declines. It appears there are interactions between neurological status/history and

physical activity were being physically active may preserve brain functioning in standard visuomotor tasks. While we observed a trend towards worse CMI performance in sedentary versus active individuals overall, more data are needed to confirm this relationship. To parallel this with youth, both healthy-active and concussed-active participants perform at the same level during the vertical condition (standard) but the concussed adolescents have longer reaction and movement times (J.A. Brown, Dalecki, Hughes, Macpherson, & Sergio, 2015). Also, concussed athletes having a higher level of physical fitness had fewer impairments in CMI performance compared to concussed athletes who were less skilled (Sergio et al., 2017). So, it could be that activity level may be protective with regards to concussion but in our sample here we do not see this effect when we group activity level and neurological status together; possibly due to having age as a covariate.

Directing to the effects of activity level alone as a main effect, we see that sedentary participants (in the V condition) made longer ballistic movement times (***MTb***) than mildly and moderately/highly active. However, the ballistic movement times of sedentary participants take up 92.9% of their full movement times. Whereas for mildly and moderately/highly active participants are 97.1% and 98.02% respectively. This could mean that sedentary individuals had more earlier corrections along their path compared to active individuals which complements the notion that active people and athletes are skilled at eye-hand coordination (C. Del Percio et al., 2011; C. Del Percio et al., 2009). In addition, sedentary participants reached the peripheral targets slower than the active groups (***MTf***); this also complements the notion that active individuals and athletes make faster movements (C. Del Percio et al., 2009). In the HR condition, we see that mildly

active participants are slower to reach for peripheral targets than moderately/highly active participants. Being more active seems to suggest that higher level of physical fitness may be associated with a more robust fronto-parietal network than those who exercise a couple times a week (C. Del Percio et al., 2011; Guo et al., 2017; C. Del Percio et al., 2009). Thus, physical activity may be associated with better standard and CMI (non-standard) performance.

Focusing finally on neurological status, we see that those with both concussion and dementia-risk histories (CDHX) have shorter ballistic trajectories (***PLb***) than those with no histories (Healthy) and those with concussion (CHX). The CDHX group made trajectories that were off from a perfect 180º trajectory to the targets, which prompted their peak velocity to drop below 10%, signaling a correction in their trajectory; they had to slow down in order to make a correction. In addition, the PLb was 73.47% of the full pathlength for CDHX participants whereas in healthy and concussion history participants it was 91.2% and 90.11% respectively. Being affected by both histories may in fact affect certain nodes of the fronto-parietal-cerebellar network responsible for planning, execution, error correction and, coordination (i.e. cerebellum, premotor cortex, posterior parietal cortex) (Balser et al., 2014). Dementia is well documented to affect the fronto-parietal network (Buchman & Bennett, 2011, M.F. Ghilardi et al., 2000; M.F. Ghilardi et al., 1999, K.M. Hawkins & Sergio, 2016; K. M. Hawkins & Sergio, 2016; K.M Hawkins & Sergio, 2014). It has been shown that having the APOE e4 allele and a history of concussion(s) can drastically increase the risk of developing dementia with age (Jordan et al., 1997; Lawrence, Comper, Hutchison, & Sharma, 2015; Luukinen et al., 2008; C. Smith, Graham, Murray, Stewart, & Nicoll, 2006; Wang et al., 2012). Thus, this supports

our hypothesis as there appears to be an additive effect of histories and CMI performance; if one has both histories they may have issues with planning and error detection of movements. Hawkins & Sergio (2014) found that older adults with Alzheimer's risk believed trajectory deviations may stem from a disrupted fronto-parietal network where internal feedback loops, required to update hand position and target are affected; eye-hand coordination is indeed compromised. We also suggest that there may be dysfunctions with feedforward mechanisms.

It is worth noting however, that all participants in the CDHX group are active. With data of concussed youth and data from mild cognitively impaired older adults, we can infer that middle-aged participants with both histories will have exacerbated CMI declines with regards to pathlength trajectory even if they are considered active.

The variance of ballistic pathlengths for the CDHX group compared to the healthy group was significantly higher. Thus, we believe that this larger variance may be indicative of neurological noise in the fronto-parietal network. The reason that the CDHX group has more noise compared to the healthy group may be because if one's brain has been exposed to some sort of insult or predisposition (i.e. concussion and dementia history) then these areas are disrupted and perform poorly in CMI tasks (W.J. Tippett et al., 2013). We typically do not see large variances for the vertical, standard task because we know that the fronto-parietal network for basic eye-hand coordination is minimally taxed.

Limitations

Limitations include a small sample size, we believe a larger sample will reflect the population more accurately. We also had low power to observe any sex differences. We know that CMI networks in females brains are different than male brains (D.J. Gorbet & Sergio, 2016) and we wished to observe those differences behaviorally in this population. Not having age-matched groups may have affected our results due to having certain groups older than others (*see Table 1)*. Lastly, we believe there may be biases based on self-reported data. Since the predicator variables are based on a subjective questionnaire where the experimenter was blinded to the responses, it was difficult to assess their authenticity. For our future work, will examine neural network integrity in working-aged adults with brain health issues.

Conclusions

CMI assessment may be sensitive enough to detect neurological effects or dementia risk and concussion history, although it is not specific to concussions and dementia risk (W.J. Tippett et al., 2013). We believe assessing CMI performance is important in detecting these deficiencies since standard visuomotor tasks do not display deficits in fronto-parietal-cerebellar network whereas non-standard tasks do. To date there has not been a lot of research on functional performance in working-aged adults affected by mild brain injury, dementia risk, or both. In this preliminary analysis, we did see interactions between brain health and physical activity as well as observing effects of physical activity and brain health separately. These data suggest that having both concussion and dementia risk may affect rule-based skilled performance in an additive

fashion in middle-aged individuals. As well, an active lifestyle rather than a sedentary one may be protective against the effects of brain health issues on basic and complex skilled motor performance.

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Appendix: Participant questionnaire, given prior to BrDI tasks.

Questionnaire

Pretest Intake Questionnaire - BrDI Flight study

(The information received will remain confidential)

ID: _____ **Age**: _____ **DOB:** _____

Dominant Hand: LEFT or RIGHT or BOTH **Sex**: Male or Female or Other

Level of Education: _____ **Work Full Time / Part Time / Neither**:_____

Ethnicity: _____ **Occupation**: _____

Sport(s) Played (recreational or competitive):

_____

How long did you play your sport(s): _____-_____

1. Do you **currently** have a concussion? (an impact to the head which MAY have resulted in: headaches, loss of consciousness, confusion, amnesia, dizziness, nausea, etc)

   YES or NO

   a) Date of concussion: _____

   b) Did you lose consciousness? _____ For how long? _____

   c)Please list any current signs and symptoms:

   _____

   _____

2. Have you **previously** had any concussions (an impact to the head which MAY have resulted in: headaches, loss of consciousness, confusion, amnesia, dizziness, nausea, etc)?

   YES or NO

   a) How many? _____

   b) Did you lose consciousness? _____ For how long? _____

   c) Date(s) and time out before returning to play:

   _____

   _____

1. Do you smoke? YES or NO

a) Do you smoke: Cigarettes, Cannabis, Both or Other: _____

b) How often do you smoke the above mentioned substance(s) per day, week or month?

_____

2. Do you **currently** have a non-head related injury? YES or NO

a) Has it kept you from play for longer than 48 hours? YES or NO

b) Has it kept you from play for longer than 3 weeks? YES or NO

3. Have you been diagnosed with any neurological disorders? YES or NO

What disorder? _____

4. Do you have a computer (YES or NO) or a tablet (YES or NO) at home?

How often do you use your computer? (all the time / often / sometimes / rarely / never)

How often do you use your tablet? (all the time / often / sometimes / rarely / never)

5. Do you do puzzles? YES or NO (all the time / often / sometimes / rarely / never)

6. Do you play video games? YES or NO (all the time / often / sometimes / rarely / never)

a) What type of games do you typically play? ACTION (time pressure) or NON-ACTION

b) How would you rate your skill compared to your peers? (Low / Intermediate / High)

7. To your knowledge, does anyone in your family have any form of dementia? YES or NO

a) What is their relationship to you (e.g., mother/father/brother/sister, **maternal** aunt/uncle/grandmother/grandfather/cousin, **paternal** aunt/uncle/grandmother/grandfather/cousin). List all if more than one relative.

_____

_____

THE FOLLOWING IS A LIST OF ACTIVITIES THAT PEOPLE MAY PARTICIPATE IN. PLEASE INDICATE THE FREQUENCY (IN DAYS PER WEEK) THAT YOU TYPICALLY PARTICIPATE IN THESE ACTIVITES.
FOR EACH ITEM CHOOSE FROM ONE OF THE FOLLOWING ALTERNATIVES:

	NEVER	RARELY (1 DAY/ WEEK)	SOMETIMES (2 DAYS/ WEEK)	FAIRLY OFTEN (3-4 DAYS/ WEEK)	VERY OFTEN (5-7 DAYS/ WEEK)
	0	1	2	3	4
1. WATCHING TV OR MOVIES	0	1	2	3	4
2. READING	0	1	2	3	4
3. SOCIALIZING (E.G. PLAYING CARDS, TALKING TO FRIENDS, ETC.)	0	1	2	3	4
4. PLAYING REC SPORTS	0	1	2	3	4
5. PLAYING COMPETITIVE SPORTS	0	1	2	3	4
6. PLAYING VIDEO/ COMPUTER GAMES	0	1	2	3	4
7. WALKING (AT LEAST 25 MINUTES)	0	1	2	3	4
8. LISTENING TO MUSIC	0	1	2	3	4
9. EXERCISING AT A GYM	0	1	2	3	4

1. DOING NON-LABOUR WORK (PAID OR VOLUNTEER)	0	1	2	3	4
2. DOING LABOUR WORK (E.G. LANDSCAPING SHOVELING, PAINTING, ETC. PAID OR VOLUNTEER)	0	1	2	3	4
3. RUNNING/JOGGING	0	1	2	3	4
13. PUZZLES, ARTS & CRAFTS (E.G. KNITTING, CROSSWORDS, ETC.)	0	1	2	3	4

LAST QUESTION!

Are you: Pre-menopausal or Peri-menopausal or Post- menopausal* or Not Applicable

*post- menopausal is defined as having no period for the past 12 months

When completed, please fold these 3 pages with your information on the inside