Effects of a Disengagement Intervention on Cognitive Performance in Those with a Mild Head Injury

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COVID-19 Thesis Impact Statement

Provide a brief summary of your design/methodology PRIOR to the pandemic and changes that occurred (maximum 500 words).

- This research investigated the influence, and potential advantage, of cognitive disengagement to supplement vigilance and attention during a cognitively-demanding task in those with a history of mild head injury. Cognitive fatigue was induced via a timed vigilance Go/No-Go Task (adapted from the NEPSY's auditory attention and response task). Research design preparations were being conducted during the provincial lockdown such that all research materials were adjusted and re-designed in order to be hosted through an online platform (i.e., Qualtrics). Under typical circumstances, autonomic physiological indices (electrodermal activity [EDA], blood pressure [BP], heart rate [HR], and respiration) would be collected *in-person* via computerized equipment (Polygraph Pro), the cognitively demanding task would be presented on the computer under experimentally-controlled conditions, and all other research materials (i.e., questionnaires) would be administered via paper/pencil oversight. Collection of all aspects of autonomic data was not possible given the restraints imposed by the COVID-19 pandemic; only heart rate was available as a physiological measure of interest. Participants could be directed to collect HR from home, either manually or through some 'smart' systems (e.g., watches). The lockdowns imposed by the COVID-19 pandemic necessitated the development and re-programming of the Go/No-Go Task for online/remote administration and required rigorous pilot-testing due to computer and internet speed variations (subjects having to use their own desk tops or lap tops or phones, and having adequate/inadequate wi-

fi speed options in order to engage the task [e.g., subjects had to respond to persistent timed-trial presentations).

Provide a brief description of how you changed your research to accommodate the public health emergency measures while completing your thesis (maximum 500 words). Please be specific, concise and/or include a timeline to better explain the impact.

- Changes and adaptations to research materials and methodology included having to design and develop a Go/No-Go Task (and its various versions, depending on the task manipulation) to be adapted to the online format. All past studies with similar timed and computerized presentations (and using similar materials) were prepared for *in-person* testing on a single device, under controlled environmental conditions; no online/remote-presentation versions of this sustained attention Go/No-Go task were available to use prior to this research thus the design had to be adapted to, and programmed for, an on-line platform that could be delivered to various at-home computer and internet systems all the while maintaining the experimental presentation parameters (e.g., auditory and visual presentation), 1 second trial and response presentation, recording of type of response (accuracy, errors, type of errors, response times, disengagement/no disengagement visually-filled intervals). There were also no examples/templates/delivery-documents for this (or similar) experimental task to be adapted and setup on Qualtrics. To the knowledge of the author, and in consultation with the Qualtrics support team, this was the first time a timed Go/No-Go Task has been designed and developed for online/electronic administration via the Qualtrics website. A large portion of the research process involved task re-design and

construction, ensuring user-input accuracy, accurate labeling of user-inputted data, as well as testing and reviewing task mechanics. Construction of the Go/No-Go task took approximately 10 months before arriving at a satisfactory final product. Following the construction of the task, participant recruitment began through Brock University's SONA website.

Provide a brief summary for your examiner(s) (maximum 300 words), of how your thesis was affected.

- The thesis was affected in several ways. Firstly, data collection did not occur under environmentally-controlled conditions and, instead, relied entirely on participant's cooperation to follow instructions, maintain focus and remain task-oriented/engaged, It also was influenced/vulnerable to the variations in devices participants had available (e.g., fast and reliable internet connection for consistent Go/No-Go Task delivery; laptop trackpad or keyboard and mouse, for responding/selecting their responses; visual and auditory compatibility between the participants' systems and the Qualtrics delivery platform for the testing stimuli; wristband device or manual assessment protocol so as to record heart rate, etc.). Further, given that much more time had to be prioritized towards designing a reliable and accurate Go/No-Go Task, less time was able to be afforded towards data collection and for follow up with the participants in order to keep them sufficiently engaged to complete the task (which required approximately 1.5 hours of their time). Finally, the provincial lockdown imposed by the COVID-19 pandemic affected individuals' cognitive and mental fatigue in unanticipated ways, such that the lockdown measures/restrictions were

found to be associated with higher observed and reported ratings of cognitive fatigue for those in the general population. Given that a central focus of this research was cognitive fatigue induction, this has led to interpretive challenges and confounds that we tried to mitigate via instructions for preparedness for testing.

Abstract

Mild head injury (MHI) is a major public health concern and cognitive fatigue following injury is one of the most commonly reported and debilitating symptoms that interfere with everyday life. The ventromedial prefrontal cortex (vmPFC) is especially susceptible during injury and is an important brain region in the context of traumatic brain injury; the vmPFC is responsible for regulating physiological arousal and the neuropathology following MHI has been shown to lead to physiological underarousal. Dampened physiological arousal has been shown to precede and give rise to cognitive fatigue, and that more severe injuries lead to both worsened physiological arousal and fatigue outcomes. The frontal regions most susceptible during injury are also largely involved in attentional processes, such that attentional processes are compromised following the neuropathology associated with MHI as well as from the onset of cognitive fatigue. Attentional deficits then arise in those with a history of MHI as a function of injury as well as cognitive fatigue compounding together; these attentional deficits then go on to impair overall cognitive functions which then present as poor performance on cognitively demanding tasks and, or, as a lessened ability to make optimal decisions in everyday life. Due to this, physiological arousal may then reflect cognitive resources available to individuals, and an opportunity to replenish these cognitive resources (i.e., a disengagement intervention) may lead to better performance outcomes on cognitively demanding tasks as well as improved fatigue ratings. This study sought to examine the effects of a disengagement intervention on cognitive performance across cognitively demanding tasks (i.e., Go/No-Go Task and Mental Rotation Task [MR Task]) in those with, and without, a history of MHI. It was found that those with a history of MHI exhibited lower physiological arousal as a function of injury severity, higher fatigue, and required more effort to meet task demands. It was also found that the Go/No-Go Task reliably induced cognitive fatigue as evidenced by diminished performance as a function of time on task,

and that the stimulus-driven Go/No-Go Task slowly depleted cognitive resources while the goal-directed MR Task quickly exhausted cognitive resources. It was also found that having the opportunity to disengage from the task for a short period of time buffered performance decrements and lead to requiring less effort across cognitively demanding tasks. Additionally, it was also found that physiological arousal was dampened and fatigue was heightened as a function of the lockdowns imposed by the COVID-19 pandemic.

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I would also like to extend a heartfelt thank you to my committee members, Drs. Tim Murphy, and Stephen Emrich. Your insights throughout this research have been invaluable, and I am grateful for the time you've both invested into this research, and in me. I am also especially thankful for the small conversations we've had over the years. Dr. Murphy, you've inspired such a passion in me during 2F23 to want to further understand statistics to the point I began a side-project with your teachings in mind. Dr. Emrich, you ignited something in me during my undergrad years to want to pursue my education to the furthest I could possibly take it. I am so thankful for the opportunity to have gotten to work more closely with you both during this program, and to have gained so much from my time under your wings.

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List of Abbreviations

Abbreviation	Definition	Page
TBI	Traumatic Brain Injury	1
CDC	Centers for Disease Control	1
ONF	Ontario Neurotrauma Foundation	1
BIC	Brain Injury Canada	1
MHI	Mild Head Injury	2
PCS	Postconcussive Symptoms	2
WHO	World Health Organization	2
EDA	Electrodermal Activity	3
vmPFC	Ventromedial Prefrontal Cortex	4
IGT	Iowa Gambling Task	5
NEPSY	Neuropsychology Assessment	7
MFS	Mental Fatigue Scale	8
POMS	Profile of Mood States	8
CCTL	Current Cognitive Task Load	8
CCFS	Current Cognitive Fatigue Scale	8
ELQ	Everyday Living Questionnaire	9
SONA	Brock University Faculty of Social Sciences' Research Sign-Up Portal	23
SD	Standard Deviation	24
LOC	Loss of Consciousness	26
ACRM	American Congress of Rehabilitation Medicine	27
HR	Heart Rate	28
MR Task	Mental Rotation Task	30
NASA TLX	National Aeronautics and Space Administration's Task Load Index	31
BIS BAS	Behavioral Inhibition Scale and Behavioral Activation Scale	32
SPSS	Statistical Package for the Social Sciences	34
ANOVA	Analysis of Variance	34
COVID-19	Coronavirus Disease of 2019	35

COVID	Coronavirus Disease	35
NCR Lab	Neuropsychology Cognitive Research Lab	35
SE	Standard Error	36
BPM	Beats Per Minute	37

Effects of a Disengagement Intervention on Cognitive Performance in Those with a Mild Head Injury

Traumatic Brain Injury

Traumatic brain injury (TBI) is a major public health concern involving disruption of the normal functioning of the brain. These injuries are often complex, may not be easily identified, and often give rise to consequences and psychiatric symptomatology that may not initially be recognized as resulting from a TBI (Belanger et al., 2017; Cassidy et al., 2004; Centers for Disease Control [CDC], 2019; Peterson et al., 2019). TBI is a subset of neurotrauma which may bring on life-changing consequences (e.g., requiring assistance to carry out everyday tasks; Ontario Neurotrauma Foundation [ONF], 2019). TBI involves a force impact injury of sudden onset, such as a hit to the head. These impacts, and its accompanying acceleration and deceleration forces, cause the brain to twist and stretch which result in shearing. Shearing forces disrupt connectivity among neurons in the brain as well as cause diffuse axonal injury and is one of the primary neuropathology in TBI (Alexander, 1995; Tanaka & Wells, 2014). The leading causes of TBI are being struck by or against an object (e.g., falls), motor vehicle accidents, and assaults (Peterson et al., 2019; Smith, 2018; Tanaka & Wells, 2014).

In Ontario, approximately 500,000 individuals currently live with a TBI and approximately 45 thousand new cases are reported every year (ONF, 2019). Nationwide in Canada, it is estimated that 1.5 million individuals currently live with a TBI and approximately 165 thousand new cases are reported across the country each year (Brain Injury Canada [BIC], 2018; ONF, 2019), and in the United States of America, 2.8 million TBI-related incidents are reported each year, with 56 - 61 thousand of these resulting in death (CDC, 2019; Peterson et al., 2019). In both Canada and the United States of America, TBI is a leading cause of death for individuals under the age of 40. Of particular note, incidents of TBI are on the rise throughout

North America, the incidents of TBI having more than doubled from the year 2005/6 to 2014 (Faul et al., 2010; Rao et al., 2017; Zhang et al., 2016).

Mild Head Injury

TBI is itself an umbrella term that refers to all head injuries across a spectrum of severity ranging from mild to severe head injuries (DeCuypere, & Klimo, 2012; Hartikainen et al., 2010; Iverson, & Lange, 2011). Of particular interest is mild head injury (MHI) as it is this subset of TBI that accounts for 70-90% of all reported TBI (Cassidy et al., 2004). MHI involves an altered state of consciousness and may include, but does not require, a loss of consciousness (Belanger et al., 2017).

The term 'mild' in the context of MHI undermines the complexity of head injury. The injury and its symptoms will be more subtle than moderate or severe injuries to the brain, and those with a history of MHI can successfully carry out normal lives with or without being affected by postconcussive symptoms (PCS; Johansson & Rönnbäck, 2015; National Center for Injury Prevention and Control, 2003; Langlois et al, 2006; Thurman et al., 1999; Ryan & Warden, 2003, Willer & Leddy, 2006). No two injuries are identical; they may differ in type of impact (e.g., fall, assault) and location of injury. Further, no symptom is unique to having a sustained a mild TBI, and no symptom of mild TBI have a unique neural basis that would be specific to mild TBI (Bigler, 2013; Masel & DeWitt, 2010; World Health Organization [WHO], 2019). Normal brain scans are often seen in patients with MHI, but psychometric testing may be able to elucidate the subtle deficits in behaviors that can result from an MHI (Kay et al., 1993; Lezak et al., 2012; Robb, 2020).

MHI Consequences

The symptoms and consequences of MHI are often regarded as controversial due to their inconsistent nature. Consequences and signs in a clinical setting are objective markers that

manifest as a result of a pathology that a physician, or practitioner, may point to (e.g., a fever). A symptom is a subjective experience that is apparent to the patient and may be reported (e.g., fatigue; King, 1968). As noted, no two injuries are alike, so no two injuries will result in the same consequences or symptoms. Head injuries are also rarely isolated to one specific location of the brain; damaged brain tissue from a TBI typically affects multiple brain regions leading to the expression of a complex combination of behavioral dysfunction (Carr, 2007; Iverson & Lange, 2011; Lannsjö et al., 2009; Lezak et al., 2012; McCauley et al., 2008; McCrea, 2008; Mittenberg & Strauman, 2000). The deleterious effects brought on by a TBI may persist for weeks, months or over the course of an individual's life (Iverson & Lange, 2003; Macciocchi et al., 1996; Ryan & Warden, 2003; Willer & Leddy, 2006). Further, it may be the case for some individuals that PCS may appear to be resolved but have actually been compensated and otherwise masked by other behaviors. This may be especially true in high-performing individuals (e.g., university students; e.g., Lezak et al., 2012; Robb, 2020).

The consequences of TBI may be categorized as behavioral, physiological, cognitive, and social, and they may interact with one another (CDC, 2019). Behavioral consequences may manifest as a lessened motivation for behavior and an inability to carry out activities; physiological consequences may manifest as both physiological and emotional underarousal as assessed through electrodermal activity (EDA; synonymous with skin conductance); cognitive consequences may manifest as deficits in the ability for self-monitoring, planning ahead, and making advantageous decisions. As a result, social consequences may manifest as the individual no longer being able to meet the demands of maintaining social relationships with family, friends or community due to mood changes, lack of perspective-taking, and behavioural challenges (e.g., irritability, self-centeredness, impulsivity, and apathy; Baker & Good, 2014; CDC, 2019; Damasio et al., 1990; Lezak, 1978; Lezak et al., 2012; Smith & Godfrey, 1995).

One of the aims within the TBI literature is to address the need for social reintegration (e.g., Alcock et al., 2018; Baker & Good, 2014; LaRiviere, 2021; Robb, 2020). The social consequences of TBI are exacerbated by the physiological, cognitive, and behavioral consequences following a TBI, and this relationship may be clarified through understanding which brain sites are most susceptible to injury during a TBI. The ventromedial prefrontal cortex (vmPFC) is a part of the brain that is particularly susceptible to injury from a TBI given its location above the orbits of the eyes and tendency to absorb a majority of an impact injury from the bony protrusions of the skull (Bechara et al., 1988; Bigler, 2008; Morales et al., 2007). The vmPFC has been shown to be implicated in both conscious behavior and unconscious processes that affect behavioral outcomes. Given it is responsible for both the regulation of emotions as well as relating those emotions to the self, injury to the vmPFC is associated with an impaired ability to evaluate and appraise emotional stimuli and increased apathy (Hogeveen et al., 2017; Ochsner & Gross, 2005; Phan et al., 2004). If an individual is unable to properly identify and reflect on emotions that may arise, it may also mean that they are less able to consciously experience them (i.e., alexithymia). Researchers (e.g., Baker & Good, 2014; Damasio et al., 1991) have found that those who had a history of TBI exhibited dampened skin conductance responses (i.e., less responsivity) when shown emotional stimuli with implications for either positive or negative consequences demonstrating both physiological and emotional underarousal. This type of finding supports the importance of ‘somatic markers’ and its associated somatic marker hypothesis, which ultimately states that somatic states manifest as “gut feelings” and act to facilitate decision making automatically through emotional processes. However, in the event that somatic states are dampened, as in the lowered autonomic arousal in persons with a history of TBI, the decision-making process is compromised. Being deprived of somatic states that would usually facilitate decision making becomes an “emotion-less”, slower, and more

cognitively-demanding process which may lead to more disadvantageous decisions and more errors on a task (Damasio et al., 1991; LaRivierre, 2021; Robb, 2020). It should be noted that, according to Damasio (2006), disadvantageous decisions in this context do not reflect, and cannot be compared to, poor decisions that may be the outcome of a minor lapse in judgment. Rather, disadvantageous decisions in this context refers to engaging in behaviors with clear detrimental consequences that may have a pronounced effect on one's life, and quality of life (e.g., investing all of one's life savings resulting in bankruptcy, despite explicit warnings from friends; familial disruption resulting in divorce).

van Noordt et al. (2017) and Robb & Good (2011; 2012; 2019) conducted a series of studies demonstrating evidence for the somatic marker hypothesis, as well as demonstrating differences in EDA across time epochs for those with a history of TBI. Repeatedly, they demonstrated that those with a history of MHI exhibited lower EDA relative to those without a history of MHI, and further, that those with a history of MHI made more disadvantageous decisions (in moral decision making and on the Iowa Gambling Task [IGT]) and this correlated with their dampened physiological arousal. The IGT is card selection task during which the goal is to amass as many points as possible. There are four decks each of which contains an embedded rule: two decks offer greater future losses (more frequent or larger losses; disadvantageous decks), and the other two decks offer greater future gains (more frequent or larger gains; advantageous decks; Bechara et al., 2000). This task, therefore, measures decision making capacity under conditions of uncertainty, as well as assesses participant's ability to implicitly learn the embedded rule. Robb and colleagues (Robb & Good, 2011, 2012; Robb, 2020) demonstrated that those with a history of MHI had a faster rate-of-return to disadvantageous decks and made more disadvantageous decisions than their no MHI cohort and this was correlated with their level of physiological arousal; those with a history of MHI who were also

physiologically underaroused made a faster rate of return to disadvantage decks as a function of being physiologically underaroused. The Yerkes-Dodson Law (1908) describes the relationship between performance and arousal; specifically, it states that performance is optimal when a certain moderate point of arousal is attained, and that performance is proportionally impaired relative to either increased or decreased arousal. Thus, those with a history of MHI have lower arousal which impairs one's ability to implicitly learn or detect the embedded rule on the IGT and/or be influenced by punishing consequences. When an individual is physiologically underaroused, they are less likely to experience the somatic markers of 'warning' and will thereby make more disadvantageous decisions and are less able to perform optimally.

MHI Symptomatology

In addition to the challenge of alexithymia and the other consequences that can accompany neural trauma (e.g., flattened affect; having no awareness or anticipation of consequences/deficits; Damasio, 2006), persons with a history of MHI experience symptoms that are classified into 3 categories: cognitive, physical, and emotional symptoms (CDC, 2019). Physical symptoms may include, but are not limited to, sensitivity to light or noise, dizziness, blurry vision, headaches, and lethargy; emotional symptoms may include, but are not limited to, erratic changes in emotional state, heightened anxiety or nervousness, irritability, easily angered, and more frequent feelings of sadness; cognitive symptoms may include, but are not limited to, attention and concentration deficits, memory problems, difficulty thinking clearly, slower processing speed, chronic cognitive fatigue, and the aforementioned alexithymia (Azouvi et al., 2017; CDC, 2019; Peterson et al., 2019;). The symptoms of MHI may be transient or persistent and permanent to the point of rendering the individual incapable of returning to their preinjury status. Further, the symptoms of MHI may be subtle and not recognized as related to an injury MHI and, as such, the person may not seek medical care for days to months after dealing with

persistent symptoms (Centers for Disease Control and Prevention, 2003; Kushner, 1998; Silverberg et al., 2021). Treating symptoms of MHI, and identifying MHI as the cause of symptoms, is further complicated by the lack of neuroimaging sensitivity to detect neural disruption, and performance on neurocognitive measures (e.g., digit span, verbal fluency, etc.) may appear comparable to those without a history of MHI. Given the difficulty in assessing symptomatology severity as well as any physical indices of a MHI, clinicians may conclude that a patient is malingering and exaggerating their symptoms (Alexander, 1995; Eslinger & Damasio, 1985). However, tests that are sensitive enough to screen for cognitive deficits do exist, even in patients that are not overly symptomatic (Alexander, 1995). Tests that screen for deficits in vigilance, attention, decision making, learning and memory may be used weeks after a TBI has been incurred (e.g., IGT, and the Neuropsychology Assessment's [NEPSY] auditory attention and response set; Bechara et al., 2000; Brooks et al., 2009). Further, there may be a dissociation between the scores achieved on a test assessing for deficits in a particular cognitive ability, and how those deficits may manifest in the unique settings of everyday life (Eslinger & Damasio, 1985; Saver & Damasio, 1991).

MHI and Fatigue

Despite the difficulty in assessing for, and recognizing, MHI symptoms, chronic cognitive fatigue is one of the most commonly reported symptoms following a TBI, as well as one of the most distressing and debilitating symptoms that interfere with one's ability to return to work, academics, and social life (Lannsjö et al., 2009; Möller et al., 2017; Palm et al., 2017; Stulemeijer et al., 2006). Ponsford et al. (2012) have provided evidence that those with a history of TBI report more severe feelings of, as well as greater susceptibility to cognitive fatigue relative to those without a history of TBI. However, despite prevalent subjective reports of cognitive fatigue, it remains a difficult topic to both measure as well as define. There is yet no

standardized definition of cognitive fatigue. There is also yet no single valid and reliable measure for cognitive fatigue that addresses all of the facets of cognitive fatigue. Instead, measuring cognitive fatigue must take a multifactored approach. Measures of cognitive fatigue come in a variety of forms that may range from assessing cognitive fatigue that occurs in everyday life from as far back to a month (e.g., Mental Fatigue Scale [MFS]), as well as general feelings of fatigue in the moment (e.g., Profile of Mood States's [POMS] Vigour-Activity and Fatigue-Inertia subscales). Further, researchers have created scales to assess for cognitive fatigue's induction either by extended self-imposed effort to maintain vigilance (e.g., Current Cognitive Task Load – Modified [CCTL]), or due to the demands of the task itself (e.g., Current Cognitive Fatigue Scale – Modified [CCFS]; LaRivierre, 2021).

Cognitive fatigue does not have a single standardized definition, and definitions that have been proposed in the literature vary and may not agree with one another. For example, Ponsford et al. (2012) recognized that although fatigue alone is a universal symptom, defining fatigue can be differentiated between physiological fatigue and psychological fatigue. According to Ponsford et al. (2012), *physiological fatigue* is defined as organ failure that may be due to excessive energy consumption, depletion of essential substrates of physiological functioning (e.g., hormones and neurotransmitters), and an inability to contract muscles. They further break down physiological fatigue into both central fatigue as well as peripheral fatigue. Central fatigue may arise from impairment within the central nervous system, and peripheral fatigue may arise from malfunction in the peripheral nervous system. In contrast, *psychological fatigue* is defined as experiencing a subjective state of weariness related to reduced motivation, prolonged mental activity, or boredom that occurs in situations such as chronic stress, anxiety or depression. In a similar (but different) vein, the *coping hypothesis* as proposed by van Zomeren and van den Burg (1985) suggests that fatigue post-TBI is due to the constant effort TBI patients need to exert in

order to meet the demands of daily life and compensate for slowed processing and attentional impairments (Belmont et al., 2006). Whereas the Ponsford et al. (2012) definition describes physiological and psychological fatigue as unique and separate from one another, the definition embedded in the coping hypothesis suggests that cognitive fatigue is the result of overexertion of brain regions that are resulting in the depletion of physiological and cognitive resources (Belmont et al., 2006; van Zomeren and van den Burg, 1985). Thus, the differences in definitions found in the literature underscore the difficulty in assessing cognitive fatigue and how it may be differently considered.

For the purposes of this research, the definition of cognitive fatigue will incorporate aspects proposed from Ponsford et al. (2012), but viewed through the lens of physiological arousal. Ponsford et al. (2012) explain fatigue as the depletion of essential substrates of physiological functioning as well as impairment to the central nervous system, and EDA is dampened when the vmPFC is injured. It may be that cognitive fatigue may arise as a function of dampened physiological arousal due to injury of the vmPFC. The proposition that cognitive fatigue may arise as a result of dampened EDA is not without merit; Amodio et al. (2021 and 2022) has demonstrated preliminary evidence for this, and LaRiviere (2021) demonstrated both a functional example of this, but also has outlined criteria for measuring and inducing cognitive fatigue in an experimental setting.

Amodio et al. (2021 and 2022) demonstrated preliminary evidence that supports the notion that physiological arousal precedes and gives rise to feelings of fatigue. In the studies by Amodio et al. (2021 and 2022), 72 participants were recruited, of which 42% reported a history of TBI. Participants were asked to provide a baseline physiological recording (EDA), as well as to complete the POMS and Everyday Living Questionnaire (ELQ). Amodio et al. (2021 and 2022) found that those with a history of MHI demonstrated significantly lower EDA relative to

their No-MHI cohort, and that injury severity also predicted EDA. It was also found that injury severity as well as EDA both uniquely predicted fatigue ratings. Though preliminary, the studies by Amodio et al. (2021 and 2022) suggest that physiological arousal may precede and give rise to feelings of cognitive fatigue. A study by Whyte et al. (1995) also suggests that sufficient arousal is a requirement to prevent the induction of cognitive fatigue as well as to maintain attention and vigilance in order to perform optimally, and this is further supported when considering the Yerkes-Dodson Law (1908).

LaRiviere (2021) conducted an experiment using a modified Stroop-inhibition task in which 42 participants were recruited; 38% reported a history of TBI. Testing times were divided into morning, afternoon, or evening testing sessions. Prior to being exposed to any testing material, a baseline measurement of EDA was recorded and participants were asked to complete the MFS, which assesses for cognitive fatigue in everyday life as far back as a month. LaRiviere (2021) also demonstrated that those with a history of TBI were both physiologically underaroused and rated themselves as significantly more cognitively fatigued relative to their non-TBI cohort. Further, LaRiviere (2021) found that across four increasingly cognitively-demanding tasks, those with a history of MHI made on average more errors overall, and as tasks got progressively more complex more errors were made and took longer to respond than those with no history of MHI.

Similarly, Ziino and Ponsford (2006) designed a selective attention task that required sustained vigilance and attention for successful completion. To accomplish this, they employed a fast rate of stimulus presentation of low target item frequency, in the context of an increased memory load. The task lasted approximately 45 minutes and contained 2424 trials, of which 100 were target trials. Both before and after the task, participants were asked to complete the Visual Analog Scale for Fatigue (VAS-F) to assess for subjective ratings of cognitive fatigue before that

may have been induced from the task. They found that those with a history of TBI made significantly more errors and had slower reactions times than those without TBI. Both groups exhibited a decrease in vigor ratings and an increase in fatigue ratings after the task. Also, after the task, those with a history of TBI reported feeling more fatigued and less vigor than those without a history of TBI, though this result did not reach statistical significance.

The research reported by LaRiviere (2021) and Ziino and Ponsford (2006) are complimentary in that LaRiviere (2021) demonstrated that those with a TBI were more fatigued prior to a task and Ziino and Ponsford (2006) found this effect emerging in their data. Also, Ziino and Ponsford (2006) demonstrated that those with a history of TBI made significantly more incorrect commissions and responded more slowly across the task and LaRiviere found this effect emerging. To date, systematic and comparative studies on fatigue after MTBI are scarce, and knowledge on causal mechanisms is lacking (Stulemeijer et al., 2006).

Of particular note, the intensity of cognitive fatigue in those with a history of TBI is not the sole impairing factor, but also the chronicity and duration of fatigue. Ouellet and Morin (2006) conducted a study to investigate the frequency and other characteristics of fatigue following TBI. To study this, they recruited 452 participants, all with a history of TBI, and administered a series of questionnaires designed to assess for injury severity, as well as fatigue and its associated characteristics (e.g., duration, onset, intensity, etc.). Ouellet and Morin (2006) found that 2.5% of participants reported never or rarely feeling fatigued during a typical week, whereas 63.9% reported feeling fatigued nearly every day or every day of the week. They also found that as the day went on, the severity of the fatigue increased as well (Ouellet and Morin, 2006). The study by Ouellet and Morin (2006) shows that daily variance of fatigue is difficult to account for as not all individuals with a history of TBI will experience fatigue, and those that do report it occurring frequently (everyday or almost everyday) may also exhibit different levels of

fatigue throughout the day, where fatigue worsens as the day goes on. LaRiviere (2021) found similar results where time of day impacted self-reports of pre- and post-task fatigue. It was shown that fatigue reported in the morning was significantly lower than in the evening. Interestingly, it was also shown that in the morning, pre- and post-task fatigue did not differ from one another, but in the evening pre-task fatigue was significantly lower than post-task fatigue (LaRiviere, 2021). The studies by Ouellet and Morin (2006) as well as LaRiviere (2021) together suggest that the induction of cognitive fatigue may be buffered or reduced soon after rest when physiological and cognitive resources are most plentiful. The studies also demonstrate that there may also be an aspect of latent or delayed induction of cognitive fatigue that is not often discussed in the literature. Specifically, fatigue may not be easily induced immediately after a task, and it may take a series of tasks for the effects of fatigue to be observed and or reported, not unlike attending a series of university courses (Jonasson et al., 2018; LaRiviere, 2021; Ouellete and Moring, 2006).

Vigilance and Attention Deficits: Consequences of Cognitive Fatigue

Cognitive fatigue is not only one of the most debilitating and distressing reported symptoms following an MHI, it may also amplify the already existing deficits reported in those with a TBI, such as vigilance and attention (Azouvi et al., 2017; CDC, 2019; Sinclair et al., 2013). Disruption in sleep quality has been shown to result in attentional deficits in healthy individuals, and frontal regions in the brain that are largely involved in attentional processes are disproportionately affected by sleep loss and fatigue (Balkin et al., 2008; Thomas et al., 2000). In those with a history of TBI where injury is most likely to occur in frontal regions as well (e.g., vmPFC; Bechara et al., 1988; Bigler, 2008; Morales et al., 2007), it may be the case that both chronic cognitive fatigue and injury to frontal areas compound to further amplify attentional deficits.

Bloomfield et al. (2010) investigated whether fatigue and TBI may interact to compound to worsen attentional deficits in those with a history of TBI who were either good sleepers or poor sleepers. In the study, 44 participants with a history of TBI were recruited of which 21were categorized as good sleepers and 23 were categorized as poor sleepers. Participants were given a battery of measures that assessed for mood, cognition, sleep quality, and attention. It was found that those with a history of TBI that were also poor sleepers exhibited significantly more attentional deficits than those with a history of TBI that were good sleepers.

Sinclair et al. (2013) have also demonstrated evidence that fatigue contributes to attentional deficits in those with a history TBI. The study by Sinclair et al. (2013) sought to investigate how primary factors (i.e., TBI status and neuropathology) and secondary factors (i.e., fatigue, depressed mood, and sleep disturbances) may contribute to attentional deficits. For their study, Sinclair et al. (2013) recruited 40 participants, of which 20 had a history of TBI; participants were given a series of measures that assessed for fatigue, sleep quality, and daytime sleepiness. Additionally, the study conducted by Sinclair et al. (2013) had a specific interest in utilizing the psychomotor vigilance task to assess for attentional deficits following TBI. The psychomotor vigilance task is a task that is often used in sleep research; it is a sustained attention task that is sensitive to the effects of sleep loss and disturbance (Dinges et al., 1997; Doran et al., 2001; Jung et al., 2011; Van Dongen et al., 2003). The psychomotor vigilance task involves a 10-minute trial where participants are asked to respond to randomly presented stimulus as quickly as possible with their non-dominant hand (Sinclair et al., 2013). What they found was those with a history of TBI that also reported fatigue and/or sleep disruptions had significantly impaired attention outcomes when compared to controls. These attentional deficits included significantly delayed mean reaction time on the psychomotor vigilance task, an increased number in lapses in attention, and more variability in responses. When participants with a history of TBI were

divided by whether or not they exhibited attentional deficits, it was found that those with a history of TBI who also did not exhibit attention deficits reported significantly lower fatigue than those with a history of TBI who exhibited attentional deficits. Sinclair et al. (2013) also found that within the TBI group that though daytime sleepiness and sleep quality were associated with inattention, fatigue had a more global association with inattention.

The studies by Bloomfield et al. (2010) and Sinclair et al. (2013) together suggest that those with a history of TBI are likely doubly disadvantaged in terms of being able to sustain attention and vigilance for long periods of time; this is due to the attentional deficit consequences that come with incurring a TBI and its associated neuropathology, but also due to being more prone to experiencing chronic cognitive fatigue. Those with a history of TBI that were also poor sleepers exhibited significantly more attentional deficits than those with a history of TBI that were good sleepers, and participants with a TBI that were identified as not having attentional deficits reported significantly lower fatigue than those that did exhibit attentional deficits (Bloomfield et al., 2010; Sinclair et al., 2013). Additionally, though Bloomfield et al. (2010) demonstrated that TBI status when coupled with poor sleep quality leads to more attentional deficits, the study by Sinclair et al. (2013) suggests that fatigue itself has a more direct and global effect on attentional outcomes. The consequences of TBI and its associated neuropathology that affect attentional processes and experiencing chronic cognitive fatigue together seem to compound to negatively affect attentional deficits seen in those with a history of TBI.

Understanding how attentional processes are differentially affected by factors such as TBI status as well as fatigue are of importance as it may inform both clinicians as well as researchers how to further understand attentional performance outcomes and what contributes to them. Understanding how attention is affected is especially important due to the vast influence

attentional functions have on other cognitive functions that are employed in everyday life. According to Lezak et al. (2012; Sivan and Benton, 1999), cognitive functions are functional properties that are not directly observable and are instead inferred from behavior. Cognitive functions may be broken down into four categories: (1) *receptive functions* which involves the ability to select, acquire, classify, and integrate information; (2) *memory and learning* which involve the ability to store and retrieve information; (3) *thinking* which involves the mental organization and reorganization of information; and (4) *expressive functions* which involve communicating and acting upon information.

How attention may influence cognitive functions is that attention is separate from cognitive functions and is instead considered a mental activity variable (Lezak et al., 2012). Mental activity variables are behavioral characteristics that are intimately involved in the efficiency of mental processes and cognitive operations, however, do not have a unique behavioral end product (Parasuraman, 1998; Gazzaniga, 1987). When considering cognitive functions, attentional functions precede cognitive functions and are said to maintain and underlie the activity of cognitive functions (Lezak et al., 2012). Because attention precedes cognitive functions, and cognitive capabilities are inferred from behavior, performance outcomes that assess for cognitive impairments can be influenced from impairments in attention. This is also true in the clinical setting when neuropsychological testing is employed; for example, a patient that is exhibiting poor performance on a test assessing for abstract reasoning may not be due to impairments from conceptual thinking, but rather due to impaired attentional functions which itself affects thinking (Lezak et al., 2012; Sivan and Benton, 1999). When attentional deficits are present, it is possible for all of the cognitive functions to be intact as well as the capability for high-level performance, yet overall cognitive productivity suffers (Lezak et al., 2012).

When fatigue is considered, the relationship between attention, cognitive functions, and performance outcomes is further complicated. The studies by Bloomfield et al. (2010) and Sinclair et al. (2013) demonstrate evidence that fatigue itself has a direct and global effect on attentional functions, and Lezak et al. (2012; Landrø et al., 2001; Zimmermann and Leclercq, 2002) also notes that fatigue may also reduce attentional capabilities; so it may be that fatigue itself precedes attention. If true, this would mean that fatigue impairs attentional functions, which in turn impairs cognitive functions, and the end result is observed in impaired performance and decision making outcomes.

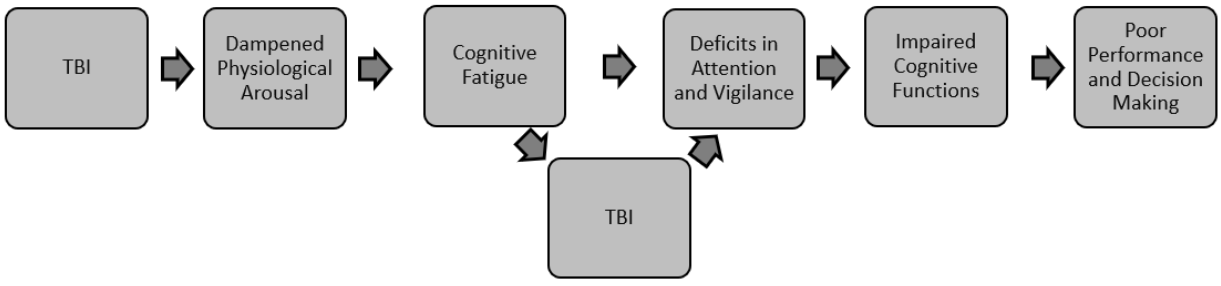
Proposed Model of Cognitive Fatigue Manifestation and Outcomes in TBI

The research discussed thus far together suggests a process through which cognitive fatigue manifests in those with a history of TBI, how cognitive fatigue affects attentional and cognitive functions, and how these functions go on to affect performance outcomes. The vmPFC regulates physiological and emotional arousal and has been shown to be especially susceptible to injury due to being situated in the frontal areas of the skull (i.e., above the orbits of the eyes) and vulnerable to absorbing the majority of the impact due to the bony protrusions it is exposed to. Those with a history of TBI have repeatedly shown to be physiologically and emotionally underaroused (i.e., EDA; Baker and Good, 2014; Bechara et al., 1988; Bigler, 2008; Damasio et al., 1991; Morales et al., 2007; Robb and Good, 2011, 2012, and 2019; van Noordt et al., 2017). Those with a history of TBI have been shown to be more cognitively fatigued relative to their No-MHI cohort prior to any cognitively demanding tasks (i.e., at baseline; LaRiviere, 2021). Prior research has shown that dampened physiological arousal precedes and gives rise to feelings of cognitive fatigue, where more severe injuries lead to more dampened physiological arousal and worsened fatigue outcomes (Amodio et al., 2021 and 2022). The neuropathology that follows TBI in frontal regions that are most at risk for injury and are largely involved in

attentional processes itself leads to attentional deficits, and these attentional deficits are disproportionately affected by the onset of fatigue (Balkin et al., 2008; Thomas et al., 2000). Because of this, the global effect that fatigue has on attentional functions when coupled with the neuropathology in frontal regions followed by TBI compound together to further negatively affect attentional deficits in those with a history of TBI (Bloomfield et al., 2010; Sinclair et al., 2013). Attentional faculties compromised by chronic cognitive fatigue then go on to impair cognitive functions as it is attentional functions that maintain and underlie the activity of cognitive functions (Lezak et al., 2012; Sivan and Benton, 1999). The behavioral end product that is then observed from poor cognitive function is poor performance and decision making on cognitively demanding tasks as well as in everyday life due to a combination of all subsequent factors (i.e., moral decision making task and IGT; Bechara et al., 2000; Lezak et al., 2012; Robb and Good 2011, 2012, 2019; Sivan and Benton, 1999; van Noordt et al., 2017; See Figure 1 for a schematic representation of the proposed model).

Figure 1

Schematic Representation of Proposed Model of Cognitive Fatigue Manifestation and Outcomes in TBI



Overcoming Fatigue

The proposed model not only provides insight into how cognitive fatigue may manifest and later go on to affect performance outcomes in those with a TBI, it may also offer insight into the point at which an intervention to alleviate fatigue may be most optimal. An intervention that allows for the replenishing and rejuvenation of physiological and cognitive resources may provide the best opportunity to alleviate cognitive fatigue as it has been shown that physiological and cognitive resources in those with a TBI deplete faster which is reflected in EDA (Robb, 2020). Unfortunately, not only are there scarcities in studies examining how cognitive fatigue may be elicited but there are also scarcities in studies investigating how to alleviate cognitive fatigue once it has been induced (Blasche et al., 2018; Prince & Bruhns, 2017; Stulemeijer et al., 2006). To date, there has yet to be research into whether disengagement from a task may ameliorate cognitive fatigue outcomes in those with a history of MHI. However, there has been studies assessing the amelioration of cognitive fatigue in healthy university students while engaging in cognitively demanding tasks. Sustained effort on cognitive tasks, not unlike attending and participating in university courses, has been shown to be a determinant of cognitive fatigue due to exhausting resources (Jonasson et al., 2018; Möller et al., 2017; Smit et al., 2005). Blasche et al. (2017) investigated ways to interrupt cognitive fatigue induction in healthy university students during their school day. Participating in university courses was the cognitively demanding task, such that attending and participating in university courses requires sustained attention, recognizing and/or recalling knowledge, and therefore deemed to be taxing on cognitive resources (Anderson & Krathwohl, 2001; Risko et al., 2012; Young et al., 2009). They recruited 66 university students that were attending 2 two-hour lectures and assigned them to one of four groups: a no break, unstructured break, physical activity break, and a relaxation break. In the unstructured break condition, participants were instructed that for 6-minutes they

may do as they like so long as they remained seated at their desks; in the exercise break condition, participants were instructed to perform 3-minutes of aerobic exercise and 3-minutes of stretching; in the relaxation break condition, participants were instructed to participate in 6-minutes of a body scan exercise. Fatigue ratings were collected three times throughout the study period; once immediately before the break, once immediately after the break, and once 20 minutes after the break. It was found that all breaks resulted in lower endorsements of feeling fatigued, as well as higher endorsements of feeling vigor when compared to those who did not receive a break. Further, an unstructured break condition resulted in the most reduction in fatigue reports. It was concluded that an unstructured break condition may be allowing the best opportunity for individuals to replenish and rejuvenate physiological and cognitive resources that may have been drained over the course of a cognitively demanding day of university courses.

The unstructured break in Blasche et al.'s (2017) study may have offered the most relief from fatigue however it is difficult to replicate in an experimental setting due to allowing participants to do as they please. Participants in the unstructured break may have engaged in a variety of activities that are difficult to account for. Some may have been seated with a partner/friend, some may have used their phone to listen to music or watch videos, others may have even taken a nap. All of these different activities may have differently affected self-reported fatigue. However, despite the variety of activities that could have been engaged in during an unstructured break, it does offer insight that a break that does not require an individual to exert effort offers the greatest relief from fatigue. Blasche et al.'s (2017) study may be demonstrating that a break where an individual is engaged in a recreational activity that does not involve being engaged in effortful cognitive or physical exertion (e.g., following directions for aerobic or body-scanning exercises) may offer the most opportunity to replenish and rejuvenate physiological and cognitive resources resulting in the most relief from fatigue. Additionally, the studies by Ouellete

and Morin (2006) as well as LaRiviere (2021) demonstrate that fatigue is at its lowest in the morning which would be soonest after rest relative to other times of day. LaRiviere (2021) also demonstrates evidence that performing a cognitively demanding task soon after rest may also offer the opportunity to replenish and rejuvenate physiological and cognitive resources; performing a task when both physiological and cognitive resources are plentiful may then result in better performance on a task relative to those who have depleted their physiological and cognitive resources without the opportunity for rest. The effects of a disengagement may carry-over the duration of a task.

To investigate this in an experimental setting, a controlled interval where participants are asked to participate in the same disengagement activity may be ideal. Specifically, a disengagement activity that could keep the attention of participants while also not being demanding of physiological and cognitive resources to maintain attention of participants (i.e., not engaging in an activity that could induce boredom or drain physiological or cognitive resources). Studies conducted by Richardson et al. (2018, 2020) suggest that listening to media with a story narrative may be an ideal disengagement activity to replenish and rejuvenate cognitive resources. These authors found that story narratives presented in both an auditory and video format are both cognitively and emotionally engaging at a physiological level. Richardson et al. (2020) recruited 102 participants that were randomly selected to be presented emotionally-charged scenes from either an audiobook that participants would listen to, or a television series that participants would watch. Physiological measures included EDA, HR, and body temperature recordings. Self-reported engagement was collected by adapting the narrative engagement scale developed by Busselle and Bilandzic (2009). Richardson et al. (2020) noted that participants' self-reported greater engagement and increase in physiological indices during the audiobook condition suggest that greater effortful exertion was required to engage in the participation of the audiobook

consistent with other study conclusions (Andreassi, 2010; IJzerman et al., 2015; Potter & Bolls, 2012; Setz et al., 2009; Sukalla et al., 2015). Richardson et al.'s (2018, 2020) studies also show that a timeframe of 2-to-5 minutes may be an optimal time frame at which participants are most susceptible to replenishing physiological and cognitive resources before boredom may set in or before participants are required to self-initiate effort to continue engaging.

Overall, the studies by Blasche et al. (2017) and Richardson et al. (2018, 2020) together indicate that a 2-to-5-minute filled interval break during which an individual is engaged in a recreational activity (e.g., watching a video with a story narrative) may offer the most opportunity to replenish and rejuvenate physiological and cognitive resources and therefore provide optimal relief from fatigue. Breaks that are longer than 5 minutes and involve effortful cognitive, physical, or physiological exertion (e.g., aerobic or body-scanning exercises; attending to an audiobook) may not offer optimal relief from fatigue, and may even work against the goals of a disengagement.

Predictions

Together these studies demonstrate that those living with a history of MHI are emotionally, and physiologically, underaroused and experience greater costs in terms of being cognitively fatigued relative to their No-MHI cohort. Further, dampened EDA in TBI may be the mechanism through which chronic cognitive fatigue manifests which then goes on to affect attentional functions, cognitive functions, and ultimately performance outcomes. Having the opportunity to disengage from a task may allow for the replenishment and rejuvenation of physiological and cognitive resources resulting in improved performance and lessened fatigue. This research will aim to examine these relationships through three research questions. The first is, will individuals with a history of MHI exhibit physiological and subjective underarousal as has been previously observed? Second, will those with a MHI perform worse on cognitively

demanding tasks relative to their non-head-injured cohort? Finally, will a short break/task-disengagement opportunity ameliorate any potential task performance decrements and fatigue increments in those with, and without, a history of MHI?

Hypotheses:

I. Individuals reporting a history of MHI will present with both subjective, and objective, evidence of physiological underarousal relative to their No-MHI cohort.

II. Those reporting a history of MHI will endorse higher baseline and post-test levels of cognitive fatigue after engaging in a cognitively demanding task as compared to their No-MHI cohort.

III. Those reporting a history of MHI will exhibit greater challenges with a cognitively demanding task as assessed through their performance on a sustained vigilance task evidenced by:

    i. less accuracy;

    ii. increased inconsistency of performance with increased duration of testing;

    iii. slowed target item response times.

IV. Finally, those reporting a history of MHI will be particularly advantaged by an opportunity for disengagement and demonstrate improved performance on a sustained vigilance task relative to their No-MHI cohort.

Methods

Participants

Following approval from the Brock University Research Ethics Board (#20-361), Brock University students were recruited to participate in this research study. Participants (N = 109) were recruited at Brock University through on campus posters, online advertising, and Brock University's research database (SONA; See Appendix C)[1] to participate individually in a single online session using the Qualtrics remote testing program platform. Through SONA, participants selected from a range of timeslots and were then provided with the study link as well as a unique alphanumeric code. Upon accessing the site, each participant was provided a consent form on which they could provide their consent 'digitally' to participate; they were advised that they could withdraw from the study at any time without consequence (see Appendix C). Participants were asked to conduct the study in a quiet and comfortable environment while also sitting up-right and invited to use a desktop computer that had a stable and reliable internet connection, and that allowed for playing audio files (e.g., Brock University library). Participants were made aware that at any point they could ask questions (e.g., via email or phone) as well as withdraw from the study without penalty. Given the online nature of the study, participants were able to complete the study at any time of day but with the condition that it must be completed in one sitting. The study description identified the intention of investigating the effects of endurance and sustained vigilance on cognitive performance, but was silent on its interest in MHI so as not to recruit participants on the basis of head injury status in order to avoid the induction of 'diagnostic threat' and demand characteristics (Nichols & Maner, 2008; Suhr & Gunstad, 2002;

[1] Originally, 139 participants began the study, and 118 participants completed the study. Of the 118 participants that completed the study, 9 outliers were identified on the Go/No-Go Task, and an additional single outlier was identified on the MR Task. Outliers were removed on the basis of engagement with the task. The demographic data and the statistical analyses were generated with the remaining 109 participants, save for statistical analyses pertaining to the MR Task which included 108 participants.

2005). Upon completion of the study, participants were debriefed and made aware of the interest of TBI in the study.

Participants' age ranged between 17 - 46 with a mean age of 21.5 (*Standard Deviations* [*SD*] = 5.4) with 86.2% identifying as female. Of these participants, 35 reported a history of MHI (32.1% overall). Demographic data organized by MHI status is presented in Table 1. Participants with a history of MHI reported that falling was the most common cause for incurring the injury with the front of the head being the most often injured; 15 reported experiencing symptoms longer than 20 mins., 5 reported having experienced a loss of consciousness, 11 reported requiring academic/employment accommodations as a result of the injury, 19 received medical treatment, and 13 reported a history of more than 1 MHI. Descriptive statistics for MHI etiology, injury location, and injury severity characteristics are presented in Tables 2, 3, and 4, respectively.

Table 1

Demographic Data for MHI and No-MHI Groups

	No-MHI	MHI
n (%)	74 (67.9%)	35 (32.1%)
Mean Age (*SD)*	21.58 (*5.36*)	21.34 (*5.55*)
Age Range	18 – 42	17 - 46
Sex (%)		
Female	65 (87.8%)	29 (82.9%)
Male	9 (12.2%)	6 (17.1%)

Table 2

Descriptive Statistics of MHI Etiology (n =35)

MHI Etiology	n	% of Total
Sports-Related Injury	13	37.1%
Falling	12	34.3%
Motor Vehicle Accident	3	8.6%
Fight/Assault	2	5.7%
Other	5	14.3%

Note: The category 'Other' includes rough and tumble play (e.g., hitting head in schoolyard during play), striking head in pool, and fainting/dizziness.

Table 3

Location of Head Injury (n = 35)

Injury Location	N	% of Total
Front of Head	12	34.3%
Back of Head	7	20%
Top of Head	3	8.6%
Left Side of Head	2	5.7%
Right Side of Head	1	2.9%
Multiple Areas	4	11.4%
I can't remember	4	11.4%
Other	2	5.7%

Note: The category ‘Other’ includes injuries that were described as neck and or whiplash.

Table 4

Descriptive Statistics of Injury Severity Characteristics (n = 35)

Injury Severity Characteristics	n	% of Total
Symptoms Lasting Longer Than 20 Minutes	15	42.9%
Loss of Consciousness (LOC)	5	14.3%
LOC Duration		
Less than 5 mins.	5	14.3%
Memory Loss of Events		
Prior to injury	2	5.7%
After injury	8	22.9%
Received Academic/Employment Accommodations as a Result of Injury	11	31.4%
Received Medical Treatment	19	54.3%
Visit to Emergency Department	11	31.4%
Visit to Health Professional (e.g., family doctor, or walk-in clinic)	14	40%
Received Stitches	1	2.9%
Received Brain Imaging	4	11.4%
Required Overnight Stay At a Medical Care Facility		
1 Night	0	0%
2 Nights	1	2.9%
Additional Medical Follow-Up (e.g., Medical Monitoring)	10	28.6%
More Than 1 Head Injury	13	37.1%

Participants were assigned to one of four groups[2]. The Disengagement condition had two levels such that participants were randomly assigned to either a no-disengagement or disengagement condition. Participants were also categorized as either reporting a history of MHI or none. MHI status was self-identified by the participant answering 'yes' to either "have you ever hit your head with a force sufficient enough to alter your state of consciousness?" or "have you ever sustained a concussion?" on the ELQ (Good, 2008). Attaining head injury status through self-report on either of the previously mentioned questions aligns with the definition of TBI set forth by the American Congress of Rehabilitation Medicine (ACRM; Kay et al., 1993; Silverberg et al., 2021). Self-report measures of MHI have been shown to be a more reliable, and easier, way to identify TBI than relying medical records and thus has been more widely adopted within the field (e.g., O'Jile et al., 2004; Ponsford et al., 2014). As MHI is subject-based, this research involves a quasi-experimental design. Participant and group information by MHI status is presented in Table 5.

Table 5

Participants in Simplified Levels of Disengagement Conditions by MHI Status

Condition	No-MHI	MHI
No Disengagement	40	13
Yes Disengagement	34	22

[2] The study also included a Cue or No Cue condition that was not a part of the dissertation (but was a part of a larger study). The disengagement condition included a no-disengagement condition, as well as a 2-min., and 4-min. disengagement intervention; differences between the cue and disengagement groups were analyzed (e.g., percentage correct, etc.) and no differences were found, perhaps due to issues of being underpowered. For the purposes of this thesis the 2-min. and 4-min. disengagement conditions have been combined.

Materials

The tasks and all self-report measures were hosted online through the Qualtrics website. All pen-and-paper self-report measures were converted to a digital format. Materials consisted of a physiological arousal measurement involving heart rate, measures of cognitive fatigue (the Mental Fatigue Scale, Current Cognitive Task Load, the Current Cognitive Fatigue Scale), cognitively demanding tasks (a sustained vigilance Go/No-Go Task, a Mental Rotation Task), a disengagement intervention (consisting of a short, animated nonverbal video), and a selection of questionnaires regarding subject health status and mood (the Profile of Mood States [POMS-2], and the Everyday Living Questionnaire [ELQ]).

Physiological Measures

Heart Rate. Heart rate (HR) data was collected as a measure of physiological arousal. Participants were asked to self-assess their HR and provide three measurements with two-minute rest intervals by entering their results into the survey platform. Participants were advised, and provided instructions on how, to use either a smart device (e.g., Fitbit, Apple watch) or manually derive an HR via a radial artery assessment. The three measures were then averaged.

Due to the online nature of the study, collecting EDA data was not an option. It has been shown that collecting HR data is comparable and also reflects EDA data (Baker & Good, 2010; Goulding et al., 2015; Vergales et al., 2014). Further, lower HR has been argued to be a potential biomarker for those with a history of TBI (Lee et al., 2021).

Disengagement Intervention

Animated Short Film. The Disengagement Intervention consisted of an animated video titled *Coin Operated* (Arioli, 2018). Two versions of the video were included in the study, a 2-minute version and a 4-minute version. Half of the participants were randomly assigned to watch an animated short film about a young boy who opened up a lemonade stand in order to earn

enough money to ride a coin-operated rocket ride. This video served as a filled interval disengagement and allowed for a degree of control over what the participants would be doing during the break from the vigilance task. A video with a story narrative was chosen as it has been shown that story narratives are engaging and may keep the attention of participants while also affording an opportunity to replenish and rejuvenate physiological and cognitive resources (Richardson et al., 2018; Sukalla et al., 2015).

Performance Measures

Sustained Vigilance Task. A Go/No-Go Task was constructed in Qualtrics and was a modified version of the NEPSY's auditory attention and response set task of vigilance (Korman et al., 1998). The task presented participants with a colour wheel containing the colours red, blue, yellow, orange, black, and green (see Appendix C). Participants were auditorily-presented with words at 1.3-second intervals that they were required to constantly monitor and respond to by selecting one of the colour wheel segments only when 'Target Colour' words (i.e., red, blue or yellow) were presented ('Go' trials). Target Colour words each occurred 23 times per phase (and there were two phases). Intermingled amongst these 69 words were 256 distractor words ('No-Go' trials) – 69 'Nontarget Colour words' (orange, black, and green; each presented 23 times per phase) and 187 'Nontarget NonColour words' (all concrete, each presented 6 to 23 times throughout). The task consisted of two phases, each with 325 trials, for a total of 650 trials for the whole task. Similar to the NEPSY-version of the task, in order to encourage sustained vigilance, participants were asked to follow an explicit rule throughout duration of the task: "when blue is said, please select red; when red is said, please select blue; when yellow is said, please select yellow; please do not make a selection if any other word is said".

Participants were considered to have made a correct commission on the task if they correctly responded to a *target colour* word (i.e., 'Go' trial) with the explicit rule in mind (e.g.,

hearing red and selecting blue). All other responses were scored as errors categorized by the following: (A) ‘Go’ trial errors - (i) an inhibition error = responding to a target colour word but not following the ‘rule’, e.g., selecting red when hearing red); (ii) an incorrect commission error = responding to a target colour word with a noncorresponding colour (e.g., hearing red and selecting orange); (iii) an omission error = not responding at all to a target colour word (‘go trial’); (B) No-Go trial errors - (i) a non-target colour correct commission error = responding to a non-target colour word with its corresponding colour (e.g., hearing black and selecting black); (iii) a non-target colour incorrect commission error = responding to a non-target colour word but not with its corresponding colour (e.g., hearing black and selecting orange); (iii) a non-target other commission error = responding to any noncolour (e.g., hearing mountain and selecting red). Further, a correct (‘Go’ trial) on-time, or late, response was possible; a participant was considered to have responded ‘on-time’ if they responded within the 1.3 second window of the trial presentation; a participant was considered to heferencesave responded late, but correctly, if the correct response was recorded on the trial immediately following the target ‘Go’ trial. On-time or late responses were not considered for any of the No-Go trials.

Mental Rotation Task. The mental rotation (MR) task is a task that examines participant’s ability for spatial manipulation (Peters et al., 1995). The task consists of 24 trials. On each trial, participants are presented with a target figure made up of blocks arranged in a particular arrangement, and a multiple-choice selection of four other blocked figures. Participants are asked to select the two choices that, if ‘rotated’ correctly, match the target figure. Each correct response is allotted a count of 0.5, for a total of 24 points maximum for the task. This task was selected because of its visual nature and its cognitively-demanding nature, especially in those with a history of TBI (Livingstone & Skelton, 2007; Rizzo et al., 2002; Skelton et al., 2006).

Self-Report Questionnaires

Mental Fatigue Scale (modified). A modified version of the Mental Fatigue Scale (MFS; Johansson et al., 2010) consisting of a 10-item questionnaire that assesses for mental/cognitive fatigue by having participants rate statements on a 9-point Likert-scale (Johansson & Ronnback, 2014) was used. Cronbach alpha coefficient for the MFS has been shown to be 0.944 (Johansson et al., 2010; Johansson, et al., 2018).

Current Cognitive Task Load (modified). A modified version of the Current Cognitive Task Load (CCTL) scale derived from NASA's Task Load Index (NASA TLX; Hart & Staveland, 1998) was used and consists of a 6-item questionnaire that assesses for sustained attention and cognitive effort. The scale was modified so that it only included pertaining to cognitive exertion and participants were to rate these statements based on their subjective experience of cognitive effort using a 10-point Likert that ranges from 0 (very low) to 10 (very high). In addition, a question regarding participants' effort strategy (derived from Ackerman et al., 2010) was added at the end of the CCTL. Specifically, it asks whether participants maintained their effort, increased their effort, decreased their effort, or first increased and then decreased effort in order to conserve energy.

Current Cognitive Fatigue Scale (modified). The Current Cognitive Fatigue Scale (CCFS) is a 15-item questionnaire that assesses acute levels of fatigue following a task and asks participants to rate statements on a scale from 1 to 5 in terms of how much a statement applies to them in the moment, ranging from "does not apply at all" to "applies completely". The CCFS is derived from the 20-item Fatigue Scale for Motor and Cognitive Functions (FSMCF) which was designed to assess for extreme fatigue based on motor and cognitive symptoms (Penner et al., 2009) and includes only the 15 statements pertaining to cognitive symptoms.

Behavioral Inhibition Scale and Behavioral Activation Scale (BIS-BAS). The Behavioral Inhibition Scale (BIS) and the Behavioral Activation Scale (BAS) is a 24-item questionnaire that assesses for individual differences in personality qualities as a function of impulsiveness and risk-taking. Specifically, it contrasts two physiological states, one of which focusses on aversive motivations (BIS) and another that focusses on appetitive/approach motivations (BAS; Carver & White, 1994). The BIS-BAS involves participants rating statements on a 4-point Likert scale as function of how much the statement describes their behaviour from 1 (very true) to 4 (very false). Reliabilities (Cronbach's alpha) range from $\alpha = .66$ to $\alpha = .76$ (Carver & White, 1994).

Profile of Mood States – 2. The second edition of the long version of the Profile of Mood States (POMS; Heuchert & McNair, 2012) was used in this study. The POMS-2 is a protected/copyrighted 65-item questionnaire that assesses one's mood state according to single-word descriptions that are rated on a 5-point Likert scale ranging from 1 (not at all) to 5 (extremely). The POMS-2 contains two subscales that are of particular interest to this study: (i) the Fatigue-Inertia subscale that assesses for tiredness and lack of engagement, and provides insight into self-endorsed dampened arousal and low energy; and (ii) the Vigour-Activity subscale that assesses for ebullience and provides insight into self-endorsed heightened arousal (Heuchert & McNair, 2012). Participants were asked to respond to the POMS-2 descriptions according their currently experienced mood state 'in the moment'.

Everyday Living Questionnaire. The Everyday Living Questionnaire (ELQ; Good, 2008) is a demographic and health questionnaire that is used to collect information such as the participants' age, sex, education, medical history, leisure activities, as well as recreational and athletic involvements. The ELQ includes statements that assess for self-reported head injury status and is the source of this subject-based factor in the study. Based on criteria used to define

MHI (e.g., Kay et al., 1993; Belanger et al., 2017), participants were asked: “Have you ever sustained an injury to your head with a force sufficient to alter your consciousness (e.g., confusion, dizziness, vomiting, seeing stars, or loss of consciousness)?” and “have you ever sustained a concussion?”. Participants who answered “yes” to either of these questions were considered to have experienced a MHI. The Postconcussive Symptoms Checklist is also embedded in the ELQ and provides the subscales for PCS Fatigue (total, intensity, duration and frequency) which is also examined in this study.

Procedure

Upon beginning the study, the consent form was both visually and auditorily presented to participants and with consent, the testing session began with instructions on how to take the baseline physiological measure of HR. They were then asked to complete the MFS which permitted a baseline measure of mental fatigue.

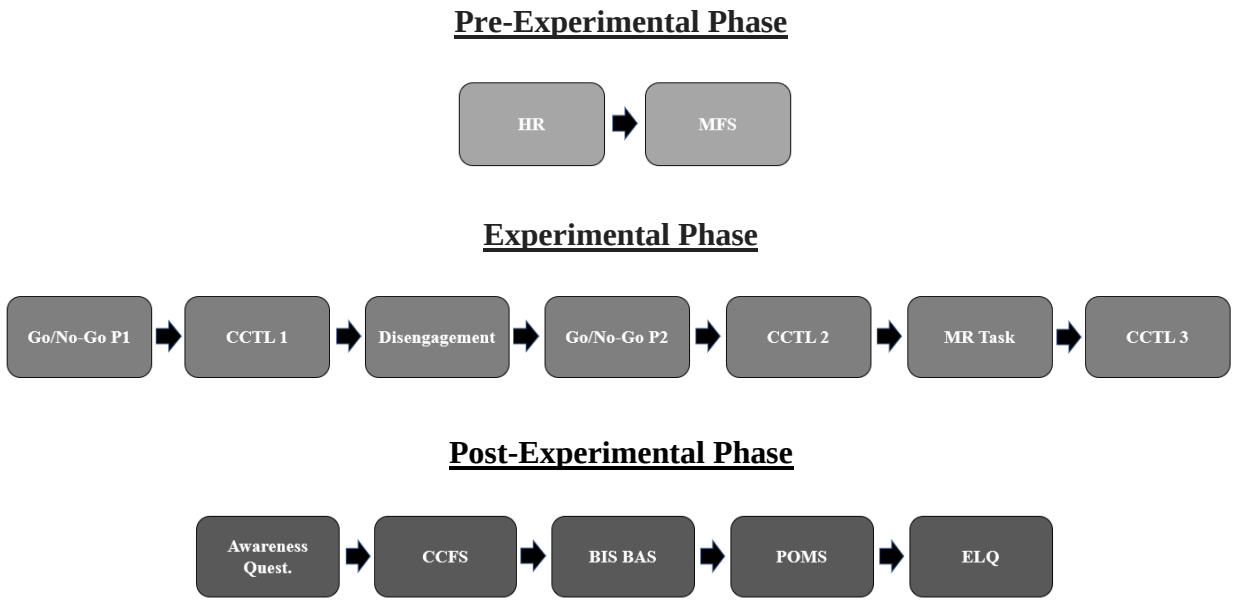
Participants next entered the experimental portion of the study and were introduced to an orientation and practice exposure to the Go/No-Go Task. Participants were advised to not stop the task once they had started, and to progress through the task and other subsequent parts as quickly as possible.

Upon completion of Phase one of the Go/No-Go Task, participants were asked to complete the first of three CCTLs. Depending on the condition, participants were then exposed to the disengagement video, or not. Following this, participants were shown a screen for 10-seconds instructing them that the page will move forward automatically, and that they would be presented the same task as previously (Phase two) and, upon its completion, asked to respond to a second CCTL. Participants were next introduced to a tutorial of the MR task followed by the 24 trials and a third opportunity to complete the CCTL. They were then given the final cognitive fatigue scale (CCFS) as well as the remaining self-report questionnaires: the BIS-BAS, POMS-2,

and the ELQ. At the end of the testing session, participants were presented with the debrief form in both visual and auditory formats.

Figure 2

Schematic Representation of the Experimental Procedure



Statistical Analyses

The statistical package for the social sciences (SPSS; version 28.0.1) was used to conduct all analyses. Given the directional hypotheses, one-tailed independent samples *t*-tests were used to examine differences in HR and MFS Scores. A one-tailed correlation and a linear regression were conducted to examine the relationship between injury severity and HR. Various Analysis of Variance (ANOVA) were conducted to examine differences between MHI groups and Disengagement conditions as a function of fatigue (i.e., postconcussive fatigue total and subscales, CCTL, MFS, CCFS) and cognitive performance measures (Go/No-Go Task, MR Task) across time (as appropriate). To analyze Go/No-Go Task performance across time, task

phases (before and after Disengagement) were separately divided into the three parts, or thirds. Follow-up pairwise comparisons using the Bonferroni correction, *t*-tests, and simple effects ANOVAs were conducted when appropriate. All *t*-test statistics were conducted as one-tailed *t*-tests. CCTL total scores were weighted so that the possible maximum scores were 10, and POMS scores were weighted so that maximum possible scores were 4. The MFS and CCFS scores were converted to *z*-scores to compare pre- and post-experimental fatigue levels. Difference scores were used for CCTL measure comparisons comparing CCTL shifts in performance after having an opportunity for disengagement, or not, with the Go/No-Go task and the MR task as compared to initial reported CCTL 1 scores (at the mid-point of the Go/No-Go task). Similarly, difference scores were examined to review accuracy of cognitive performance on the Go/No-Go and MR tasks as a function of having an opportunity for disengagement, or not.

Additionally, although not a part of the original study, this dataset was compared to past datasets from within the Neuropsychology Cognitive Research Lab (NCR Lab) that used similar measures collected prior to the onset of the lockdowns imposed by the COVID-19 pandemic (see LaRiviere 2021 and Robb 2020 for demographics information). ANOVAs were conducted to review differences between Pre-COVID and Mid-COVID groups as a function of MHI Status with respect to physiological measures as well as fatigue measures (HR, and MFS). Statistical analyses for COVID Period are provided in the Appendix (see Appendix A). All assumptions were met unless otherwise stated. Statistical significance was set at $p < .05$, although p values $< .10$ are discussed, and p values $> .10$ are available in the Appendix (see Appendix B). Tabled results of the inferential analyses are provided in the Appendix (see Appendix B).

Results

Hypothesis 1: Individuals reporting a history of MHI will present with both subjective, and objective, evidence of physiological underarousal relative to their No-MHI cohort.

A *t*-test comparing HR between the two MHI groups was conducted. No differences were found between individuals who reported experiencing a previous MHI (M = 71.52, SE = 2.08) and those who did not (M = 73.84, SE = 1.67) in terms of average HR (t [107] = .82, p = .21, CI [-3.28, 7.91]; Figure 3).

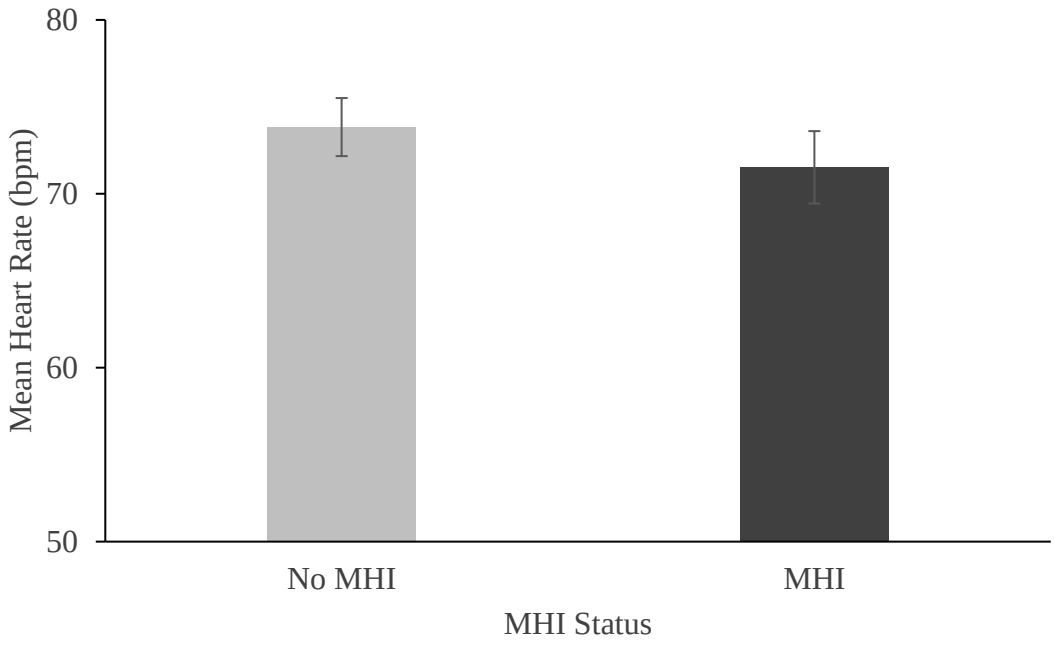


Figure 3. *Mean heart rate ([HR] with Standard Errors [SEs]) for the MHI and No MHI Groups*

[3]However, examination of the relationship between MHI Status as a function of severity of injury (defined in terms of severity indicators as reported in the ELQ such as length of LOC, number of MHIs, presence of PTA, etc.) and HR produced a significant negative correlation (*r*

[3] A linear regression with injury severity entered as the predictor variable and HR as the dependent variable was also conducted excluding the MHI participant reporting an average HR below 40 bpm. The regression model showed that that injury severity did not predict HR (R^2 =.004, F (1, 106) = .39, p > .05, CI [-7, .37]).

[107] = -.19, p = .02) demonstrating that greater injury severity was associated with lower HR, as predicted. To further understand the relationship between injury severity and HR, a follow-up linear regression conducted with injury severity entered as the predictor variable and HR as the dependent variable demonstrated that injury severity significantly predicted HR and for every 1 unit increase in injury severity, HR decreased by -0.47 beats per minute (BPM; R^2 = .03, F (1, 107) = 3.97, p = .04, CI [-.94, -.002]). These results demonstrate that MHI Status is associated with dampened autonomic arousal and supports the first Hypothesis.

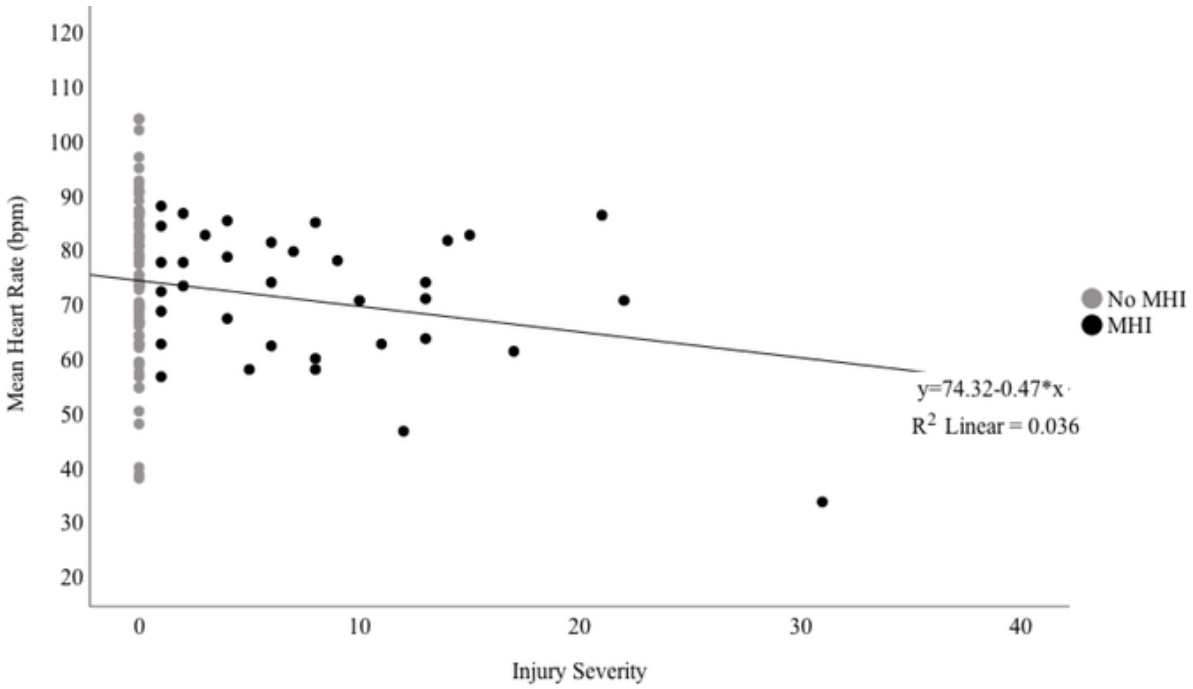


Figure 4. *Scatterplot displaying linear relationship between Injury Severity and HR for both MHI and No-MHI Groups*

In addition, a *t*-test was conducted to examine baseline subjective fatigue (MFS scores) between MHI and No-MHI groups. No significant differences were found between MHI (M = 12.64, SE = .97) and No-MHI groups (M = 11.61, SE = .6 t [107] = -.94, p > .05). Both groups produced a score higher than the criterion score of 10.5 indicating that all participants were reliably cognitively fatigued (Jonasson et al., 2018). Additionally, the relationship between MHI

Status as a function of injury severity and baseline subjective fatigue was examined; the analyses demonstrated that there was no significant correlation between injury severity and baseline subjective fatigue (r [107] = -.02 p = .43; Figure 5).

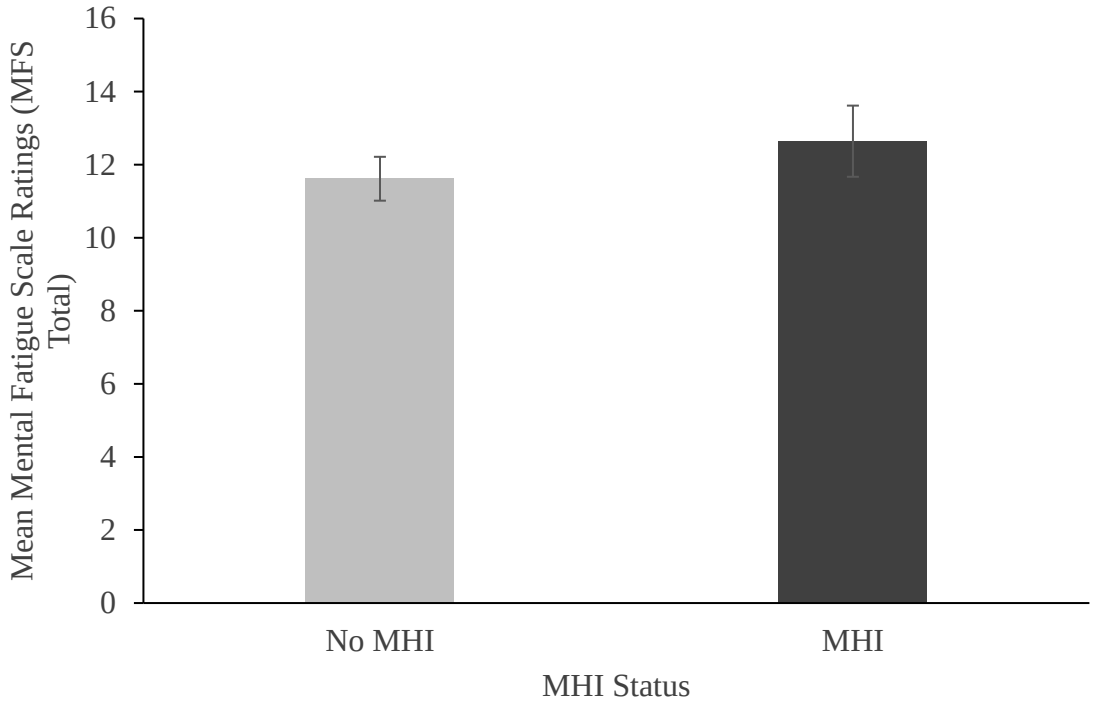
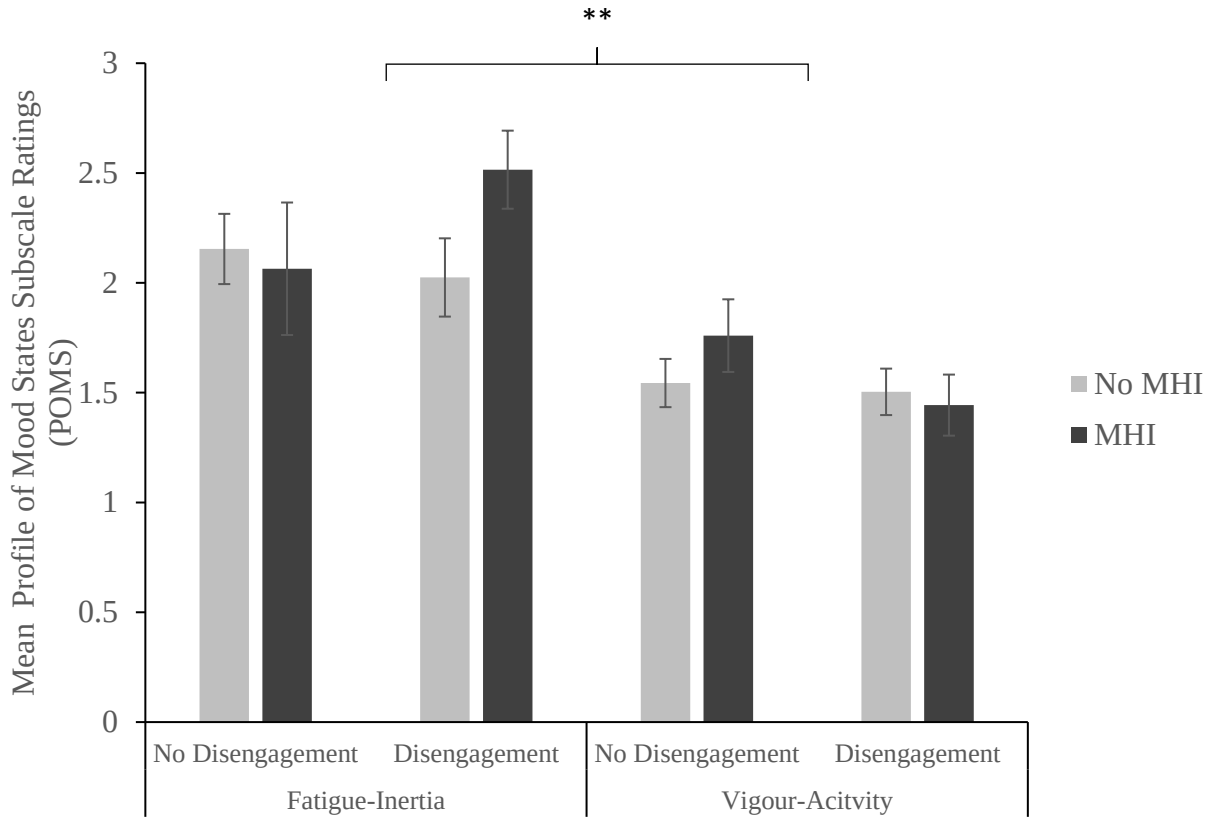


Figure 5. *Mean Mental Fatigue Scores (MFS; with SEs) as a function of MHI Status*

To examine post-task subjective arousal, a 2 (MHI Status: MHI, or No-MHI) x 2 (Disengagement Condition: Disengagement, or No-Disengagement) x 2 (POMS Subscales: Fatigue-Inertia, and Vigour-Activity) Mixed Model Analysis of Variance (ANOVA) with repeated measures on the last factor was conducted. A significant main effect with respect to the fatigue and activity subscales was found such that Fatigue-Inertia scores (M = 2.18, SE = .13) were significantly greater than the Vigour-Activity scores (M = 1.54, SE = .06; F [1, 105] = 20.13, p < .001). There were no other main or interactive effects. Additionally, the relationship between MHI Status as a function of injury severity and POMS subscale scores were further

investigated via a correlation analyses. Neither Fatigue-Inertia or Vigour-Activity subscales were found to correlate with injury severity (r [107] = -.21, p = .41; r [107] = -.36, p = .36). Overall, these results indicate that all participants, regardless of MHI status, reported feeling more underaroused in terms of fatigue and inertia than they felt energized and engaged (Figure 6).

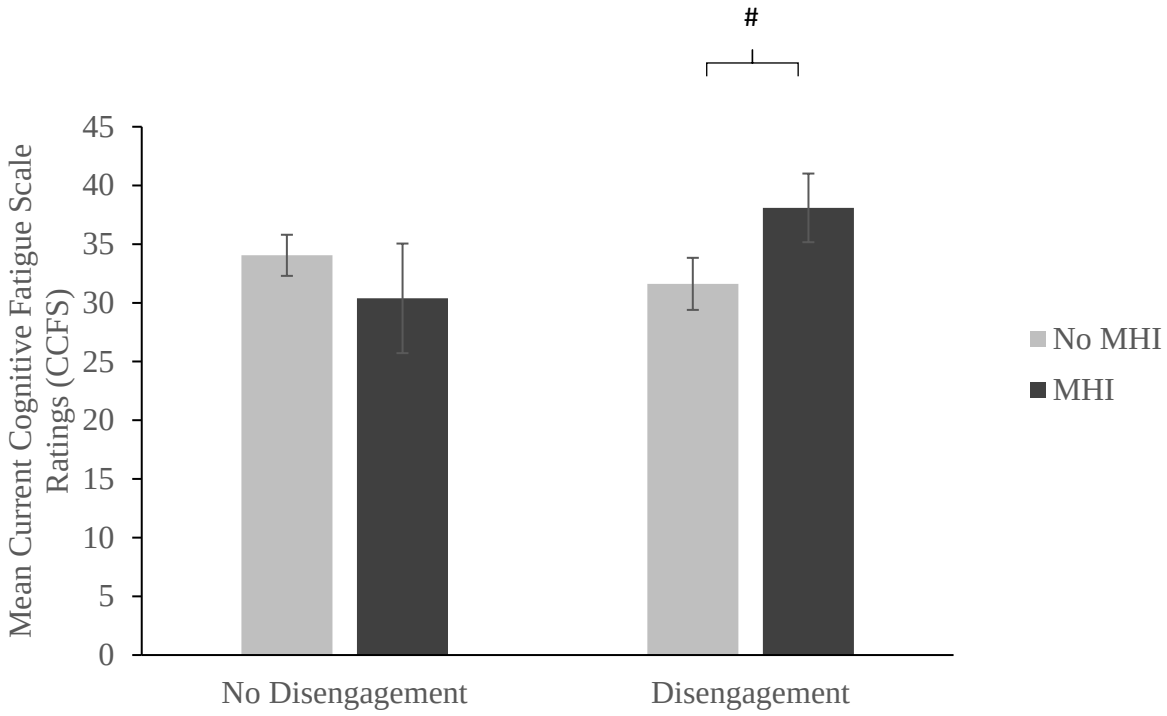


Note: * $p < .05$; ** $p < .001$

Figure 6. *Mean Mood Ratings (Profile of Mood States Scores [POMS];with SEs) for subscales Fatigue-Inertia and Vigour-Activity as a function of MHI Status and Disengagement Conditions*

Additionally, to further examine post-task fatigue, a 2 (MHI Status: MHI, or No-MHI) x 2 (Disengagement Condition: Disengagement, or No-Disengagement) ANOVA was conducted on CCFS scores and produced a non-significant interaction (F [1, 105] = 3.46, p = .066). To further understand the interaction, post-hoc tests using the Bonferroni correction were used. A non-significant difference was found such that the No-MHI group who received an opportunity

for disengagement experienced less fatigue post-task, and the MHI disengagement group reported greater fatigue (p = .092; Figure 7).



Note: # < .10; * p < .05; ** p < .001

Figure 7. *Mean CCFS Scores (with SEs) for MHI and No MHI Groups and Disengagement Conditions*

Hypothesis 2: Those reporting a history of MHI will endorse higher baseline and post-test levels of cognitive fatigue after engaging in a cognitively demanding task as compared to their No-MHI cohort.

A 2 (MHI Status: MHI, No-MHI) x 2 (Disengagement Condition: Disengagement, No-Disengagement) ANOVA was conducted to examine differences in PCS Fatigue Total scores. No main effects on Fatigue Total scores were found, nor was there an interaction (Figure 8).

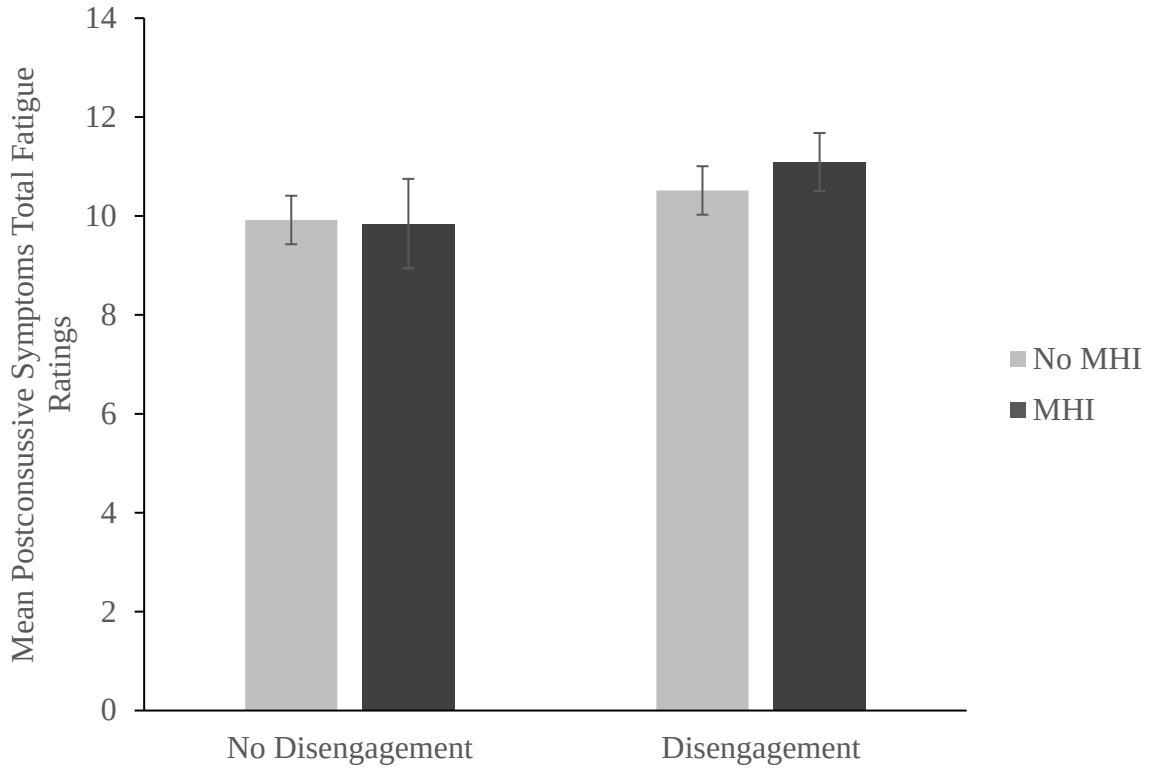
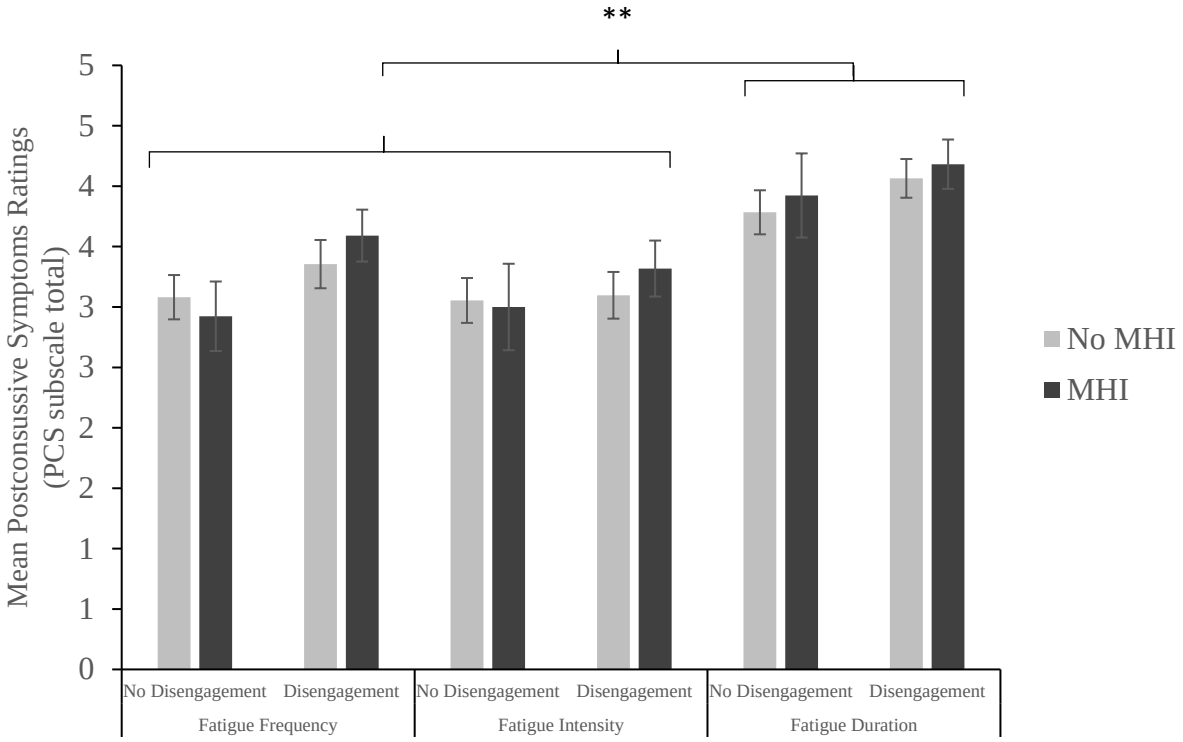


Figure 8. *Mean PCS Total Fatigue Scores (with SEs) for the MHI and No MHI Groups and Disengagement Conditions*

Further examination of PCS fatigue assessed the fatigue subscales with a 2 (MHI Status: MHI, No-MHI) x 2 (Disengagement Condition: Disengagement, No-Disengagement) x 3 (PCS Fatigue Subscale Scores: Frequency, Intensity, Duration) Mixed Model ANOVA with repeated measures on the last factor was conducted. A significant main effect of the type of subscale measure was found indicating that the subscales were rated differently (F [2, 198] = 55.14, p < .001) such that Fatigue Duration was scored significantly greater relative to the other two subscales (p's < .001). The relationship between Fatigue frequency, intensity, and duration, and MHI Status as a function of injury severity was examined; none were found to correlate with injury severity (r [107] = -.1, p = .16; r [107] = -.05, p = .3; r [107] = -.6, p = .28). Thus,

participants, regardless of MHI status, reported similar levels of fatigue; fatigue duration was more prevalent than other fatigue symptoms for all individuals (Figure 9).



Note: * $p < .05$; ** $p < .001$

Figure 9. *Mean PCS Subscale Scores (with SEs) for the MHI and No MHI Groups and Disengagement Conditions*

To examine changes of fatigue across the study, a 2 (MHI Status: MHI, No-MHI) x 2 (Disengagement Condition: Disengagement, No-Disengagement) x 2 (Pre- and Post-task Fatigue: MFS, CCFS Scores [*z*-scores]) Mixed Model ANOVA with repeated measures on the last factor was conducted. No main effect for Pre- and Post-task fatigue was found, nor was there an interaction effect (Figure 10).

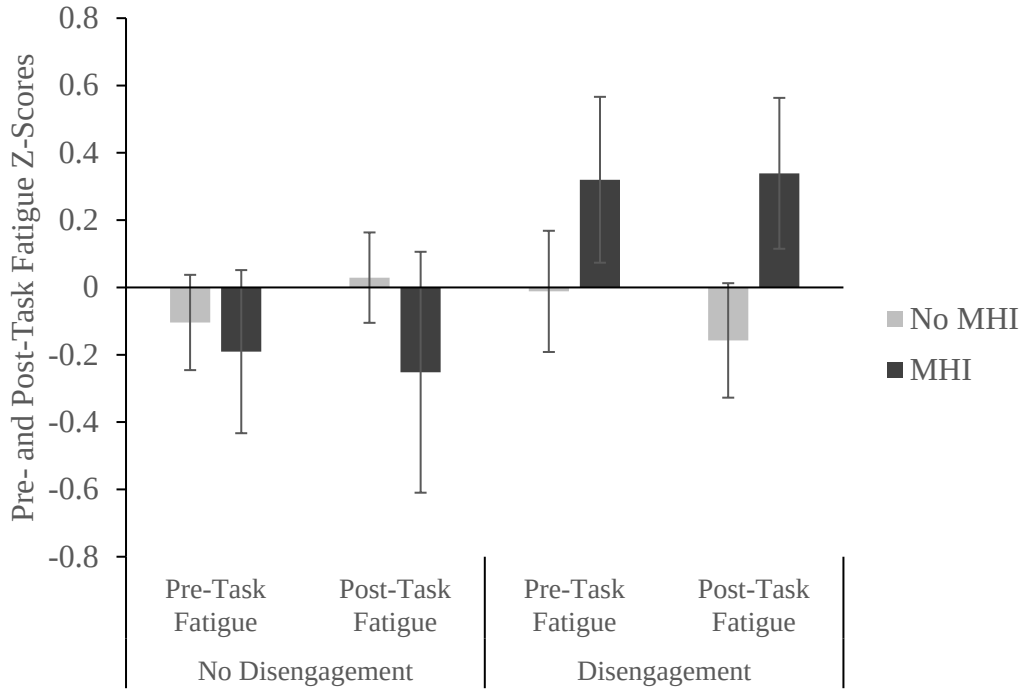


Figure 10. *Mean z-scores of MFS and CCFS Scores (with SEs) for the MHI and No MHI Groups and Disengagement Conditions*

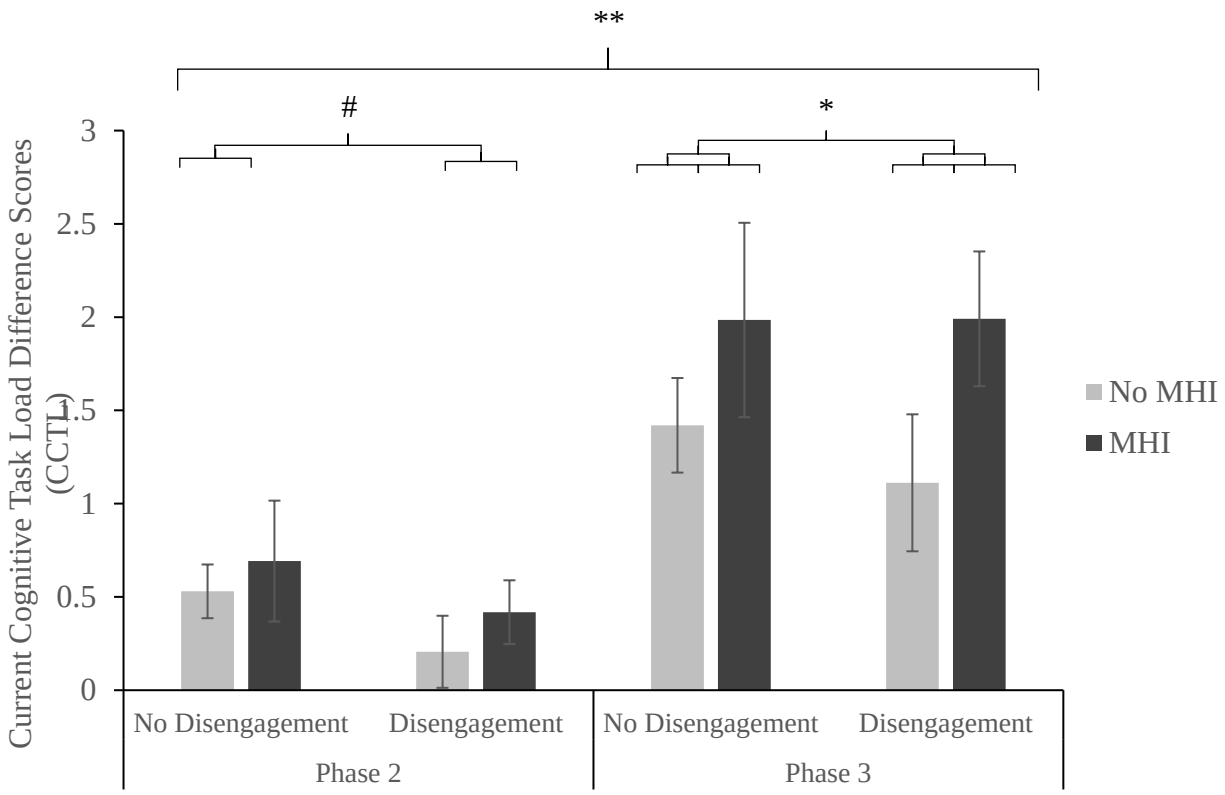
Additionally[4], and in order to examine changes of self-reported exerted cognitive effort across the experimental phase, a 2 (MHI Status: MHI, No-MHI) x 2 (Disengagement Condition: Disengagement, No-Disengagement) x 2 (Cognitive Effort difference scores: Post-Phase 2, post-MR) Mixed Model ANOVA with repeated measures on the last factor was conducted. A significant main effect of post-task status was found such that cognitive effort scores were significantly greater for participants after having completed the cognitively-demanding tasks (Post-Phase 2 - M = .43, SE = .09; Post-MR - M = 1.5, SE = .18; F [1, 105] = 37.77, p < .001). Also, results indicated a nonsignificant result in the expected direction for the main effect of MHI status, such that those with a history of MHI (M = 1.27 SE = .14) reported greater post-task cognitive effort/expenditure than those without (M = .82, SE = .21; F (1, 105) = 3.42, p = .067).

[4] The degrees of freedom change as a function of the number of subjects contributing to the data set for the different measures as well as a function the analysis (i.e., 2x2x2 ANOVA).

Follow-up independent sample *t*-tests indicated that whereas for Post-Phase 2 there was no difference in cognitive effort between the MHI and No-MHI groups, Post-MR (i.e., after having to subsequently complete a different cognitively demanding task), those with a reported history of MHI (M = 1.99, SE = .32) produced significantly greater cognitive effort scores than their No-MHI cohort (M = 1.27, SE = .21; t (107) = -1.9, p = .03, CI [-1.45, .03]).

In a similar manner, for Phase 2 (but not MR), the results indicated a nonsignificant result in the expected direction for an examination of the effects of disengagement as noted with an independent samples *t*-test (t [107] = 1.48, p = .071, CI [-.1, .66]), such that having the opportunity to disengage from the sustained attention demands of the Go/No-Go task, even for a short period of time, produced lower cognitive effort endorsement (M = .29, SE = .13) than for those who did not have the opportunity to disengage from the task (M = .57, SE = .13).

In summary, these results imply that having the opportunity to halt the sustained attention (while still being passively engaged), may have permitted some relief from the level of cognitive effort required on behalf of the participants and that those with history of MHI were more impacted than their No-MHI cohort providing support for Hypothesis 2 (Figure 11).



Note: # $p < .10$; * $p < .05$; ** $p < .001$

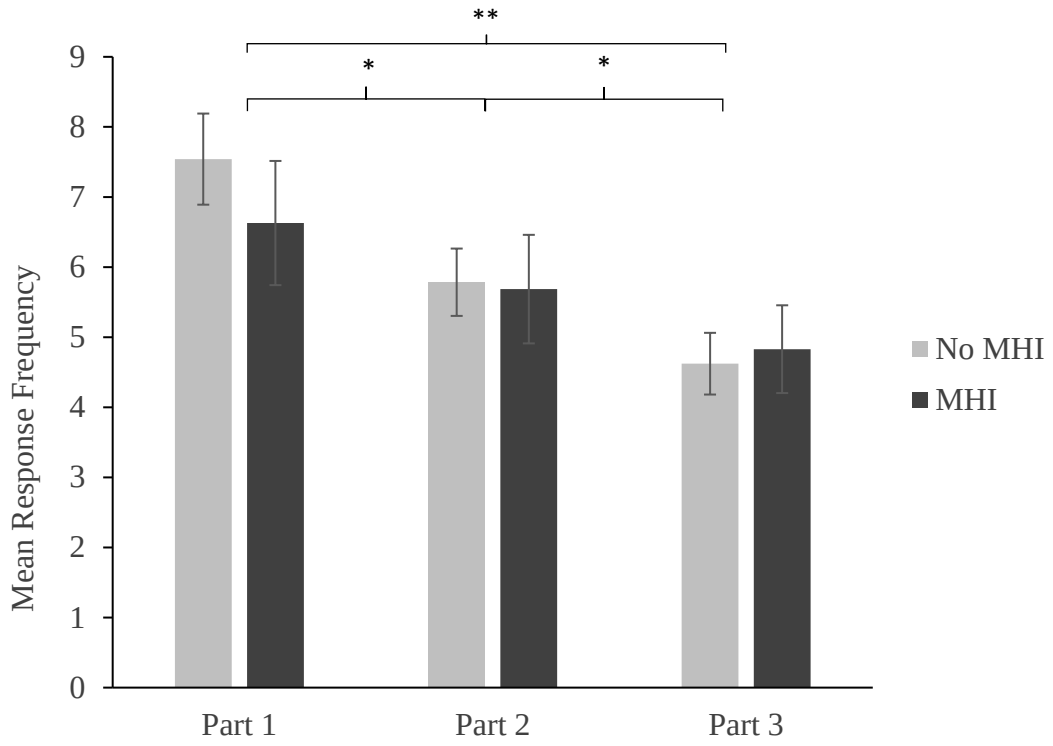
Figure 11. *Mean CCTL Difference Scores (with SEs) for the MHI No MHI Groups and Disengagement Condition across the Post-Experimental Phase of the study*

Hypotheses 3 & 4: Those reporting a history of MHI will exhibit greater challenges with a cognitively demanding task as assessed through their performance on a sustained vigilance task. Further, those reporting a history of MHI will be particularly advantaged by an opportunity for disengagement and demonstrate improved performance on a sustained vigilance task relative to their No-MHI cohort.

Phase 1 of the Go/No-Go Task

To examine participant performance in Phase 1 of the Go/No-Go Task, a 2 (MHI Status: MHI, or No-MHI) x 3 (errors across time [in thirds]) Mixed Model ANOVA with repeated

measures on the last factor was conducted on performance accuracy as a function of omission errors (corrected for a violation of sphericity). A significant main effect of Errors across Time was found (F [1.81, 193.77] = 11.34, $p < .001$). Follow-up pairwise comparisons demonstrated that as participants progressed in the Go/No-Go Task across time (assessed every 108 trials), performance accuracy declined/omission errors increased such that the final third of the Go/No-Go Task resulted in the most errors, and the middle third of the task resulted in more than the first third of the task, and this was found for both those with and without a history of MHI (p's <.05). These results indicate that as time on task increased, so too did errors in all participants in Phase 1 of the Go/No-Go Task (Figure 12).



Note: * $p < .05$; ** $p < .001$

Figure 12. *Mean Response Frequency (with SEs) for the MHI and No MHI Groups across task parts in Phase 1 of the Go/No-Go Task*

Similarly, additional ANOVAs were conducted examining On-Time responses, Late responses, and overall accuracy. No main effects, nor interactions, were found for either On-Time responses (Figure 13), Late responses (Figure 14), or for overall accuracy (Figure 15). Neither varied as a function of time-on-task or MHI status in Phase 1 of the Go/No-Go Task.

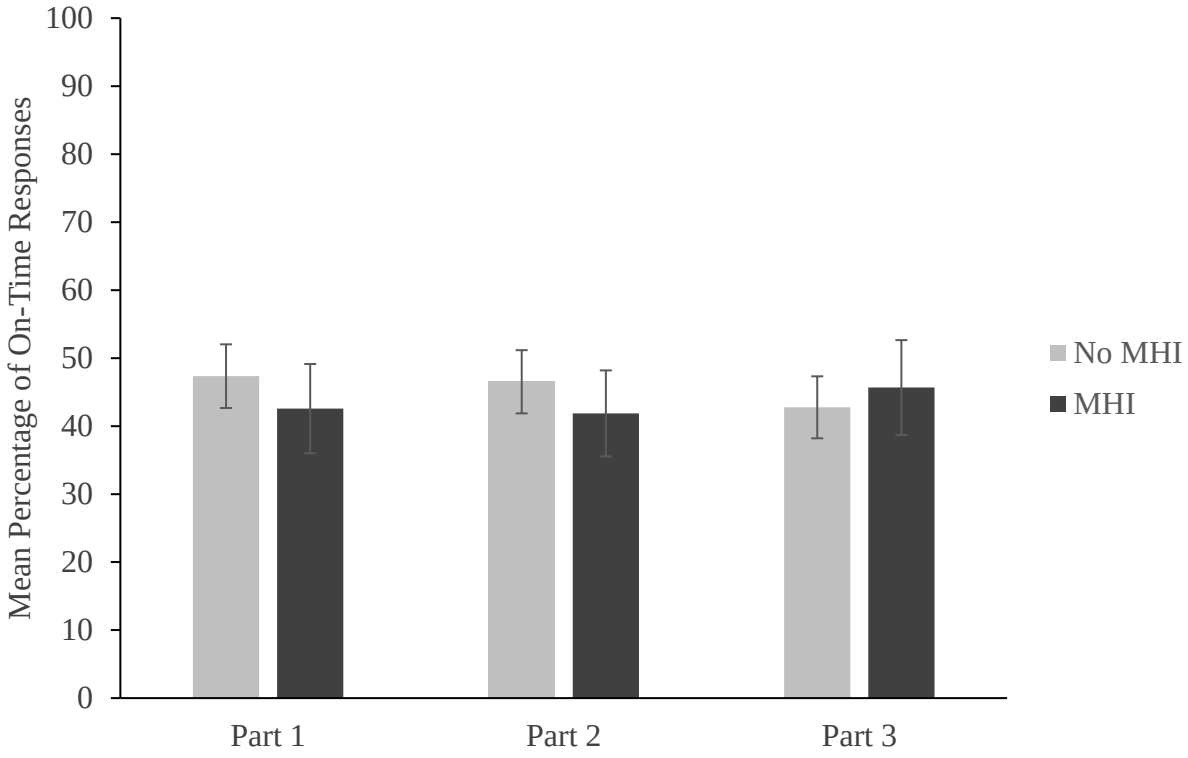


Figure 13. *Mean Percentage of On-Time Responses (with SEs) between MHI Groups across Task Parts in Phase 1 of the Go/No-Go Task*

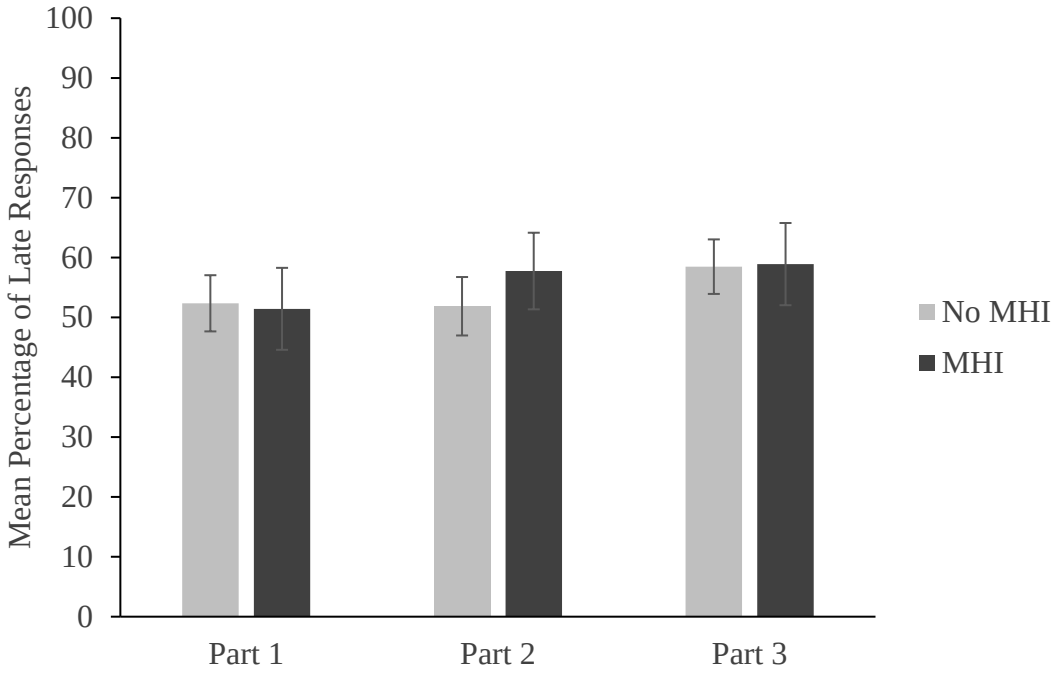


Figure 14. *Mean Percentage of Late Responses (with SEs) between MHI Groups across Task Parts in Phase 1 of the Go/No-Go Task*

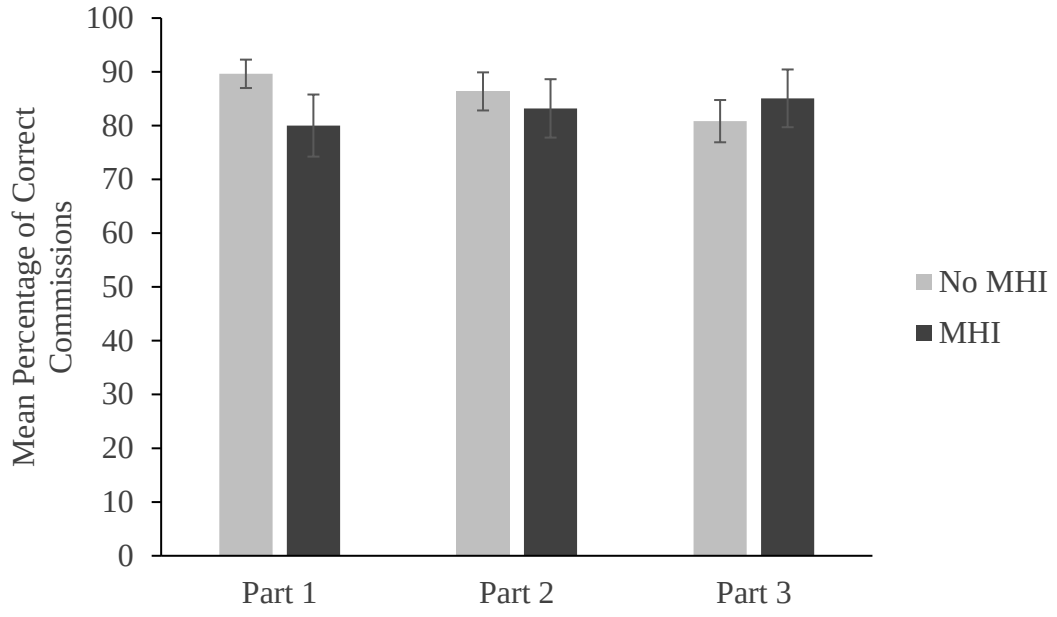
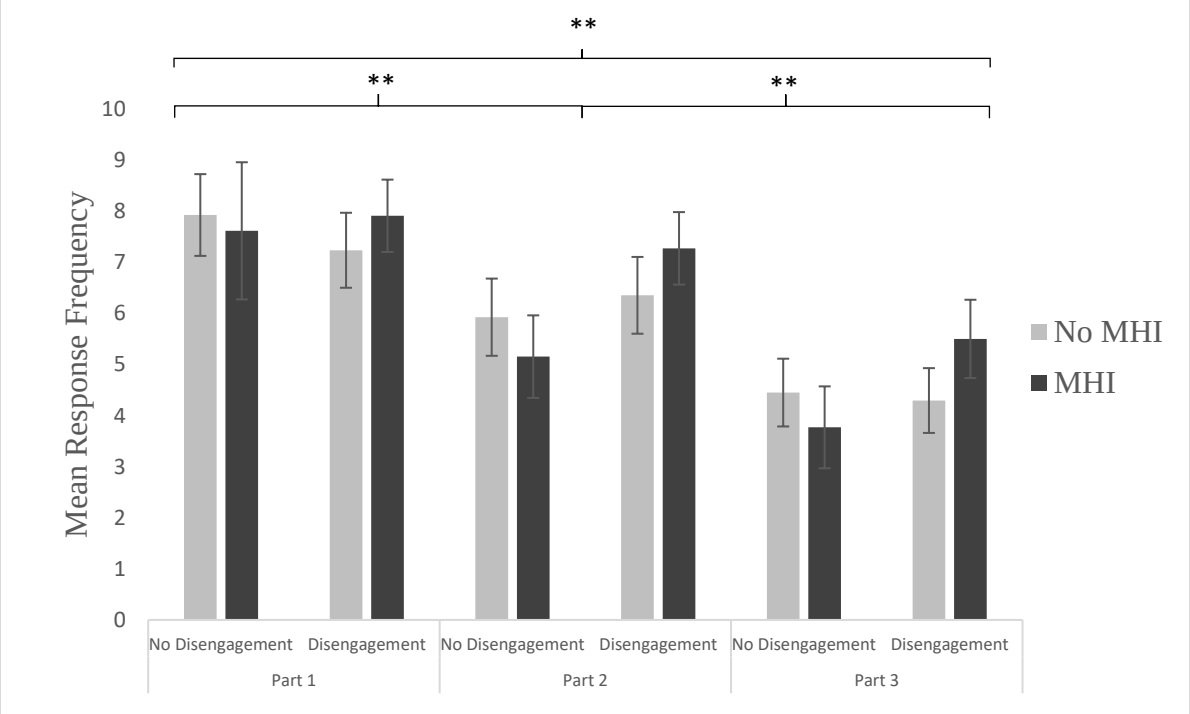


Figure 15. *Mean Percentage of Correct Commissions (with SEs) between MHI Groups across Task Parts in Phase 1 of the Go/No-Go Task*

Phase 2 of the Go/No-Go Task

The same analyses were conducted for Phase 2 of the Go/No-Go task. Once again, similar to Phase 1 results, a significant main effect of Errors across Time was found (F [1.84, 193.07] = 35.24, $p < .001$). Follow-up pairwise comparisons demonstrated that as participants progressed in the task across time (assessed every 108 trials), performance accuracy declined/omission errors increased (p's < .001) such that the final third of the task resulted in more errors, than the middle third or the first third of the task, and this was the case for both groups of MHI (Figure 16).

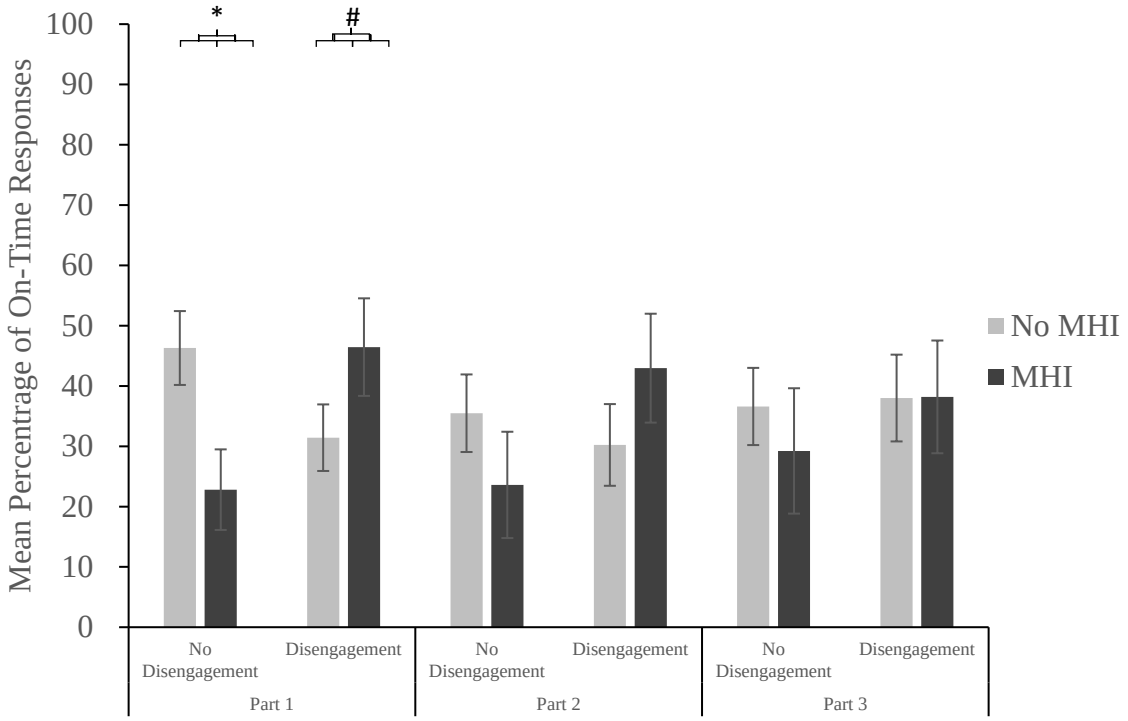


Note: * $p < .05$; ** $p < .001$

Figure 16**.** *Mean Response Frequency (with SEs) for the MHI and No MHI Groups and Disengagement Conditions Across Task Parts in Phase 2 of the Go/No-Go Task*

In addition, a nonsignificant result in the expected direction was found for the 3-way interaction between MHI, Disengagement, and accurate On-Time Responses across Time was found (F [2, 177.67] = 2.79, p = .073). Further analysis indicated that this was attributable to

part 1 (first third) of the task, such that a significant interaction between MHI Status and Disengagement Status was found (F [1, 105] = 6.78, p = .011) with the MHI group (M = 22.81, SE = 6.68) producing a significantly lower Percentage of On-Time Responses relative to their No-MHI cohort (M = 46.3, SE = 6.12; equality of variances not assumed; t [33.38] = 2.59, p = .007, CI [5.05, 41.92]); whereas for the Disengagement condition, a nonsignificant difference in the opposite direction was found (M_{MHI} = 46.45, SE = 8.08; $M_{No\text{-}MHI}$ = 31.43, SE = 5.52; t [54] = -1.59, p = .059, CI [-33.96, 3.92]). Neither parts 2 or 3 of the task produced significant findings (Figure 17).



Note: # p < .10; * p < .05; ** p < .001

Figure 17. *Mean Percentage of On-Time Responses (with SEs) for the MHI and No MHI Groups and Disengagement Conditions across Task Parts in Phase 2 of the Go/No-Go Task*

Similarly, ANOVAs were conducted to examine Late Responses as well as overall accuracy. No main effect for Late Responses (Figure 18) or overall accuracy (Figure 19) was found, nor were there any interaction effects. Neither Late Responses or overall accuracy varied as a function of time on task in Phase 2, nor as a function of MHI status.

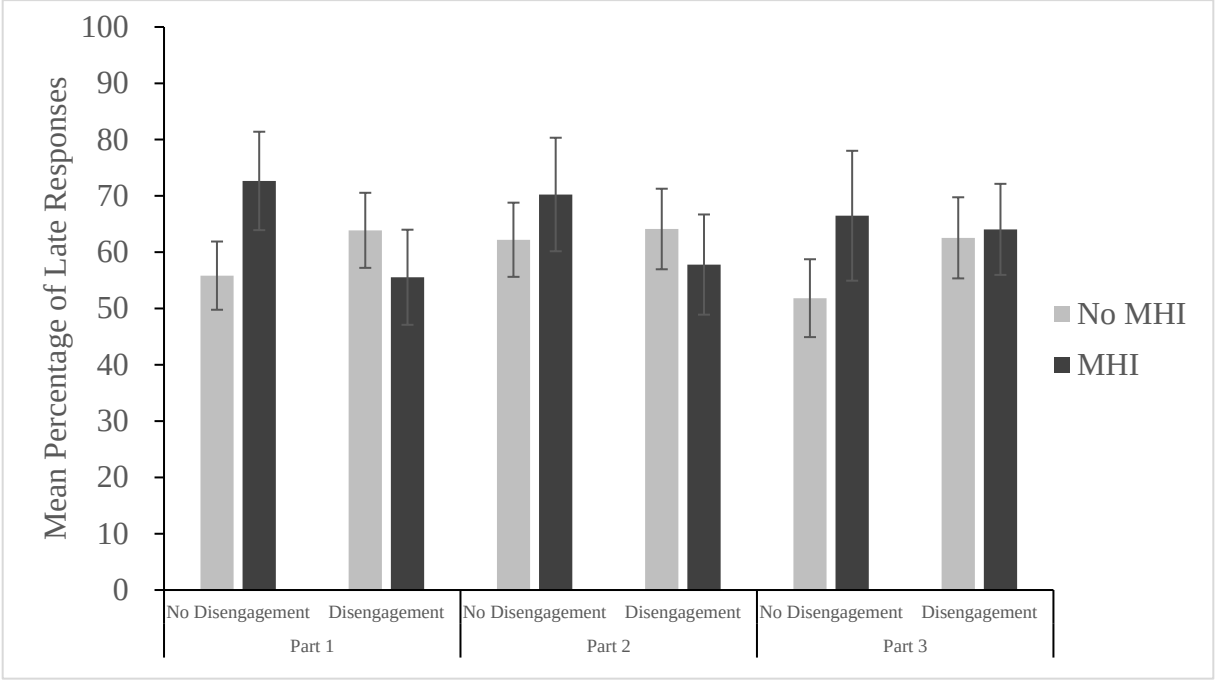


Figure 18. *Mean Percentage of Late Responses (with SEs) for the MHI and No MHI Groups and Disengagement Conditions across Task Parts in Phase 2 of the Go/No-Go Task*

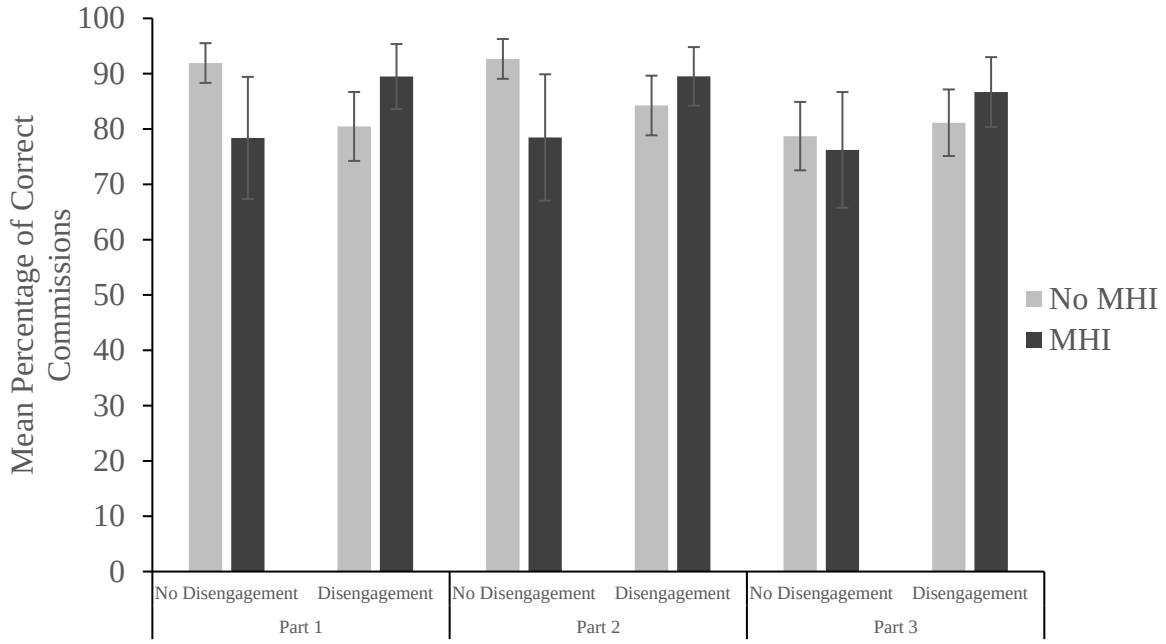


Figure 19. *Mean Percentage of Correct Commissions (with SEs) for the MHI and No MHI Groups and Disengagement Conditions across Task Parts in Phase 2 of the Go/No-Go Task*

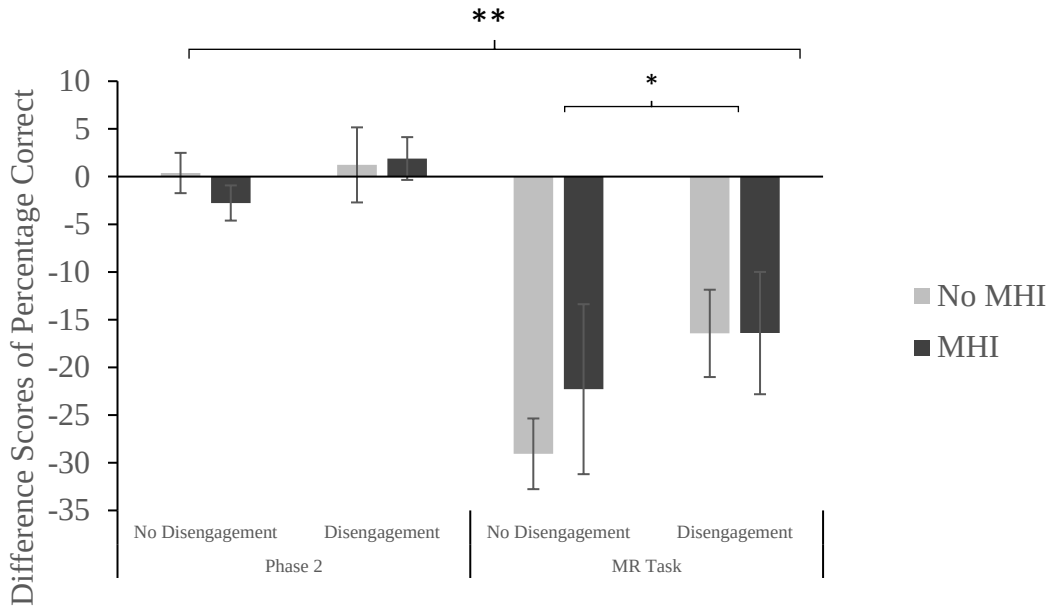
Overall, these results mirror the Phase 1 findings, such that as time engaged with the task increased, so did omission errors (i.e., performance accuracy declined). Also, those with a history of MHI who had the opportunity to disengage from the Go/No-Go Task exhibited fewer omission errors overall. These results lend support to Hypothesis 3b (i.e., those with a history MHI will exhibit increased inconsistency of performance with increased duration of testing) and Hypothesis 4 (i.e., those with a history of MHI who do get the opportunity to disengage would be advantaged).

Phase 2 of the Go/No-Go Task and Mental Rotation Task

To examine changes in performance across cognitively demanding tasks, a 2 (MHI Status: MHI, No-MHI) x 2 (Disengagement Condition: Disengagement, No-Disengagement) x 2 (Cognitive Demanding Task: Go/No-Go Task Phase 2, Mental Rotation Task) Mixed Model ANOVA with repeated measures on the last factor was conducted on percentage correct

difference scores. A main effect of Task was found such that correct difference scores decreased significantly as participants progressed through the cognitively demanding tasks from Go/No-Go Task Phase 2 (M = .58, SE = 1.52) to the Mental Rotation Task (M = -21.76, SE = 2.61; F [1, 105] = 49.27, $p < .001$). Also, there was a nonsignificant main effect in the expected direction of Disengagement Condition, such that those in the No-Disengagement condition (M = -13.44, SE = 2.69) did not score as well as those in the Disengagement condition (M = -7.43, SE = 2.31; F [1, 105] = 2.85, p = .094). Whereas for Go/No-Go Task Phase 2, there were no differences between the two Disengagement conditions, participants in the Mental Rotation Task produced significantly higher percentage correct difference scores for the Disengagement condition (M = -16.42, SE = 3.68) than those in the No-Disengagement condition (M = -27.4, SE = 3.53; t [107] = -2.14, p = .018, CI [-21.15, -0.8]; Figure 20).

These results indicate that performance on a series of cognitively demanding tasks diminished across time, and that participants who were given the opportunity to disengage from the tasks exhibited fewer decrements in performance in the latter Mental Rotation Task. In other words, the effect of the Disengagement Intervention buffered performance decrements and had a lasting impact on a subsequent cognitively demanding task. However, there was no MHI-specific effect.

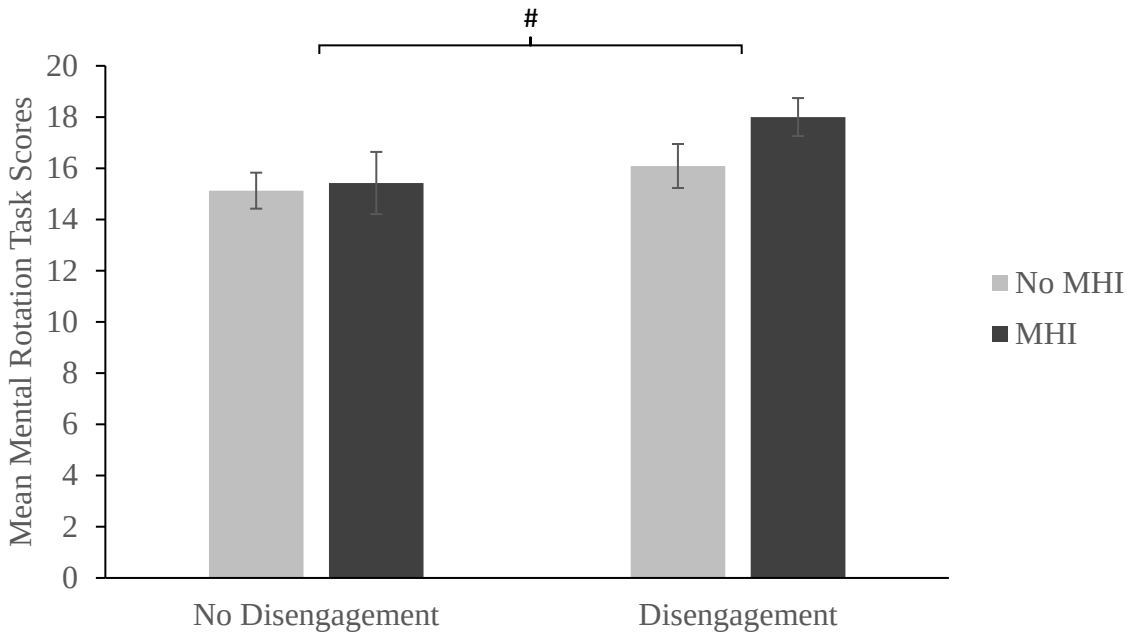


Note: * $p < .05$; ** $p < .001$

Figure 20. *Mean Percentage Correct Difference Scores (with SEs) for the MHI and No MHI Groups and Disengagement Conditions across cognitively demanding tasks*

Mental Rotation Task

To examine participant performance on the MR Task, 2 (MHI Status: MHI, or No-MHI) x 2 (Disengagement Condition: Disengagement, or No-Disengagement) repeated measures ANOVA was conducted. A nonsignificant main effect in the expected direction was observed for the Disengagement Condition demonstrating that those who had an opportunity to disengage earlier in the testing scored higher (accuracy) than those who did not (F [1, 104] = 3.53, p = .063). No other significant effects were found. These results reflect a potential benefit of having the opportunity for some limited disengagement from ongoing cognitive demands (Figure 21).



Note: # $p < .10$

Figure 21. *Mean Mental Rotation Task Scores (with SEs) for the MHI and No MHI Groups and Disengagement Conditions*

Discussion

This study was conducted to examine how cognitive fatigue manifests, particularly in persons with a history of MHI, and the efficacy of disengagement as a therapeutic means to alleviate cognitive fatigue symptoms. Cognitive fatigue post-MHI is one of the most commonly reported and debilitating symptoms that interferes with an individual's ability to return to meaningful pre-injury activities (e.g., work, academics, social life; Palm et al., 2017; Möller et al., 2017; Lannsjö et al., 2009; Stulemeijer et al., 2006). It was therefore a goal of this research to investigate ways to facilitate social reintegration for those who have sustained an MHI by alleviating cognitive fatigue through an intervention strategy. Research has been inconsistent in validating disengagement interventions as a therapeutic means of alleviating cognitive fatigue

(Borragán et al., 2017; Wylie & Flashman, 2017; Beaulieu-Bonneau, & Ouellet, 2017; Kohl et al., 2009; Jonasson et al., 2018).

For those with a history of TBI, it has been shown that the vmPFC is particularly susceptible to injury. As such, the vmPFC's associated processes and functions, such as regulating both physiological and emotional arousal, as well as attentional functions, are also most at risk to be compromised post-injury (Damasio et al., 1991; Baker & Good, 2014; Balkin et al., 2008; Thomas et al., 2000). It has also been shown that dampened physiological arousal as a result of TBI gives rise to fatigue and that more severe injuries lead to further dampening of autonomic activation and worsening fatigue outcomes (e.g., Amodio et al., 2021; 2022). Together these factors worsen attentional abilities, which then compromise other executive functions, resulting in poor performance and decision making in everyday life (e.g., Lezak et al., 2012; Sivan & Benton, 1999; Bechara et al., 1998; Robb & Good 2011; 2012; 2019; van Noordt et al., 2017). To alleviate fatigue, a Disengagement Intervention is of particular interest as it may specifically target an individual's depleted cognitive resources and allow the opportunity for their replenishment and rejuvenation.

Objective and Subjective Levels of Arousal

It was expected that those with MHI would present with both physiological and self-reported levels of underarousal relative to their No-MHI cohort. Under optimal research conditions, EDA would have been the preferred method of observing changes in autonomic arousal; however, due to the limits imposed as a result of the COVID-19 pandemic, at-home HR measures were chosen due to their ease of access (i.e., no requirement for particular equipment). While no group differences between MHI and No-MHI were found on HR measures (e.g., as per Baguley et al., 2009; Tan et al., 2009), severity of injury was found to predict HR such that the more severe the indicators of TBI (e.g., length of symptoms, medical services) predicted lower

average heart rate. This finding is consistent with other research demonstrating similar physiological outcomes for more severe injuries (e.g., Jung & Good, 2007; Amodio et al., 2021). Interestingly, recent studies by others (e.g., Ong et al., 2021) have shown that COVID-19 lockdown have affected HR baselines, such that as severity of lockdown increased, HR decreased (Ong et al., 2021), consistent with other studies that have found loneliness and isolation are associated with dampened physiological arousal in the general population (Brown et al. 2018; Roddick & Chen, 2021; Cacioppo et al., 2002; Petitte et al., 2015). As a result, our measures of HR may have been similarly muted as they were collected during the strict lockdown period in Ontario.

Similarly, subjective measures of self-reported arousal (e.g., MFS; POMS-2 Fatigue-Inertia and Vigour-Activity subscales) demonstrated no differences between the MHI and No-MHI groups and is in contrast to some other recent studies (e.g., Jonasson et al., 2018; LaRiviere et al., 2020; Robb & Good, 2019). However, in an earlier study, Ziino and Ponsford (2006) demonstrated difficulty in elucidating differences between MHI groups on the MFS. Further, as implicated with the HR findings, "lockdown fatigue" (Galanti et al., 2021; Labrague & Ballad, 2021; Mohammed et al., 2022) may be a confound for the subjective results as well. The requirement to adapt to new and additional responsibilities that came with the change of lifestyle and uncertainty was taxing on cognitive resources resulting in higher fatigue in the general population, thereby masking attempts to identify mild TBI differences.

Pre- and Post-Task Fatigue

This study took a multifaceted approach to examine fatigue using self-report measures and attentional performance measures to investigate cognitive fatigue before, during, and after, sustained and cognitively demanding tasks. There was some evidence that cognitive demands did impact cognitive fatigue with increased duration of engagement in that responses

diminished/omission errors increased as time-on-task increased, and accuracy across time diminished, for both phases of the sustained vigilance task. These findings agree with past research investigating cognitive fatigue induction via task engagement showing that performance declines with more time spent on a task (Boksem et al., 2005; LaRiviere, 2021; Ziino & Ponsford, 2006).

Further, the cognitive cost to remain engaged for a prolonged duration was evident in terms of reported 'current cognitive' load (as measured by the CCTL), or cognitive exertion experienced, which increased as a function of time-on-task, particularly for those who reported an MHI. These findings provide evidence for the coping hypothesis which states that those with a history of TBI may have to exert more effort relative to their No-TBI peers in order to achieve a similar level of performance (van Zomeren & van den Burg, 1985). According to the coping hypothesis, overexertion of certain brain regions is a result of needing to compensate for slowed processing speed and attentional deficits. Having sustained one's attention for a constant 20 minutes engaging a stimulus-driven task may have exhausted the participants' capacity so that in order to continue with the experiment and resolve the goal-directed puzzle-solving working memory mental rotation task had a substantial cognitive cost (e.g., Boksem et al., 2005; Corbetta & Shulman, 2002), particularly for individuals who have a history of MHI. These findings may be representative of the types of challenges that occur in everyday life and the types of reactions that can occur as cognitive demands persist across the day.

Effects of the Disengagement Intervention

It was expected that a disengagement intervention would alleviate cognitive fatigue, and that this would be demonstrated in both self-report measures as well as performance on cognitively demanding tasks. It was found that the tasks employed in this study did induce cognitive fatigue as evidenced by performance decrements across the experimental phase, and

some evidence that disengagement did ameliorate self-reported fatigue as well as performance measures. Specifically, while it was found that for all participants, errors increased as a function of time-on-task, those with a history of MHI who were given the opportunity to disengage from the task were found to exhibit even lower rate of errors relative to those with a history of MHI who did not get the opportunity to disengage. In a similar vein, those with a history of MHI who were given the opportunity to disengage from the task exhibited greater efficacy by responding on-time. Thus, those with a history of MHI who were given the opportunity to disengage made fewer errors and responded more quickly and may represent that the disengagement intervention led to a speed-accuracy advantage for these participants by providing a buffer to performance decrements.

Finally, the results demonstrated that reported cognitive exertion was lower for those who had received the opportunity to disengage from the task immediately after the sustained vigilance task, and this was observed even moreso for the MHI participants. No advantage of having disengaged during the Go/No-Go task, however, was observed for the final mental rotation task, perhaps reflecting too much time had elapsed to have any gains afforded successfully persist to the third task. Alternatively, a ceiling effect may have been witnessed because all participants reported substantially higher cognitive effort experiences after the third task.

Limitations

This research has many important limitations to consider. Perhaps the most glaring limitation of this research is when it took place, i.e., during the height of the COVID-19 pandemic. The COVID-19 pandemic, and its lockdown measures, presented many obstacles to overcome and required adopting unconventional and less-than-optimal research practices relative to prior studies in the lab. These included, but are not limited to, not being able to use experimental collection of autonomic function equipment which limited the efficiency and

accuracy of data collection (computer acquired, as opposed to manual acquisition), the variety of measures possible (i.e., electrodermal activity, respiration, blood pressure and heart rate), the control of context (i.e., in the lab, with research supervision versus at home, unsupervised engagement). Thus, for example, being constrained to collecting the at-home HR measures, it was found some of the reported scores were impossible/possible typographical errors (e.g., HR of 20 or of 888). Impossible scores were removed from the dataset to calculate averages; however, it does raise concerns regarding the accuracy surrounding any of the HR measures provided (i.e., not being able to discriminate between accurate versus inaccurate entries that were not as obvious).

Similar constraints were observed for the other performance measures. For example, the vigilance task engagement could not be monitored in terms of research supervision and time of testing. Computer equipment variances were evident because each participant had to manage with their own electronic devices (some using faster computers, tablets, phones, some with mouses, others with track pads) as opposed to a single version of computer as provided in the lab setting. Additionally, the study involved adapting traditionally pen-and-paper self-report questionnaires to an on-line format; and in all cases, testing was arranged to allow for flexible hours preferences at the discretion of the participants (although attempts were introduced to discourage extreme variances – e.g., through e-mail messages, presented sign-up times). The inability to monitor and supervise participants in-person disallowed control over the delivery of the disengagement intervention, a primary manipulation in this study, as it is unknown if participants did, or did not, adhere to the study protocol and review the intervention as intended. Again, there was an attempt to manage/track this, such as using the on-line platform's built-in tool to time and monitor how long any individual remained on a particular page.

The pandemic presented many obstacles, but of particular relevance to this research was the unanticipated effects it would have on fatigue. Research has emerged that the pandemic and its lockdowns led to much higher, and generic, fatigue effects in the general population which, in turn, has led to difficulties in interpreting the data presented in this study, and its generalizability outside of the COVID-19 era (e.g., Labrague & Ballad, 2021; Galanti et al., 2021; Mohammed et al., 2022). Since this research was designed to investigate fatigue induction, alleviation, and how it differently presents in MHI groups presumably under constant circumstances and this assumption cannot be adopted for the pandemic years.

Outside of the obstacles presented by the COVID-19 pandemic, other issues are present within this research. The sample of participants was rather homogenous such that 86% of participants were female, despite the fact that males have a higher rate of MHI/TBI. This calls into question the representation of the sample and makes it difficult to generalize these results to the greater MHI/TBI populations (Heskestad et al., 2009). Additionally, the sample consisted entirely of university students, again compromising the issue of representation. For example, it may be the case that those who have sustained an MHI and are able to navigate their concussive symptoms/consequences and otherwise meet the demands of the university environment may be better able to compensate for their injury and experience fewer complications than those with a history of MHI/TBI in a clinical setting and cannot overcome the cognitive challenges introduced by injury. Indeed, those with a history of MHI are reported to often find it difficult to return work, complete academics, and engage social life postinjury whereas the current sample has demonstrated being able to navigate an otherwise demanding (academic) environment and lifestyle (Palm et al., 2017; Möller et al., 2017; Lannsjö et al., 2009; Stulemeijer et al., 2006). Further, the sample size may have been inadequate to detect effect sizes; it was expected that 35-45% of participants would report a history of MHI (Segalowitz & Lawson, 1995), however only

32% of participants endorsed a history of MHI. The lack of statistical power in this study complicates the interpretation of the results, and especially so in the case of the reported nonsignificant findings.

Additionally, given the quasi-experimental study design employed, the ability to assert causation regarding the effects MHI Status on measures and outcomes are instead constrained to description of correlational, or associated, outcomes. Further challenging is the self-report retrospective nature of the MHI Status variable. While this is the most common manner of assessing MHI Status (e.g., Radoi et al., 2019), it is constrained by the participants' memories and integrity.

Conclusions

These findings provide evidence for the proposed model for how cognitive fatigue manifests such that physiological arousal is associated with fatigue (i.e., when arousal is dampened, fatigue is worsened), and that for those with a history of MHI, more severe injuries lead to worsened arousal outcomes, and thus, potentially worsened fatigue. Fatigue also manifests as a result of time-on-task and presents as worsened performance outcomes such that participants respond less, are less accurate, and less efficient as a function of time-on-task. Further, as fatigue manifests and performance worsens, more cognitive effort is required to maintain performance on attention-based tasks, and those with a history of MHI need to exert more effort relative to their No-MHI cohort in order to attain a similar level of performance particularly over the longer duration. The lockdowns imposed by the COVID-19 pandemic have been shown to have led to lowered physiological arousal as well as heightened baseline fatigue relative to participants in Pre-COVID times which may be an important confound in this study (see appendix A).

The findings presented also provide evidence that allowing for change, or break, or disengagement from the task-at-hand may buffer performance decrements across time and may be an effective therapeutic intervention to introduce for cognitively demanding tasks for both those with, or without, MHI. The benefits of changing one's cognitive set may result invoking less cognitive effort/recruitment and thereby preserving one's fatigue. While performance decrements were observed in those who had the opportunity to disengage, the opportunity to take a cognitive break may allow for the replenishing and rejuvenation of cognitive resources as evidence by participants making fewer errors and maintaining improved performance and less effort over the longer term compared to those who did not.

In summary, those with a history of MHI exhibit lower physiological arousal as a function of injury severity, and experience heightened cognitive costs over the longer term relative to their No-MHI cohort. The lockdown imposed by the COVID-19 pandemic introduced several constraints on the study and follow-up testing in less restricted times would allow confirmation, or not, of these conclusions. Fatigue was found to manifest as a function of time-on-task and present as worsened performance across time. Disengagement was found to lead to better performance outcomes on cognitively demanding tasks, and its benefits may have implications for therapeutic recommendations.

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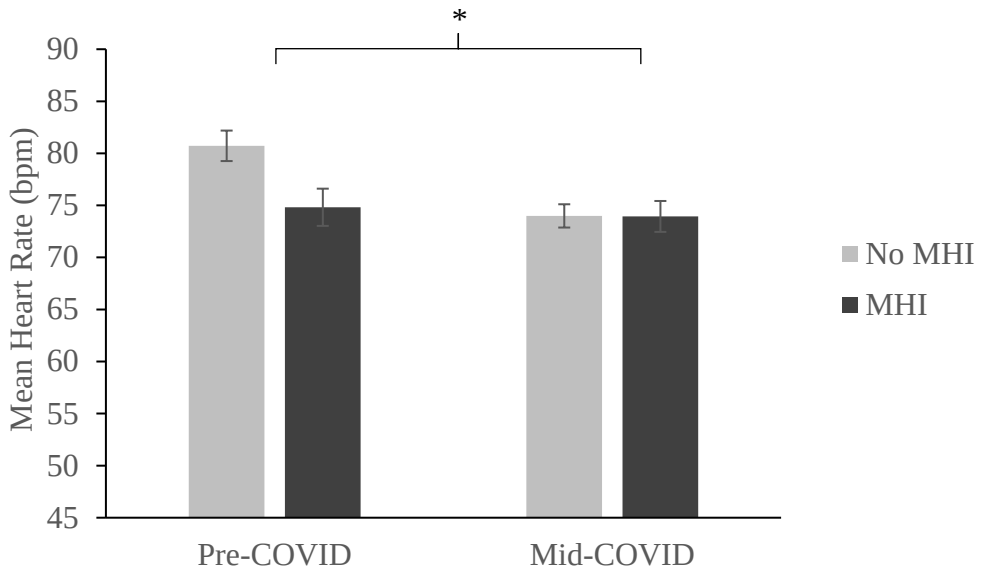
Appendix A: Additional Post-Hoc COVID Analyses

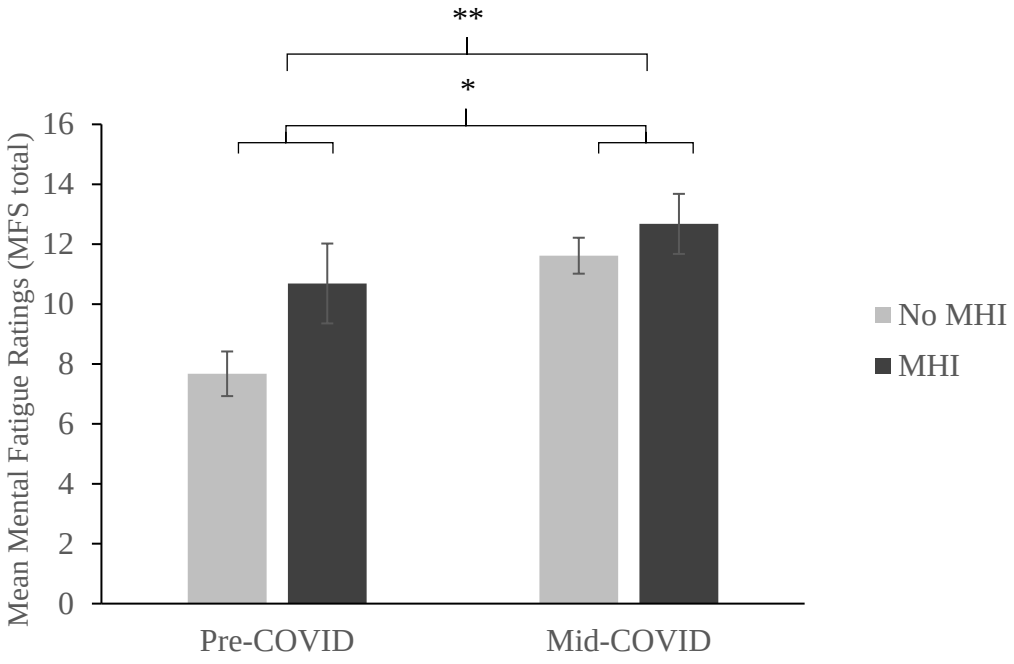
Additional Analyses: COVID-19 Pandemic and MHI Effects

Given the context-dependent nature of HR and the disruption in testing introduced by COVID, additional analyses were conducted *post hoc* comparing baseline (pre-experimental) heart rate across other studies in our lab (see LaRiviere 2021 and Robb 2020) and the present research. A 2 (COVID Period: Pre-COVID, Mid-COVID) x 2 (MHI Status: MHI, No-MHI) ANOVA was conducted to examine differences with respect to HR and fatigue. A significant main effect of COVID Period was found such that HR was significantly higher, and fatigue ratings significantly lower, in participants Pre-COVID (F [1, 120] = 4.45, p = .037; F [1, 146] = 9.24, p < .001). In addition, fatigue scores (MFS) were significantly higher for both participants Mid-COVID, and notably for those with a history of MHI (F [1, 146] = 4.37, p = .038). In line with other research (Galanti et al., 2021; Labrague, and Ballad, 2021; Mohammed et al., 2022; Ong et al., 2021), these results indicate that the lockdowns imposed by the COVID-19 pandemic may have had a dampening effect on physiological arousal (Figures 22 & 23).



Note: * $p < .05$; ** $p < .001$

Figure 22. *Mean HR (with SEs) between COVID Periods and MHI Groups*



Note: * $p < .05$; ** $p < .001$

Figure 23. *Mean MFS Scores (With SEs) Between COVID Periods and MHI Groups*

Appendix B: Tables of Statistical Analyses

Table 6

Means, Standard Deviations, and Independent Samples t-Test Results Comparing Average HR Between MHI and No-MHI Groups

Groups	*N*	*M*	SD	*t*-Test Results
No-MHI	74	73.84	14.37	t (107) = .82, p = .21, CI [-3.28, 7.91]
MHI	35	71.52	12.32	

Table 7

Summary of Results For Linear Regression With Injury Severity Entered as the Predictor Variable for HR

Predictor	*b*	*SE B*	*β*	*t*	*p*
Injury Severity	-0.47	0.24	-1.89	-1.99	0.049

Table 8

Means, Standard Deviations, and Independent Samples t-Test Results Comparing MFS Scores Between MHI and No-MHI Groups

Groups	*N*	*M*	SD	*t*-Test Results
No-MHI	74	11.61	5.16	*t* (107) = -.94, *p* = .18, CI [-3.21, 1.15]
MHI	35	12.64	5.76	

Table 9

Summary of Results for 2 (MHI Status: MHI, or No-MHI) x 2 (Disengagement Condition: Disengagement, or No-Disengagement) x 2 (POMS Subscales: Fatigue-Inertia, and Vigour-Activity)

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
POMS Subscales	1	20.13	< .001	0.16
POMS Subscales x MHI Status	1	0.19	0.66	0.002
POMS Subscales x Disengagement Condition	1	1.47	0.23	0.01
POMS Subscales x MHI Status x Disengagement Condition	1	2.35	0.13	0.02
Error	105			
Between-Subjects Effects				
MHI Status	1	1.64	0.2	0.92
Disengagement Condition	1	0.007	0.94	0.02
MHI Status x Disengagement Condition	1	0.49	0.49	0.005
Error	105			

Table 10

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) ANOVA to Examine Differences in CCFS Scores Between MHI Groups and Disengagement Conditions

Source	*DF*	*F*	*p*	η_p^2
MHI Status	1	0.26	0.6	0.003
Disengagement Condition	1	0.93	0.34	0.009
MHI Status x Disengagement Condition	1	3.46	0.066	0.03
Error	105			

Table 11

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) ANOVA to Examine Differences in PCS Fatigue Total Scores Between MHI Groups and Disengagement Conditions

Source	*DF*	*F*	*p*	η_p^2
MHI Status	1	0.17	0.69	0.002
Disengagement Condition	1	2.22	0.14	0.02
MHI Status x Disengagement Condition	1	0.28	0.6	0.003
Error	99			

Table 12

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement or No-Disengagement) x 3 (PCS Subscales; Fatigue Frequency, Intensity, and Duration) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in PCS Subscale Scores Between MHI Groups and Disengagement Conditions.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
PCS Subscales	1	72.89	< .001	0.42
PCS Subscales x MHI Status	1	0.26	0.61	0.003
PCS Subscales x Disengagement Condition	1	1.31	0.26	0.01
PCS Subscales x MHI Status x Disengagement Condition	1	1.4	0.24	0.01
Error	99			
Between-Subjects Effects				
MHI Status	1	0.17	0.69	0.002
Disengagement Condition	1	2.22	0.14	0.02
MHI Status x Disengagement Condition	1	0.28	0.6	0.003
Error	99			

Table 13

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 2 (MFS and CCFS Scores [z-Scores]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in MFS and CCFS Scores Between MHI Groups and Disengagement Conditions Across the Study.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1	0.02	0.89	< .001
Time x MHI Status	1	0.006	0.94	< .001
Time x Disengagement Condition	1	0.6	0.6	0.003
Time x MHI Status x Disengagement Condition	1	0.9	0.35	0.009
Error	105			
Between-Subjects Effects				
MHI Status	1	0.38	0.54	0.004
Disengagement Condition	1	1.82	0.18	0.02
MHI Status x Disengagement Condition	1	2.56	0.11	0.02
Error	105			

Table 14

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 2 (CCTL Difference Scores) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in CCTL Scores Between MHI Groups and Disengagement Conditions Across the Post-Intervention Experimental Phase

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1	37.77	< .001	.27
Time x MHI Status	1	1.99	.16	.02
Time x Disengagement Condition	1	.15	.7	.001
Time x MHI Status x Disengagement Condition	1	.12	.73	.001
Error	105			
Between-Subjects Effects				
MHI Status	1	3.42	.067	.03
Disengagement Condition	1	.84	.362	.008
MHI Status x Disengagement Condition	1	.14	.71	.001
Error	105			

Table 15

Summary of Results For 2 (MHI, or No-MHI) x 3 (Response Frequency [in Thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Response Frequency Between MHI Groups Across Phase 1 of the Go/No-Go Task.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.81	11.34	< .001	0.1
Time x MHI Status	1.81	0.68	0.46	0.006
Error	193.77			
Between-Subjects Effects				
MHI Status	1	0.13	0.72	0.001
Error	107			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 16

Summary of Results For 2 (MHI, or No-MHI) x 3 (Percentage of On-Time Responses [in Thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage of On-Time Responses Between MHI Groups Across Phase 1 of the Go/No-Go Task.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.87	0.03	0.97	< .001
Time x MHI Status	1.87	491.02	0.48	0.007
Error	200.56			
Between-Subjects Effects				
MHI Status	1	0.1	0.76	0.001
Error	107			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 17

Summary of Results For 2 (MHI, or No-MHI) x 3 (Percentage of Late Responses [in Thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage of Late Responses Between MHI Groups Across Phase 1 of the Go/No-Go Task.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	2	1.44	0.24	0.01
Time x MHI Status	2	0.4	0.67	0.004
Error	214			
Between-Subjects Effects				
MHI Status	1	0.07	0.79	0.001
Error	107			

Table 18

Summary of Results For 2 (MHI, or No-MHI) x 3 (Percentage of Correct Commissions [in Thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage of Correct Commissions Between MHI Groups Across Phase 1 of the Go/No-Go Task.

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	2	0.22	0.81	0.002
Time x MHI Status	2	2.28	0.11	0.02
Error	214			
Between-Subjects Effects				
MHI Status	1	0.33	0.57	0.003
Error	107			

Table 19

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 3 (Response Frequency [in thirds]) Mixed Model ANOVA with Repeated Measures on the Last Factor to Examine Differences in Response Frequency Between MHI Groups and Disengagement Conditions Across Phase 2 of the Go/No-Go Task

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.84	35.24	< .001	0.25
Time x MHI Status	1.84	0.03	0.96	<.001
Time x Disengagement Condition	1.84	1.97	0.15	0.02
Time x MHI Status x Disengagement Condition	1.84	0.2	0.8	0.002
Error	193.07			
Between-Subjects Effects				
MHI Status	1	0.05	0.82	<.001
Disengagement Condition	1	0.67	0.42	0.006
MHI Status x Disengagement Condition	1	0.99	0.32	0.009
Error	105			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 20

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 3 (Percentage of On-Time Responses [in thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage of On-Time Responses Between MHI groups and Disengagement Conditions Across Phase 2 of the Go/No-Go Task

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.69	0.65	0.5	0.006
Time x MHI Status	1.69	0.3	0.71	0.003
Time x Disengagement Condition	1.69	0.09	0.89	0.001
Time x MHI Status x Disengagement Condition	1.69	2.79	0.073	0.03
Error	177.67			
Between-Subjects Effects				
MHI Status	1	0.12	0.73	0.001
Disengagement Condition	1	0.59	0.45	0.006
MHI Status x Disengagement Condition	1	2.66	0.11	0.03
Error	105			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 21

Summary of Results For x 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 3 (Percentage of Late Responses [in thirds]) Mixed Model ANOVA with Repeated Measures on the Last Factor to Examine Differences in Percentage of Late Responses Between MHI Groups and Disengagement Conditions Across Phase 2 of the Go/No-Go Task

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.63	0.22	0.76	0.002
Time x MHI Status	1.63	0.48	0.58	0.005
Time x Disengagement Condition	1.63	1.01	0.35	0.1
Time x MHI Status x Disengagement Condition	1.63	0.4	0.63	0.004
Error	171.37			
Between-Subjects Effects				
MHI Status	1	0.36	0.55	0.003
Disengagement Condition	1	0.07	0.8	0.001
MHI Status x Disengagement Condition	1	1.43	0.24	0.01
Error	105			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 22

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 3 (Percentage Correct Difference Scores; Go/No-Go Task Phase 2 and Mental Rotation Task) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage Correct Difference Scores Between MHI Groups and Disengagement Conditions Across Go/No-Go Task Phase 2 and Mental Rotation Task

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1	49.29	< .001	.319
Time x MHI Status	1	.59	.44	.006
Time x Disengagement Condition	1	1.15	.29	.01
Time x MHI Status x Disengagement Condition	1	.76	.39	.007
Error	105			
Between-Subjects Effects				
MHI Status	1	.09	.76	.001
Disengagement Condition	1	2.85	.094	.03
MHI Status x Disengagement Condition	1	.04	.83	< .001
Error	105			

Table 23

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) x 3 (Percentage of Correct Commissions [in Thirds]) Mixed Model ANOVA With Repeated Measures on the Last Factor to Examine Differences in Percentage of Correct Commissions Between MHI Groups and Disengagement Conditions Across Phase 2 of the Go/No-Go Task

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1.51	1.85	0.17	0.02
Time x MHI Status	1.51	0.5	0.56	0.005
Time x Disengagement Condition	1.51	0.66	0.48	0.006
Time x MHI Status x Disengagement Condition	1.51	0.8	0.42	0.008
Error	158.86			
Between-Subjects Effects				
MHI Status	1	0.09	0.76	0.001
Disengagement Condition	1	0.2	0.66	0.002
MHI Status x Disengagement Condition	1	2.13	0.15	0.02
Error	105			

Note: Corrected for a violation of sphericity using statistics derived from Greenhouse-Geisser.

Table 24

Summary of Results For 2 (MHI, No-MHI) x 2 (Disengagement, No-Disengagement) x 2 (Cognitive Demanding Task: Go/No-Go Task Phase 2, Mental Rotation Task) Repeated Measures ANOVA to Examine Differences in Percentage Correct Difference Scores Between MHI Groups and Disengagement Conditions Across Cognitively Demanding Tasks

Source	*DF*	*F*	*p*	η_p^2
Within-Subjects Effects				
Time	1	49.29	< .001	0.32
Time x MHI Status	1	0.59	0.44	0.006
Time x Disengagement Condition	1	1.15	0.29	0.01
Time x MHI Status x Disengagement Condition	1	0.76	0.39	0.007
Error	105			
Between-Subjects Effects				
MHI Status	1	0.09	0.76	0.001
Disengagement Condition	1	2.85	0.09	0.02
MHI Status x Disengagement Condition	1	0.04	0.84	< .001
Error	105			

Table 25

Summary of Results For 2 (MHI, or No-MHI) x 2 (Disengagement, or No-Disengagement) Repeated Measures ANOVA to Examine Differences in Mental Rotation Task Performance Between MHI Groups and Disengagement Conditions

Source	*DF*	*F*	*p*	η_p^2
MHI Status	1	1.38	0.24	0.01
Disengagement Condition	1	3.53	0.063	0.03
MHI Status x Disengagement Condition	1	0.73	0.39	0.007
Error	104			

Note: Degrees of freedom are different here as an outlier was removed for these analyses

Table 26

Summary of Results For 2 (Pre-COVID, or Mid-COVID) x 2 (MHI, or No-MHI) ANOVA to Examine Differences in HR Between COVID Periods and MHI Groups

Source	*DF*	*F*	*p*	η_p^2
COVID Periods	1	4.45	0.037	0.04
MHI Status	1	2.72	0.101	0.02
COVID Periods x MHI Status	1	2.63	0.107	0.02
Error	120			

Table 27

Summary of Results For 2 (Pre-COVID, or Mid-COVID) x 2 (MHI, or No-MHI) ANOVA to Examine Differences in MFS Scores Between COVID Periods and MHI Groups

Source	*DF*	*F*	*p*	η_p^2
COVID Periods	1	9.24	0.003	0.06
MHI Status	1	4.37	0.04	0.03
COVID Periods x MHI Status	1	1	0.32	0.007
Error	146			

Appendix C: Research Ethics Approval & Data Collection Materials

Brock University
Office of Research Ethics
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	10/29/2021	
PRINCIPAL INVESTIGATOR:	GOOD, Dawn - Psychology	
FILE:	20-361 - GOOD	
TYPE:	Masters Thesis/Project	STUDENT: Francesco Amodio SUPERVISOR: Dawn Good
TITLE:	Investigating cognitive endurance and sustained vigilance in persons with and without Mild Head Injury	

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 10/1/2022

The Brock University Social Science Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **10/29/2021 to 10/1/2022.**

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 10/1/2022. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Office of Research Ethics web page at: https://brocku.ca/research-at-brock/office-of-research-services/research-ethics-office/#application-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Angela Book, Chair
Social Science Research Ethics Board

Dipanjan Chatterjee, Chair
Social Science Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

On-Campus Poster and Social Media Advertisement

Endurance & Cognitive Performance Study Opportunity

What is it?

- A study looking into the effects of endurance and sustained vigilance / attention on cognitive performance
- Participation will take ~1.5 hours in 1 online session

Who is eligible?

- Brock students aged 17 or older
- Must be fluent in English

What will you do?

- Answer questionnaires as well as complete computer-based tasks

Why participate?

- Aid in research aimed at understanding how sustained vigilance affects performance on tasks
- Earn 0.5 credits for every 30 mins of participation (max 1.5)

If interested in participating, please scan the QR code to be brought directly to the SONA sign-up page

OR for more information please contact Francesco Amodio at fa14em@Brocku.ca, or Cole Wilson at cw17nd@Brocku.ca

This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University [#20-361]. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

Endurance & Cognitive Performance Study Opportunity

Swipe for more details

Link in description

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Swipe for sign-up and contact info

If interested in participating, please follow the link in the description to the SONA sign-up page

OR

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Consent and Debrief Forms

Informed Consent

Investigating the effects of a go/no-go task on cognitive fatigue

Principal Student Investigator:
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(905) 688-5550 x 3556 x 3869

INVITATION
You are invited to participate in a study that involves research. The purpose of this study is to investigate the effects of a go/no-go task on cognitive fatigue.

WHAT IS INVOLVED
Participation will take approximately 1.5 hours of your time in total. As a participant in this study, we will ask you to be involved in providing us with a physiological measure (i.e., heart rate). You will be asked to follow a set of detailed instructions that will direct you on how to measure your heart rate. You will then be asked to report your heart rate in the Qualtrics survey. In addition to the physiological measure, you will be asked to complete a number of self-report measures related to demographics (e.g., sex, age, medical history, lifestyle), cognitive fatigue, sustained effort, including questions asking directly about your history of substance use (e.g. alcohol use, and cannabis). You will be asked to provide information about yourself such as sex, age and level of education. As a result, you may find some of the questions to be personal or sensitive in nature, and you may choose to omit any question you prefer not to answer. Lastly, you will be asked to perform a go/no-go task. You may find that this task may lead to feelings of cognitive fatigue ("brain drain"); however, you may choose not to participate in the task at any point. Detailed instructions will be provided to you throughout the testing session. In total, the study will take approximately 1.5 hours to complete. Once you have completed the research study, further details regarding the specific purposes of the study will be explained to you by the researcher and you will be provided a debriefing form.

VOLUNTARY PARTICIPATION
Your participation is completely voluntary. You may withdraw from this study at any time without penalty of loss of benefits to which you are entitled. If you choose to withdraw at any time, please exit the survey and email the researcher immediately. Should you decide at completion of the study that you would like to withdraw your data from the study, please contact the Principal Investigator and advise her of this. All participants will be compensated with 0.5 research credits for every half hour of research, earning a maximum of 1.5 research credits.

All information obtained in this study will be kept strictly confidential. All data will be coded with an alphanumeric code so that no data will have your personal identification associated with it. However, there will be a master list advising the Principal Researchers (Dr. Dawn Good and

graduate student, Francesco Amodio) of each participants' identity so that we can correctly match your data across the various tests and multiple sources of collection (i.e., computer collected and physiological measures). This restricted access list will be held by the Principle Reseachers. Further, the results of the study will be presented in a statistical format and as a group - no individual participant information will be published or identified. The information you provide (your data, answers, with only an alphanumeric code identifier) will be kept locked in a secure location for ten years, to which only researchers and research assistants have access. Data will be subsequently destroyed. If you choose to withdraw from the study prior to completion, your data will not be used in the analyses and will be destroyed. The researcher will only use data for research purposes. Further, the information/data you provide will not be accessible or given to any other resource (e.g., health professional) without your explicit request and/or consent (in this event an additional consent form that is consistent with the guidelines of PHIPA [2004] for release of information would be required and signed by you).

POTENTIAL BENEFITS AND RISKS

The current study does require you to perform in a go/no-go task that some may find cognitively demanding, which could lead to experiencing feelings of unsolicited exhaustion. However, if you wish to discontinue your participation, you are able to at any time. Should you experience any concerns or feelings of exhaustion that arise as a result of your participation in this research study, you will be provided with contact information (e.g., counselling) at the end of the testing session. Your performance, responses, experience and concerns will remain confidential. Should there be any health-related concerns or responses that require further addressing (e.g. heart rate), the Principal Investigator will contact you directly and advise you of such, while respecting confidentiality and privacy as dictated by the Personal Health Information Protection Act, PHIPPA, legislation (e.g., https://www.ontario.ca/laws/statute/04p03). You will receive a detailed debriefing form about the study at the end of testing. You will receive course credit compensation for your participation. Also, you may contact the researchers via e-mail if you wish to view the results of the study.

CONFIDENTIALITY

Your name will be associated only with this consent form. All information collected will be confidential and kept separately from this consent form, and coded by an alpha-numeric code assignment. As noted above, a master list will be kept linking data codes to individuals' data. Only Dr. Dawn Good and Francesco Amodio will have access to this the master list and this list is necessary to link names to participant's data as we are using clinical measures that may require follow-up. If an individual has an elevated score on any test, the Principal Investigator, Dr. Dawn Good, C. Psych., or Student Investigator, Francesco Amodio, will be contacted immediately. Either the Student Investigator (Francesco) or Principal Investigator (both of whom have access to the master list) will match the participant's coded number to his/her name and Approved by Office of Research Ethics Board: # review the results. Note that all test scores will be evaluated for his/her status by the Principal Investigator (according to established protocol – e.g., Distress Centre of Ontario; and Brock University's Student Development Centre's "Students-at-risk" protocol) and provided facilitated access to services as needed. If there is an elevated score, our protocol is for the participant to be contacted within 24 hours. The Student or Principal Investigator will advise the participant as to why s/he is being contacted and will engage in discussion that ultimately provides the participant with psychological/psychiatric resources and

contact information. All task data and notes taken will be kept in a locked, secure database at all times and will be destroyed after 10 years. Only Francesco Amodio, Dr. Good, and their research assistants will have access to the data. All research assistants have completed confidentiality agreements. In addition, any information gathered from this study that is presented at conferences or is published is summarized and group results (rather than individuals) are emphasized which preserves anonymity.

VOLUNTARY PARTICIPATION

This study forms part of research projects associated with Faculty Research, M.A. and undergraduate theses. Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. If you choose to withdraw at any time please leave the survey and inform the researcher via email, right away.

PUBLICATION OF RESULTS

This study forms part of a M.A. research project associated with Faculty Research, M.A., and undergraduate theses. Results of this study may be published in professional journals and presented at conferences. Feedback about this study will be available after April, 2022. Please contact the principal faculty or student investigators (Dr. Dawn Good or Francesco Amodio) via the contact information provided on this form/ on SONA website.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact Dr. Dawn Good or Francesco Amodio at Brock University using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University [insert file #]. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

Thank you for your assistance in this project.

CONSENT FORM

[ ] I have read the information presented about the current study being conducted by Dr. Dawn Good and Francesco Amodio investigating the effects of a go/no-go task on cognitive fatigue.
[ ] I have read and understand the above information regarding this study.
[ ] I have received a copy of this form.
[ ] I understand that I may ask questions at any time during the study and in the future.
[ ] I understand that I may withdraw from this study at any time.
[ ] I agree to participate in this study.
[ ] I give permission to be contacted regarding this study or future studies

THANK YOU FOR YOUR TIME AND PARTICIPATION IN THIS STUDY!!

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Participant Debriefing Form

Francesco Amodio & Dr. Dawn Good
Neuropsychology Cognitive Research Lab, Department of Psychology, Brock University

PURPOSE AND BACKGROUND

Thank you for your participation in this research study. This research was conducted by Dr. Dawn Good and Francesco Amodio in the Departments of Psychology and Neuroscience at Brock University. Our goal within this study is to investigate the effect of sustained attention and vigilance on cognitive competencies (e.g., accuracy and response time) in a cognitively-effortful go/no-go task in university students who have, and have not, experienced a previous mild head injury (MHI; concussion). We were unable to advise you of our added interest in concussion prior to your participation since previous research has demonstrated that disclosing this information can bias recruitment and performance (Nichols & Maner, 2008; Suhr & Gunstad, 2002). Numerous young adults incur head injuries every year and the majority of these injuries are mild in nature. Approximately 25 to 45 percent of university students have sustained a concussion (often through sports or falls), with a small proportion experiencing persistent symptoms after three months (the majority will have resolved fully within 3 weeks). Research has shown that people with MHI commonly report cognitive fatigue problems as a major symptom (Jonasson, Levin, Renfors, Strandberg, & Johansson, 2018; Kohl, Wylie, Genova, Hillary, & Deluca, 2009) and chronic cognitive fatigue as well as chronic somatic depressive symptomology (e.g., Krzeczkowski, Robb, & Good, 2017) coupled with autonomic/physiological underarousal, may amplify the challenges that persons with TBI have with respect to decision-making, learning, and quality of life. We were also interested in your history of substance use (e.g. alcohol use, and cannabis) as research has shown that alcohol and, or, cannabis use may impair processing speed as well as capacity for sustained vigilance (Jacobus, Courtney, Hodgdon, & Baca, 2019; Ponsford, Tweedly, & Taffe, 2012).

Given the opportunity to recuperate cognitive resources during a brief rest/break, individuals may be able to compensate for the mental fatigue and strain experienced and, in turn, may demonstrate improved capacity in terms of learning, accuracy and vigilance on cognitively demanding tasks. To date, there is yet no evidence-based treatments for cognitive fatigue following TBI (Wylie & Flashman, 2017), and those that do mention rest as an option, do so in the context of acute physical recovery post-trauma in order to promote recovery in both TBI and MHI/concussion populations (e.g., Schneider, Iverson, Emery, McCrory, Herring, & Meeuwisse, 2013) despite limited empirical evidence (Iverson & Gioia, 2016). There is some support demonstrating that elevated cognitive activity is associated with poorer recovery from concussion (Majerske, Mihalik, Ren, et al., 2008; Brown, Mannix, O'Brien, Gostine, Collins, & Meehan, 2014; Schneider et al., 2013). This research is aimed at further understanding how a rest/break/Disengagement Intervention may ameliorate MHI-induced cognitive fatigue outcomes and advantage cognitive competency.

FINAL REPORT

Your participation is important for us to be able to examine group differences between persons who have experienced a MHI and those who have not. University students are interesting to us because they represent a very competent group of individuals who have many substantive and goal-oriented skills that can compensate, support, protect and mask any challenges that may accompany an injury to the head. By identifying the individual differences across the domains of

affect and cognition amongst MHI and No-MHI University students, we will gain a greater understanding of the factors contributing to one's resilience in neuropsychological health.

All of the data collected within this study will be in the form of aggregate data and averages and will not, in any way, reflect or indicate the performance of any single participant.

To ensure confidentiality and privacy, individual names, while collected, are not associated with data or files used in this study, with the exception of a master list to which only the Principal Researchers have access. As a result, individual results cannot be provided. All data will be summarized and presented as a group in a thesis project, in publishable journals, and at conferences. You are invited to view the results after completion of the study in April 2022. Should there be any need or request for health-related data to be released to another Regulated Health Professional or person of your preference, a "Consent to Release Personal Information" form would be required and would need to be explicitly requested by you. If you are interested in obtaining a copy of the final report of this study, contact the NCR lab at Brock University (905) 688-5550 ext. 3556, or 5523 - the lab offices of the primary investigator, Dr. Dawn Good [dawn.good@brocku.ca].

CONTACT INFORMATION

It is our intention to confirm with you that your experience in this study has been a rewarding one and you are thanked for your contribution to this research endeavor. However, if you had any negative experiences (e.g., reading/responding to sensitive questions, increased cognitive demands) as a result of participating in this research study, please contact either of the Principal Investigators (listed below). If wish to speak with a counsellor, please contact one or more of the following:

- Brock University Counselling Services, Schmon Tower 400, (905) 688- 5550 extension 4750, http://www.brocku.ca/personal-counselling
- The Principal Investigator, Dr. Dawn Good, Department of Psychology, B308 MC, extension 3869, dawn.good@brocku.ca.
- Community-based Mental Health Programs and Services in Niagara can be accessed via: www.Familysupportniagara.com/resources/Niagara-mental-health-programs-services-directory/:
- Canadian Mental Health Association (CMHA) Niagara Branch – [905] 688-2543
- Distract Centre Niagara – [905] 688-3711
- Your family physician or Brock's Student Health Services [brocku.ca/health-services].

Should you like more information regarding history of head trauma, or its sequelae, please visit the following websites: The Ontario Brain Injury Association (OBIA): http://www.obia.ca/, The Ontario Neurotrauma Foundation (ONF): http://www.onf.org/ or the Brain Injury Association of Niagara (BIAN): www.bianiagara.org). Should you wish directed assistance, OBIA is an educational and advocacy resource, and has inquiry help lines – [905] 641-8877. Should you have any further concerns, please contact your family doctor for additional information.

This project has been reviewed and received ethics clearance through the Office of Research Ethics Board #. If you have any pertinent questions regarding your rights as a participant, or feel

your rights have been violated, please contact the Research Ethics Officer via e-mail at reb@brocku.ca or you may call (905) 688-5550 extension 3035.

Thank you again for your time and participating in this study!!!

If you have any questions or concerns, please feel free to contact us at the Brock University Neuropsychology Cognitive Research Lab:

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List of Questionnaires and Materials

a. Pre-test Questionnaires:

Mental Fatigue Scale-modified (MFS-m; Johansson et al., 2010): This questionnaire contains 10 questions that concern fatigue in general, lack of initiative, mental fatigue, mental recovery, concentration difficulties, memory problems, slowness of thinking, sensitivity to stress, increased tendency to become emotional, irritability, sensitivity to light and noise, decrease or increased sleep and 24-hour symptom variation. Participants are asked to read each item which describes a common activity to be related to four response alternatives. A rating of 0 indicates normal function, 1 indicates a problem, 2 indicates pronounces symptoms and 3 indicates maximal symptoms.

b. Test Materials:

Go/No Go Task: Participants will be presented via computer platform a modified version of the NEPSY's Auditory Attention and Response Set Task (Korkman, Kirk, & Kemp, 2007). This task is a vigilance/attention task requiring participants to 'listen' to a word list with several 'target' (i.e., select colour words - 'go' trials) and nontarget (i.e., colour and non-colour words - 'no-go' trials) items and when they hear a target word, they are to select the corresponding coloured circle on the computer screen in front of them. Most of the trials (80%) will be 'no-go' trials, making sustained attention a requirement for accurate performance.

After eight minutes, they will be given a zero-, 2- or 4-minute break from the task, and then be presented with the task again for eight minutes.

After each eight-minute session, Ss will be presented with cognitive fatigue rating scales.

Mental Rotation Task: The mental rotation (MR) task is a task that examines participant's ability for spatial manipulation (Peters et al., 1995). The task consists of 24 different trials. On each trial participants are presented with a target figure made of blocks arranged in a specific manner, as well as four other figures made of blocks two of which match the target figure. Participants are asked to select the two blocks that match the target block. Each correct response amounts to 0.5 points, where a participant may attain a maximum 1 point per trial and 24 points maximum for the whole task. This task was selected as a general measure of spatial ability but also because of the cognitive demands of the task that spatial abilities may pose on individuals, especially in those with a history of TBI (Livingstone & Skelton, 2007; Skelton et al., 2006; Rizzo et al., 2002).

Current Cognitive Task Load-modified (CCTL-m; Hart & Staveland, 1988; Ackerman and Kanfer, 2010): This 7-item task is derived from the NASA Task Load Index (NASA TLX) and consists of an assessment of self-report mental fatigue experienced immediately following a cognitively demanding task.

Current Cognitive Fatigue Scale (CCFS; Penner et al., 2009): A 15-item scale designed to assess overall acute levels of cognitive fatigue following cognitive tasks addressing cognitive domains such as energy, concentration, cognitive capabilities (decision-making, social, learning), and slowness of thinking.

Explicit Knowledge questions: A set of 15 follow-up questions regarding the participants' experience and knowledge of the cognitive task (e.g., presence of cues).

c. Post-test Self-report Inventories:

Behavioral Inhibition Scale and Behavioral Activation Scale (BIS and BAS; Carver & White, 1994): This 24-item questionnaire assesses individual differences in one's self-regulation for inhibition and activation on a Likert scale from "1" (very true for me) to "4" (very false for me).

The Everyday Living Questionnaire (Brock University Neuropsychology Cognitive Research Lab) will provide demographic and health status information including history of mild head injury, concussion, time elapsed since injury, treatment of injury, substance use, and indices of stressful life events and/or changes, and other information such as sex, age, level of education, and general health questions such as exercise and sleep habits.

Cannabis Use Disorders Identification Test – modified ([CUDIT-m] Brock University Neuropsychology Cognitive Research Lab; derived from the CUDIT; Adamson & Sellman, 2003) Should participants report the use of cannabis, they will be asked to complete this questionnaire which is composed of 23 questions that survey cannabis use in more detail.

d. Protected Questionnaires: (not included here as they are copyrighted and protected scales)

Profile of Mood States - Second Edition (long version) (POMS-2-long; Heuchert & McNair, 2012): This self-report measure is utilized as a brief measure of mood state, asking participants to rate 65 emotional adjectives on a five-point scale (1 = not at all; 5 = extremely).

a. Pre-test Questionnaires:

Mental Fatigue Scale (modified)

We are interested in *your present condition*, that is, how you have felt during *the past month*. When you are comparing your condition with "than before", compare it with how it was before the injury or getting ill.
Each question below is followed by four statements that describe: No (0), Slight (1), Fairly serious (2) and Serious (3) problems.
We would like you to place a circle around the figure before the statement that best describes your problems. Should you find that your problem falls between two statements, there are also figures to indicate this.

1. Fatigue

Have you felt fatigued during the past month? It does not matter if the fatigue is physical (muscular) or mental. If you recently experienced something unusual (for example an accident or short illness) you should try to disregard it when assessing your fatigue.

0	I do not feel fatigued at all. (No abnormal fatigue, do not need to rest more than usual).
0.5	
1	I feel fatigued several times every day but I feel more alert after a rest.
1.5	
2	I feel fatigued for most of the day and taking a rest has little or no effect
2.5	
3	I feel fatigued all the time and taking a rest makes no difference.

2. Lack of initiative

Do you find it difficult to start things? Do you experience resistance or a lack of initiative when you have to start something, no matter whether it is a new task or part of your everyday activities?

0	I have no difficulty starting things.
0.5	
1	I find it more difficult starting things than I used to. I'd rather do it some other time.
1.5	
2	It takes a great effort to start things. This applies to everyday activities such as getting out of bed, washing myself, and eating.
2.5	
3	I can't do the simplest of everyday tasks (eating, getting dressed). I need help with everything.

3. Mental fatigue 1

Does your brain become fatigued quickly when you have to think hard?

0	I can manage in the same way as usual. My ability for sustained mental effort is not reduced.
0.5	
1	I become fatigued quickly but am still able to make the same mental effort as before
1.5	
2	I become fatigued quickly and have to take a break or something else more often than before.
2.5	
3	I become fatigued so quickly that I can do nothing or must abandon everything after a short period (appox. five minutes).

4. Mental fatigue 2

Do you become mentally fatigued from things such as reading, watching TV or taking part in a conversation with several people?

0	I can manage in the same way as usual. My ability for sustained mental effort is not reduced.
0.5	
1	I become fatigued quickly but am still able to make the same mental effort as before
1.5	
2	I become fatigued quickly and have to take a break or something else more often than before.
2.5	
3	I become fatigued so quickly that I can do nothing or must abandon everything after a short period (appox. five minutes).

5. Mental fatigue 3

Do you have to take breaks or change to another activity after being mentally fatigued?

0	I can manage in the same way as usual. My ability for sustained mental effort is not reduced.
0.5	
1	I become fatigued quickly but am still able to make the same mental effort as before
1.5	
2	I become fatigued quickly and have to take a break or something else more often than before.
2.5	
3	I become fatigued so quickly that I can do nothing or must abandon everything after a short period (appox. five minutes).

6. Mental recovery

If you have to take a break, how long do you need to recover after you have worked "until you drop" or are you no longer able to concentrate on what you are doing?

0	I need to rest for less than an hour before continuing whatever I am doing.
0.5	
1	I need to rest for more than an hour but do not require a night's sleep.
1.5	
2	I need a night's sleep before I can continue doing whatever I am doing.
2.5	
3	I need several days rest in order to recover.

7. Concentration difficulties

Do you find it difficult to gather your thoughts and concentrate?

0	I can concentrate as usual.
0.5	
1	I sometimes lose concentration, for example when reading or watching TV.
1.5	
2	I find it so difficult to concentrate that I have problems, for example, reading a newspaper or taking part in a conversation with a group of people.
2.5	
3	I always have such difficulty concentrating that it is almost impossible to do anything.

8. Memory problems

Do you forget things more often than before, do you need to make notes, or do you have to search for things at home or at work?

0	I have no memory problems.
0.5	
1	I forget things slightly more often than I should, but I am able to manage by making notes.
1.5	
2	My poor memory causes frequent problems (for example forgetting important meetings or turning off the cooker).
2.5	
3	I can hardly remember anything at all.

9. Slowness of thinking

Do you feel slow or sluggish when you think about something such that you feel that it takes an unusually long time to conclude a train of thought or solve a task that requires mental effort?

0	My thoughts are neither slow nor sluggish when it comes to work involving mental effort.
0.5	
1	My thoughts are a bit slow one or a few times each day when I have to do something that requires serious mental effort.
1.5	
2	My thoughts often feel slow and sluggish, even when carrying out everyday activities, for example, a conversation with a person or when reading the newspaper
2.5	
3	My thoughts always feel very slow and sluggish.

10. Sensitivity to stress

Do you find it difficult to cope with stress that is, doing several things at the same time while under time pressure?

0	I am able to cope with stress, in the same way as usual.
0.5	
1	I become more easily stressed but only in demanding situations that I was previously able to manage.
1.5	
2	I become stressed more easily than before. I feel stressed in situations that previously did not bother me.
2.5	
3	I become stressed very easily. I feel stressed in unfamiliar or trying situations.

11. 24-hour variations

Do you find that at certain times of the day or night the problems we asked about (for example tiredness, lack of concentration) are better or worse? In the statements below, "regularly" means at least 3 to 4 days of the week.

0	I have not noticed that my problems are regularly better or worse at certain times, or I do not have any specific problems.
1	There is a clear difference between certain times of the day. I can predict that I will feel better at certain times and worse at other times.
2	I feel unwell at all times of the day and night.

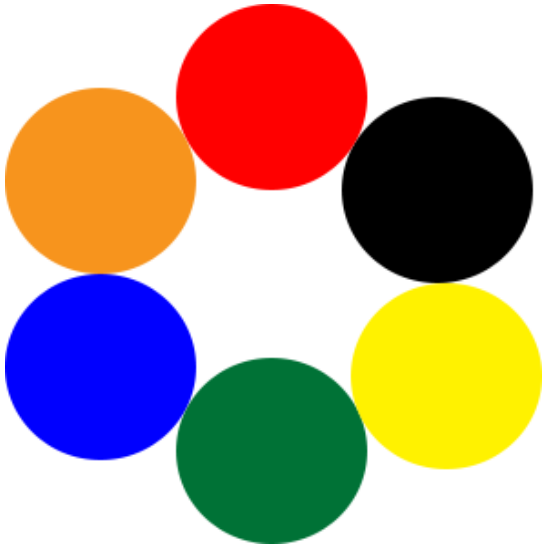
If you experience 24-hour variations:

When do you feel at your *best*? Morning Afternoon Evening Night

When do you feel at your *worst*? Morning Afternoon Evening Night

b. Test Materials:

Go/No-Go Task Colour Wheel



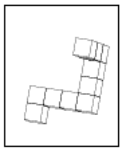
Go/no-go rule [i.e., if red, then select blue; if blue, then select red; if yellow, select yellow; if any other colour, do nothing]); the go/no-go task consists of two sets of 480 words (including 20% target colour words – e.g., red, blue, yellow; 10% nontarget colour words; 70% nontarget noncolour words)

Mental Rotation Task

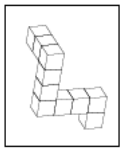
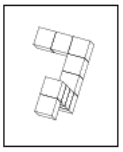
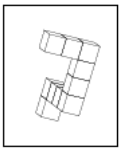
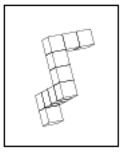
MENTAL ROTATION TASK

Here are two drawings of a new figure that is different from the one shown in the first 5 drawings. Do note, that these two drawings show an object that is different and cannot be "rotated" to be identical with the object shown in the first five drawings.

Now look at this object:
1.



Two of these four drawings show the same object.
Can you find those two? Please select them on screen

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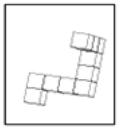
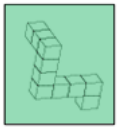
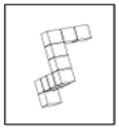
Now look at this object:
1.



Two of these four drawings show the same object.
Can you find those two? Please select them on screen

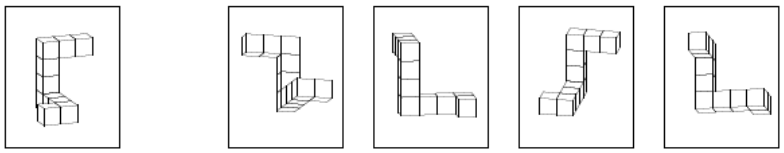


If you marked the first and third drawings, you made the correct choice.

Here are three more problems. Again, the target object is shown twice in each set of four alternatives from which you choose the correct ones.

2.a



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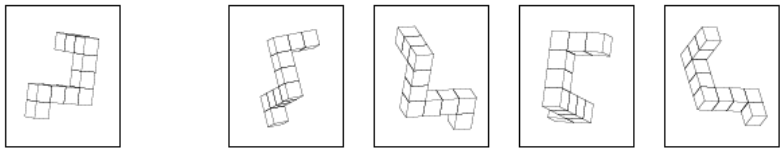

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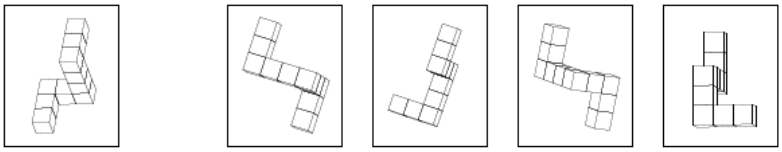
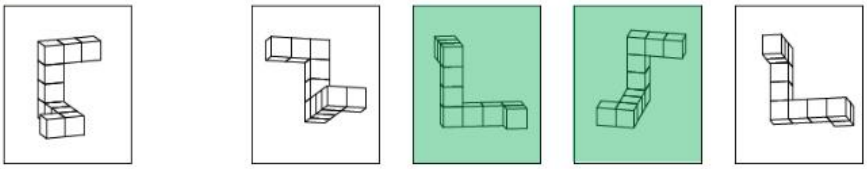


Here are three more problems. Again, the target object is shown twice in each set of four alternatives from which you choose the correct ones.

2.a



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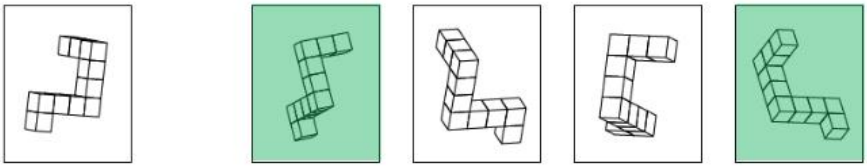

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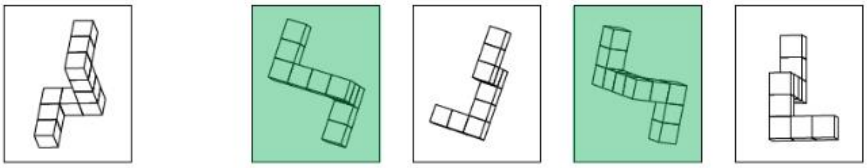


Correct Choice:

2: second and third
3: first and fourth
4: first and third

When you do the test, please remember that for each problem set there are two and only two figures that match the target figure.

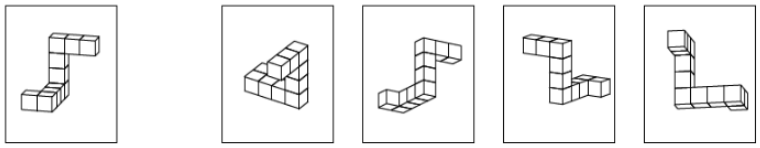
You will only be given a point if you mark off both correct matching figures, marking off only one of these will result in no marks.

MENTAL ROTATION TASK

When you do the test, please remember that for each problem set there are two and only two figures that match the target figure.

You will only be given a point if you mark off both correct matching figures, marking off only one of these will result in no marks.

1.a



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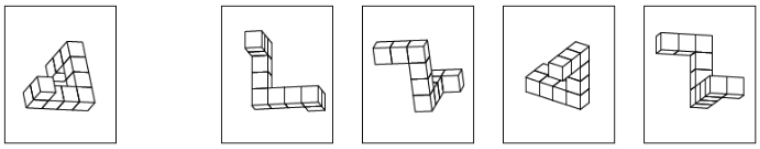

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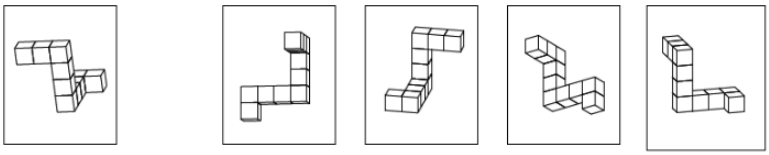

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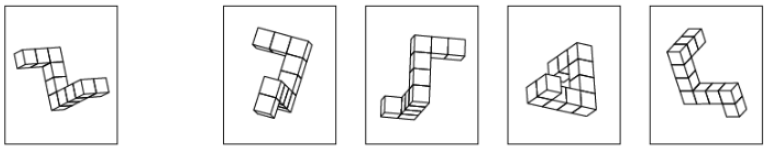

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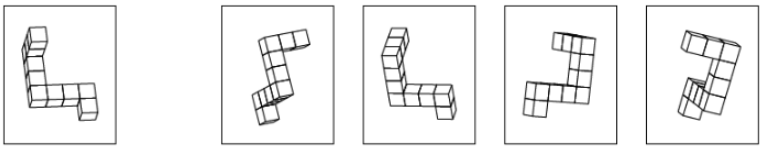

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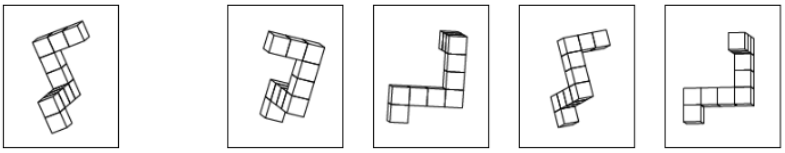

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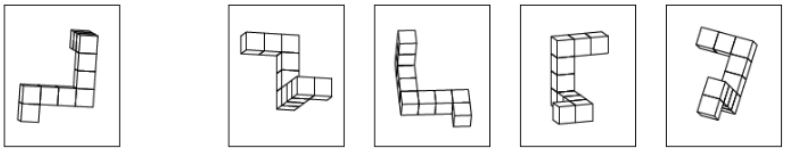

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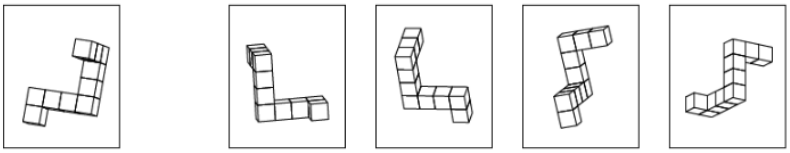

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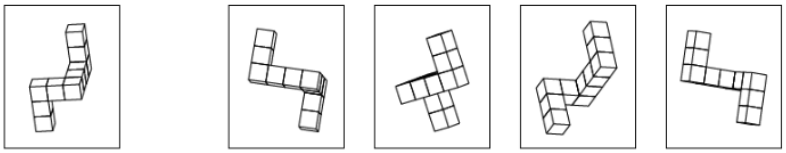

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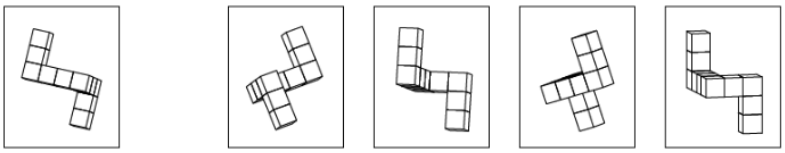

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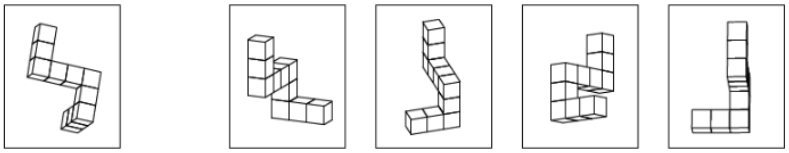

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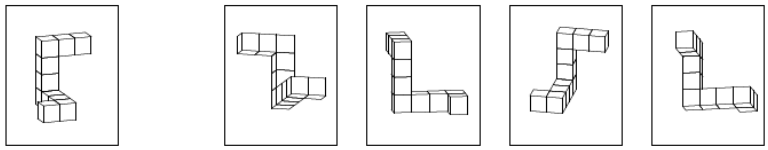

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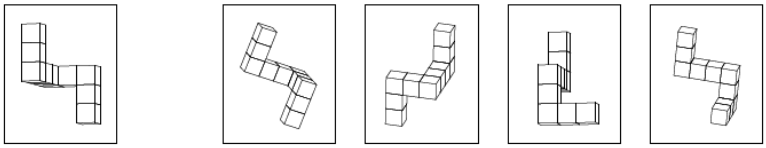

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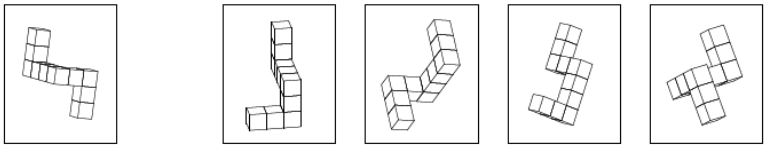

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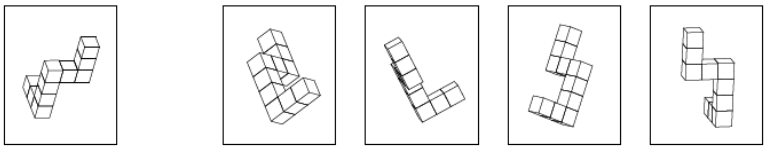

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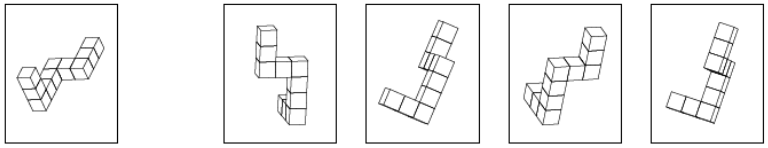

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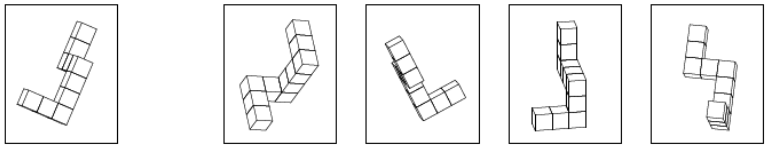

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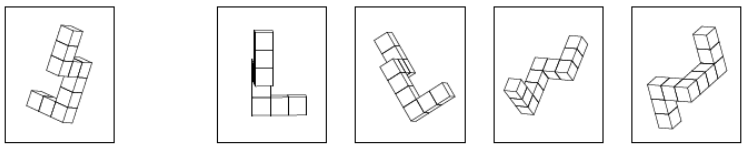

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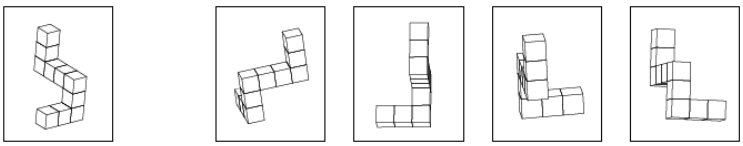

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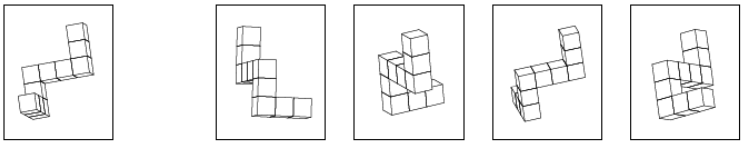

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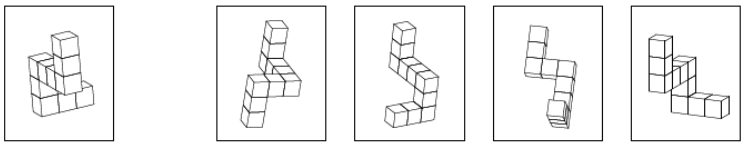

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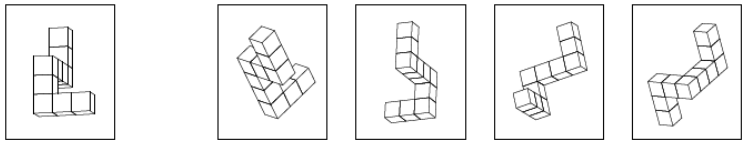

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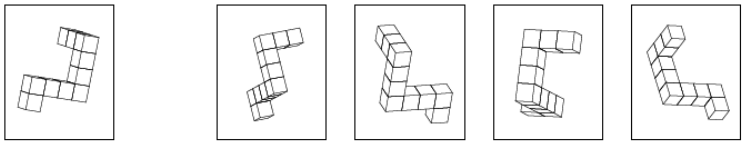

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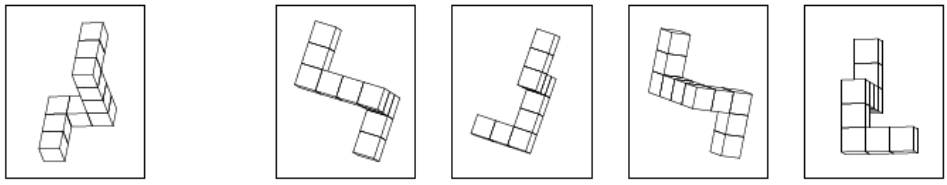


→

Current Cognitive Task Load-modified

CCTL-m

Each question below is followed by a 10 point scale. Rank your response to each question with respect to the task you just completed. The last question is a multiple-choice response. Please choose only one of the response options.

Mental Demand — How mentally demanding was the task?

0 1 2 3 4 5 6 7 8 9 10

Very Low — Very High

Temporal Demand — How hurried or rushed did you feel during the task?

0 1 2 3 4 5 6 7 8 9 10

Very Low — Very High

Performance — How successful did you feel in accomplishing what you were asked to do?

0 1 2 3 4 5 6 7 8 9 10

Very Low — Very High

Frustration — How stressed were you during the task?

0 1 2 3 4 5 6 7 8 9 10

Very Low — Very High

Effort — How hard did you have to work to accomplish your level of performance?

0 1 2 3 4 5 6 7 8 9 10

Very Low — Very High

During the session I… (choose one):

a) I kept my effort at a constant level
b) I increased my effort during this task when necessary
c) I decreased my effort because I became cognitively fatigued
d) I first increased my effort, then later I decreased my effort because I wanted to conserve my energy

FOLLOW-UP QUESTIONNAIRE

Please answer the questions below as best as possible.

1. On a scale from 0-10, where 0 is not well and 10 is very well, how likely were you at predicting when the next Target Colour Word would occur?

0 1 2 3 4 5 6 7 8 9 10

Not well
Very Well

2. a) Did you engage in any strategies that improved your performance?

- Yes
- No

b) if so what were they?

_____

3. a) Did you detect any structured pattern that predicted the Target Colour Word?

- Yes
- No

b) If so, please describe

_____

4. There were certain words that came before the Target Colour Words. Please identify which words, if any, predicted a Target Colour Word and describe the relationship.

5. On a scale from 0-10, how well do you think you would do if you were to do the task again?

0 1 2 3 4 5 6 7 8 9 10

Not well
Very Well

6. Can you describe any strategies that could diminish the mental fatigue associated with this task?

_____

Current Cognitive Fatigue Scale:

CCFS

In the following statements we would like to get an idea of how you are **currently** feeling. Please place a check mark in the box that would best describe how you **currently** feel.

	Does not apply at all	Does not apply much	Slightly applies	Applies a lot	Applies completely
1. I am mentally exhausted now that I have completed the task.					
2. Due to concentrating on the task, I am more mentally fatigued than other people of my age would be.					
3. I would be less capable of making decisions if I was asked to do that now.					
4. I want considerably less social contact now.					
5. It would be more difficult now to learn new things if I was asked to.					
6. The demands of the task were more mentally exhausting than other tasks I have done.					
7. My powers of concentration decreased considerably as the task went on.					
8. I am now less motivated than others would be to start activities that involve mental effort.					
9. My thinking is slower now than it was before the task.					
10. Because of the mental fatigue I am experiencing right now, I feel less like doing things that require concentration.					
11. I am no longer able to react quickly compared to before the task.					

12. I would be less capable of recalling words if I was asked to.					
13. As the task went on, I lost concentration considerably quicker than others would have.					
14. I feel an extreme lack of mental energy right now.					
15. If I was asked to remember things, I would be noticeably more forgetful.					

c. Post-test Questionnaires:

BIS/BAS Scale

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

1. A person's family is the most important thing in life.	1 ☐	2 ☐	3 ☐	4 ☐
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.	1 ☐	2 ☐	3 ☐	4 ☐
3. I go out of my way to get things I want.	1 ☐	2 ☐	3 ☐	4 ☐
4. When I'm doing well at something I love to keep at it.	1 ☐	2 ☐	3 ☐	4 ☐
5. I'm always willing to try something new if I think it will be fun.	1 ☐	2 ☐	3 ☐	4 ☐
6. How I dress is important to me.	1 ☐	2 ☐	3 ☐	4 ☐
7. When I get something I want, I feel excited and energized.	1 ☐	2 ☐	3 ☐	4 ☐
8. Criticism or scolding hurts me quite a bit.	1 ☐	2 ☐	3 ☐	4 ☐
9. When I want something I usually go all-out to get it.	1 ☐	2 ☐	3 ☐	4 ☐
10. I will often do things for no other reason than that they might be fun.	1 ☐	2 ☐	3 ☐	4 ☐
11. It's hard for me to find the time to do things such as get a haircut.	1 ☐	2 ☐	3 ☐	4 ☐
12. If I see a chance to get something I want I move on it right away.	1 ☐	2 ☐	3 ☐	4 ☐

13. I feel pretty worried or upset when I think or know somebody is angry at me.	1 ☐	2 ☐	3 ☐	4 ☐
14. When I see an opportunity for something I like I get excited right away.	1 ☐	2 ☐	3 ☐	4 ☐
15. I often act on the spur of the moment.	1 ☐	2 ☐	3 ☐	4 ☐
16. If I think something unpleasant is going to happen I usually get pretty "worked up."	1 ☐	2 ☐	3 ☐	4 ☐
17. I often wonder why people act the way they do.	1 ☐	2 ☐	3 ☐	4 ☐
18. When good things happen to me, it affects me strongly.	1 ☐	2 ☐	3 ☐	4 ☐
19. I feel worried when I think I have done poorly at something important.	1 ☐	2 ☐	3 ☐	4 ☐
20. I crave excitement and new sensations.	1 ☐	2 ☐	3 ☐	4 ☐
21. When I go after something I use a "no holds barred" approach.	1 ☐	2 ☐	3 ☐	4 ☐
22. I have very few fears compared to my friends.	1 ☐	2 ☐	3 ☐	4 ☐
23. It would excite me to win a contest.	1 ☐	2 ☐	3 ☐	4 ☐
24. I worry about making mistakes.	1 ☐	2 ☐	3 ☐	4 ☐

Everyday Living Questionnaire

Please fill in or check off an answer for each of the following. If you have any questions regarding clarification, please ask the researcher. Thank you for your time and effort!

1. How old are you? _____ years of age

2. a. To which gender do you most identify?

Male	❑	Transgender Male	❑
Female	❑	Gender Variant/Non-Conforming	❑
Transgender Female	❑	Prefer not to Answer	❑
Not Listed Please Specify:	❑		

b. Biological sex: Male ❑ Female ❑

3. What is your relationship status?

Single	❑	Divorced	❑
In a relationship (not married)	❑	Widowed	❑
In a relationship (common-law)	❑	Separated	❑
Married	❑		

4. What is the highest level of education you have presently **completed**? (e.g., if you finished high school last year and are currently in your first year of university, you have completed high school/Grade 12)

Less than high school	❑			
High School/Grade 12	❑			
College (years)	1	2	3	4+
University (years)	1	2	3	4+

5. What is the highest level of education your **mother** has received?

Less than high school	❑			
High School/Grade 12	❑			
College (years)	1	2	3	4+
University (years)	1	2	3	4+
Unsure	❑			

6. What is the highest level of education your **father** has received?

Less than high school	❑			
High School/Grade 12	❑			
College (years)	1	2	3	4+
University (years)	1	2	3	4+
Unsure	❑			

7. What is the overall average income your parent(s)/guardian(s)?

Under $25,000	❑	$125,000 - $149,999	❑
$25,000 – $49,999	❑	$150,000 or more	❑
$50,000 – $74,999	❑	Unsure	❑
$75,000 - $99,999	❑	N/A	❑
$100,000 – $124,999	❑		

8. To which ethnicity do you most identify:

Caucasian/European	❑
Black/African American	❑
Asian	❑
Indigenous	❑
Middle Eastern	❑
Other Please Specify:	❑

9. Which faculty is your major affiliated with?

Social Sciences	❑
Humanities	❑
Maths and Sciences	❑
Education	❑
Applied Health Sciences	❑
Business	❑
Undeclared	❑

10. Which hand is your dominant hand (i.e., are you right or left-handed)? Right ❑ Left ❑ Both ❑

11. Have you ever been hospitalized for any of the following? (check all that apply)

Fractures	❑
Illness	❑
Surgery	❑
Neurological complications	❑
Other	❑

If you checked off any of the above, briefly please provide details (e.g., How old were you? How did it happen?):

12. Have you ever been diagnosed with any neurological condition (e.g., epilepsy, multiple sclerosis, migraines, etc.)? Yes ❑ No ❑

a. If yes, if you wish to disclose your diagnosis, please do so:

13. Have you ever been diagnosed with a psychiatric condition (e.g., depression, anxiety, schizophrenia, etc.)? Yes ❑ No ❑

    a. If yes, if you wish to disclose your diagnosis, please do so:

14. Are you currently taking any prescribed medications for a neurological **or** psychiatric condition? Yes ❑ No ❑

    a. If yes, if you wish to disclose what medication, please do so:

15. Are you currently taking any prescribed medication for a thyroid condition? Yes ❑ No ❑

    a. If yes, if you wish to disclose what medication, please do so:

16. Are you currently taking any prescribed contraception (e.g., birth control pill)? Yes ❑ No ❑

17. Do you take medication for asthma such as an inhaler? Yes ❑ No ❑

18. Have you ever sustained an injury to your head with a force sufficient to alter your consciousness (e.g. confusion, dizziness, vomiting, seeing stars, **or** loss of consciousness)? Yes ❑ No ❑

19. Have you ever sustained a concussion? Yes ❑ No ❑

If you answered **NO to BOTH question 18 and 19**, move ahead to **question 38 (page 10)**

If you answered **YES to EITHER question 18 or 19**, please answer the following questions:

If you have had more than one injury/concussion, please refer to the ***MOST RECENT*** time you injured your head:

20. If you answered yes to question 18 either 19, did you experience these symptoms for more than 20 minutes? Yes ❑ No ❑

21. Was there evidence of skull fracture? Yes ❑ No ❑

22. Did you experience a loss of consciousness associated with the head injury? Yes ❑ No ❑ Unknown ❑

a. If **you answered yes**, how long was the loss of consciousness?

< 5 minutes	❑	< 1 week	❑
< 30 minutes	❑	< 1 month	❑
< 24 hours	❑	> 1 month	❑

23. Where did you strike/hit your head?

Front of the head	❑
Back of the head	❑
Right side of the head	❑
Left side of the head	❑
Top of the head	❑
Neck/Whiplash	❑
Indirect force (head was not directly hit)	❑
Cannot remember	❑

24. How did you injure your head?

Motor vehicle collision	❑
Fall	❑
Fight/Assault	❑
Sports-related injury Please specify sport:	❑
Other Please specify:	❑

25. Please briefly describe the incident during which the head injury occurred:

26. Please answer the following questions:

a. Did you have any loss of memory for events just PRIOR TO the injury? Yes ❑ No ❑

i. If **you answered yes**, what was the approximate length of time?

≤ 1 minute	❑	< 30 minutes	❑
< 5 minutes	❑	< 1 hour	❑
< 10 minutes	❑	≤ 24 hours	❑
< 20 minutes	❑	> 24 hours	❑

b. Did you have any loss of memory for events just AFTER the injury? Yes ❑ No ❑

i. If **you answered yes**, what was the approximate length of time?

≤ 1 minute	❑	< 30 minutes	❑
< 5 minutes	❑	< 1 hour	❑
< 10 minutes	❑	≤ 24 hours	❑
< 20 minutes	❑	> 24 hours	❑

c. Did you require any academic/employment accommodations for your injury? Yes ❑ No ❑

d. Did you receive any medical treatment for your injury? Yes ❑ No ❑

i. If yes, please provide the following details:

Visit to the emergency department	❑
Visit to a health professional (e.g., family doctor, walk-in clinic, etc.)	❑
Received stitches to the head/face	❑
Received stitches elsewhere	❑
Brain scan completed (e.g., CT, MRI)	❑
Overnight stay (single night) at a medical care facility	❑
Overnight stay (2 or more nights) at a medical care facility	❑
Sustained a bone fracture	❑
Sustained soft tissue injuries (e.g., muscles, ligaments)	❑
Surgical intervention directly related to the head trauma	❑
Other surgical intervention (e.g., orthopedic, vascular, etc.)	❑
Additional medical follow-up required (e.g., appointments, other medical assessment/monitoring)	❑

e. Approximately how old were you at the time of injury? _____years

i. If the injury occurred in the last 2 years, how many months has it been since you hit your head? _____ months

27. Did the injury result in any litigation process (e.g., a lawsuit or legal action/charge)? Yes ❑ No ❑

28. Have you sustained **more than one** injury to your head with a force sufficient to alter your consciousness (e.g., confusion, dizziness, vomiting, seeing stars, **or** loss of consciousness)? Yes ❑ No ❑

29. Have you sustained **more than one** concussion? Yes ❑ No ❑
    a. **If yes to 28 or 29**, how many times? **_____**

If you answered **NO to BOTH question 28 and 29**, move ahead to **question 38 (page 10)**

If you answered **YES to EITHER question 28 OR 29**, please answer the following questions with respect to your ***FIRST (LEAST RECENT)*** head injury/concussion:

30. If you answered yes to question 28 or 29 did you experience these symptoms for more than 20 minutes? Yes ❑ No ❑

31. Was there evidence of skull fracture? Yes ❑ No ❑

32. Did you experience a loss of consciousness associated with the head injury? Yes ❑ No ❑ Unknown ❑

a. If **you answered yes**, how long was the loss of consciousness?

< 5 minutes	❑	< 1 week	❑
< 30 minutes	❑	< 1 month	❑
< 24 hours	❑	> 1 month	❑

33. Where did you strike/hit your head?

Front of the head	❑
Back of the head	❑
Right side of the head	❑
Left side of the head	❑
Top of the head	❑
Neck/Whiplash	❑
Indirect force (head was not directly hit)	❑
Cannot remember	❑

34. How did you injure your head?

Motor vehicle collision	❑
Fall	❑
Fight/Assault	❑
Sports-related injury Please specify sport:	❑
Other Please specify:	❑

35. Please briefly describe the incident during which the head injury occurred:

36. Please answer the following questions:

a. Did you have any loss of memory for events just PRIOR TO the injury? Yes ❑ No ❑

i. If **you answered yes**, what was the approximate length of time?

≤ 1 minute	❑	< 30 minutes	❑
< 5 minutes	❑	< 1 hour	❑
< 10 minutes	❑	≤ 24 hours	❑
< 20 minutes	❑	> 24 hours	❑

b. Did you have any loss of memory for events just AFTER the injury? Yes ❑ No ❑

i. If **you answered yes**, what was the approximate length of time?

≤ 1 minute	❑	< 30 minutes	❑
< 5 minutes	❑	< 1 hour	❑
< 10 minutes	❑	≤ 24 hours	❑
< 20 minutes	❑	> 24 hours	❑

c. Did you require any academic/employment accommodations for your injury? Yes ❑ No ❑

d. Did you receive any medical treatment for your injury? Yes ❑ No ❑

i. If yes, please provide the following details:

Visit to the emergency department	❑
Visit to a health professional (e.g., family doctor, walk-in clinic, etc.)	❑
Received stitches to the head/face	❑
Received stitches elsewhere	❑
Brain scan completed (e.g., CT, MRI)	❑
Overnight stay (single night) at a medical care facility	❑
Overnight stay (2 or more nights) at a medical care facility	❑
Sustained a bone fracture	❑
Sustained soft tissue injuries (e.g., muscles, ligaments)	❑
Surgical intervention directly related to the head trauma	❑
Other surgical intervention (e.g., orthopedic, vascular, etc.)	❑
Additional medical follow-up required (e.g., appointments, other medical assessment/monitoring)	❑

e. Approximately how old were you at the time of injury? _____years

i. If the injury occurred in the last 2 years, how many months has it been since you hit your head? _____ months

37. Did the injury result in any litigation process (e.g., a lawsuit or legal action/charge)? Yes ❑ No ❑

If you were instructed to move ahead to question 38 please begin here

38. Have you ever been involved in a litigation process (e.g., lawsuit or legal action/charge) of any sort? Yes ❑ No ❑

39. Have you ever experienced any other neural trauma (e.g. stroke, anoxia)? Yes ❑ No ❑

a. **If yes**, please explain:

40. Do you smoke cigarettes? Yes ❑ No ❑

a. If **yes**, how long have you been smoking cigarettes? _____

b. Approximately how many cigarettes do you smoke in a day? _____

c. What are your general motives for smoking cigarettes? Select **all that apply.**

To deal with anxiety	❑
To cope with pain	❑
For pleasure	❑
Social interaction	❑
Other Please explain:	❑

41. Have you ever tried alcohol? Yes ❑ No ❑

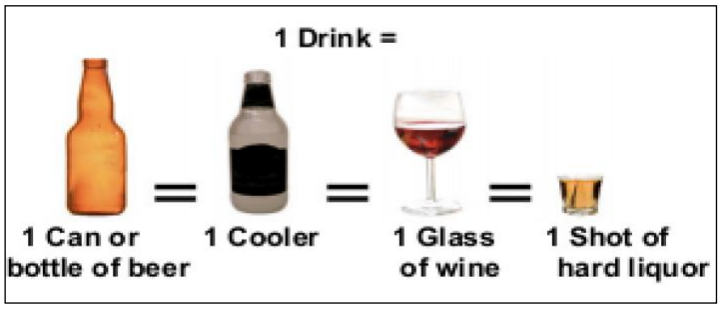
a. Do you regularly use alcohol? Yes ❑ No ❑

b. If **yes**, how long have you been drinking alcohol? _____

c. How old were you when you started using alcohol? _____

d. On average, how many days per week do you consume alcohol? _____ days/week

e. On average, how many drinks do you consume in one outing? _____drinks



f. On average, how many days per week do you drink to **intoxication**? _____ days/week

No use	❑	Weekly	❑
Once or Twice	❑	Daily	❑

g. How many times have you used alcohol in the past 30 days?

h. What are your general motives for consuming alcohol? Select **all that apply.**

For recreational enjoyment	❑
Social (e.g., at parties, with friends…etc.)	❑
To cope with anxiety and stress	❑
To address mood (e.g., depression)	❑
To manage pain (e.g. physical)	❑
To promote sleep	❑
Other medical reasons Please explain:	❑
Other Please explain:	❑

42. Have you ever tried cannabis (in any form)? Yes ❑ No ❑
43.

a. If you answered "no" to the previous questions, since cannabis is legal for recreational use, how likely are you to try it?

Never	❑	Not likely	❑
Somewhat likely	❑	Likely	❑
Very Likely	❑		

If you answered "yes" to question 42, please answer questions ***a to e****

a. Do you regularly use cannabis? Yes ❑ No ❑

b. If **yes**, how long have you been using cannabis? _____

c. How old were you when you started using cannabis? _____

d. On average, how many days per week do you use cannabis? _____

e. On average, how many days per week do you use cannabis to **impairment?** _____

*Also answer the accompanying questions in the CUDIT-m.

44. Do you engage in any recreational drug use? Yes ❑ No ❑

a. If yes, if you wish to disclose, please do so:

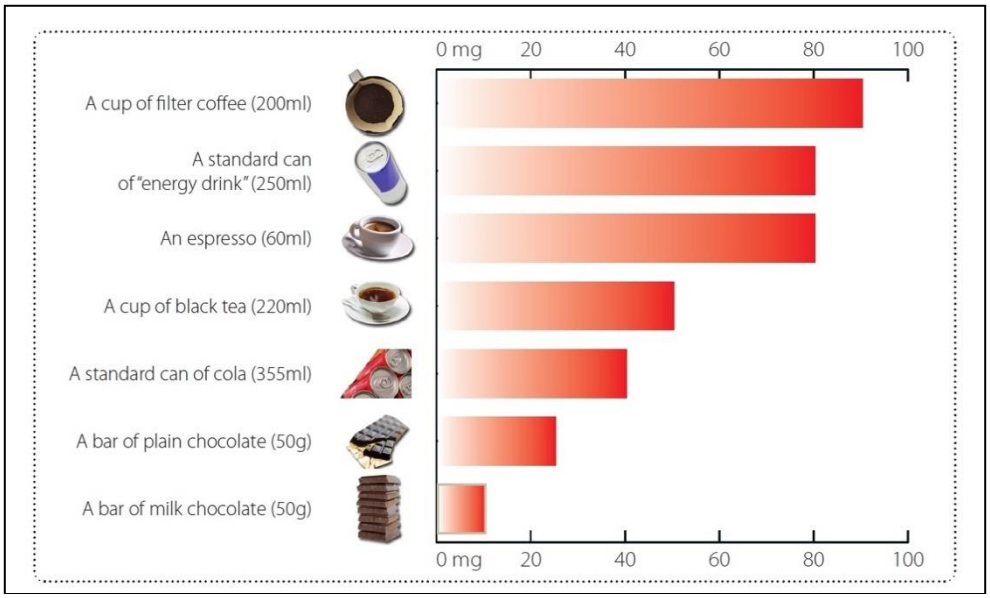
i. Do you take any performance enhancing drugs (e.g., anabolic steroids, hormones, stimulant drugs – **other than caffeine-based products** – such as amphetamine, ephedrine)? Yes ❑ No ❑

a. If yes, if you wish to disclose, please do so:

j. Did you consume caffeine today (e.g., coffee, tea, energy drink, chocolate)? Yes ❑ No ❑

a. **If yes**, how much time has passed since you last consumed caffeine today?

Less than 1 hour	❑
1 hour or More	❑



b. **If yes,** how much did you consume in milligrams?

_____

k. Do you have sensitivity to perfumes or scents? Yes ❑ No ❑

a. **If yes**, please rate your sensitivity on a scale from 1 to 9 (circle one number):

Not at all Sensitive								Very Sensitive
1	2	3	4	5	6	7	8	9

l. Do you have a valid driver's license? Yes ❑ No ❑

a. **If yes**, how long have you had a driver's license?

1-3 years	❑	7+ years	❑
4-6 years	❑	N/A	❑

m. Do you wear glasses or contacts? Yes ❑ No ❑

n. What is your current living situation?

On your own	❑	With parents/guardians	❑
With roommates	❑	Other	❑
With partner	❑		

o. How many university courses are you taking this semester?

1-2 courses	❑	5 courses	❑
3 courses	❑	6+ courses	❑
4 courses	❑	N/A	❑

p. Please rate your enjoyment of academics on a scale from 1 to 9 (circle one number):

Do not enjoy at all								Enjoy Very Much
1	2	3	4	5	6	7	8	9

q. What is your current academic average across all courses this semester (i.e., overall average)?

< 50%	❑	90% +	❑
50 – 59%	❑	Unsure	❑
60 – 69%	❑	Prefer not to say	❑
70 – 79%	❑	Unsure	❑
80 – 89%	❑		

r. Have you ever received any extra assistance during your educational history? Yes ❑ No ❑

a. **If yes**, please check all that apply:

	Elementary School	**High School**	**University**
Learning Resource Teacher	❑	❑	❑
Tutor	❑	❑	❑
Educational Assistant	❑	❑	❑
Speech Language Pathologist	❑	❑	❑
Occupational Therapist	❑	❑	❑
Physical Therapist	❑	❑	❑
Other Please specify:	❑	❑	❑

s. Have you ever been diagnosed or classified as having a Learning Disorder? Yes ❑ No ❑

a. If yes, if you wish to disclose your diagnosis, please do so:

t. Do you **currently** consider yourself a musician? Yes ❑ No ❑

u. Have you **ever** considered yourself to be a musician? Yes ❑ No ❑
   a. **If yes to 55 or 56,** at what level did you/do you play/perform?

Professionally	❑
Recreationally	❑
Both	❑

   b. How many months or years did you play/perform for (if current, how many months or years have you been playing for)?
   _____

   c. What age did you start playing/performing at? _____ years old

v. How many hours per week do you listen to music?

0	❑	11-20	❑
1-2	❑	21-40	❑
3-5	❑	41+	❑
6-10	❑		

w. Please indicate the type of music you listen to **MOST** often **(choose only one)**?

Country	❑
Classical	❑
Rock	❑
R&B	❑
Blues	❑
Independent (Indie	❑
Jazz	❑
Hip Hop	❑
Electronic (House/Dance)	❑
Rap	❑
Folk/Celtic	❑
Pop	❑
Opera	❑
Heavy Metal	❑
Reggae	❑
Acoustic/Soft Rock	❑
Other Please specify:	❑

x. Please rate your enjoyment of your life situation on a scale from 1 to 9 (circle one number):

Do not enjoy at all								Enjoy Very Much
1	2	3	4	5	6	7	8	9

y. Please rate how stressful your day-to-day life is on a scale from 1 to 9 (circle one number):

Not stressful at all								Very Stressful
1	2	3	4	5	6	7	8	9

z. Do you **currently** engage in any sporting/athletic activities? Yes ❑ No ❑

a. **If yes,** which sport(s) do you **currently** participate in (check all that apply):

	Recreational	**Competitive**	**Both**
Soccer	❑	❑	❑
Hockey	❑	❑	❑
American Football	❑	❑	❑
Fencing	❑	❑	❑
Figure Skating	❑	❑	❑
Volleyball	❑	❑	❑
Cheerleading	❑	❑	❑
Baseball/Softball	❑	❑	❑
Basketball	❑	❑	❑
Track and Field	❑	❑	❑
Indoor Soccer	❑	❑	❑
Extreme Intramurals (Mixed Sports)	❑	❑	❑
Martial Arts	❑	❑	❑
Tennis	❑	❑	❑
Rowing/Kayak	❑	❑	❑
Lacrosse	❑	❑	❑
Rugby	❑	❑	❑
Wrestling	❑	❑	❑
Curling	❑	❑	❑
Swimming	❑	❑	❑
Other (Please specify):	❑	❑	❑

b. How many hours per week do you **currently** participate in sports?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

c. Out of the sports endorsed above, which **ONE** do you participate in the **most** each week?

Soccer	❑	Extreme Intramurals (Mixed Sports)	❑
Hockey	❑	Martial Arts	❑
American Football	❑	Tennis	❑
Fencing	❑	Rowing/Kayak	❑
Figure Skating	❑	Lacrosse	❑
Volleyball	❑	Rugby	❑
Cheerleading	❑	Wrestling	❑
Baseball/Softball	❑	Curling	❑
Basketball	❑	Swimming	❑
Track and Field	❑	Indoor Soccer	❑
Other (Please specify):	❑		

aa. Did you engage in any sporting/athletic activities in **high school**? Yes ❑ No ❑

a. **If yes,** which sport(s) did participate in when you were in **high school** (check all that apply):

	Recreational	**Competitive**	**Both**
Soccer	❑	❑	❑
Hockey	❑	❑	❑
American Football	❑	❑	❑
Fencing	❑	❑	❑
Figure Skating	❑	❑	❑
Volleyball	❑	❑	❑
Cheerleading	❑	❑	❑
Baseball/Softball	❑	❑	❑
Basketball	❑	❑	❑
Track and Field	❑	❑	❑
Indoor Soccer	❑	❑	❑
Extreme Intramurals (Mixed Sports)	❑	❑	❑
Martial Arts	❑	❑	❑
Tennis	❑	❑	❑
Rowing/Kayak	❑	❑	❑
Lacrosse	❑	❑	❑
Rugby	❑	❑	❑
Wrestling	❑	❑	❑
Curling	❑	❑	❑
Swimming	❑	❑	❑
Other (Please specify):	❑	❑	❑

b. How many hours per week did you participate in sports in **high school**?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

c. Out of the sports endorsed above, which **ONE** did you play the **most** in **high school**?

Soccer	❑	Extreme Intramurals (Mixed Sports)	❑
Hockey	❑	Martial Arts	❑
American Football	❑	Tennis	❑
Fencing	❑	Rowing/Kayak	❑
Figure Skating	❑	Lacrosse	❑
Volleyball	❑	Rugby	❑
Cheerleading	❑	Wrestling	❑
Baseball/Softball	❑	Curling	❑
Basketball	❑	Swimming	❑
Track and Field	❑	Indoor Soccer	❑
Other (Please specify):	❑		

bb. Did you engage in any sporting/athletic activities in **elementary school**? Yes ❑ No ❑

a. **If yes,** which sport(s) did participate in when you were in **elementary school** (check all that apply):

	Recreational	**Competitive**	**Both**
Soccer	❑	❑	❑
Hockey	❑	❑	❑
American Football	❑	❑	❑
Fencing	❑	❑	❑
Figure Skating	❑	❑	❑
Volleyball	❑	❑	❑
Cheerleading	❑	❑	❑
Baseball/Softball	❑	❑	❑
Basketball	❑	❑	❑
Track and Field	❑	❑	❑
Indoor Soccer	❑	❑	❑
Extreme Intramurals (Mixed Sports)	❑	❑	❑
Martial Arts	❑	❑	❑
Tennis	❑	❑	❑
Rowing/Kayak	❑	❑	❑
Lacrosse	❑	❑	❑
Rugby	❑	❑	❑
Wrestling	❑	❑	❑
Curling	❑	❑	❑
Swimming	❑	❑	❑
Other (Please specify):	❑	❑	❑

b. How many hours per week did you participate in sports in **elementary school**?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

c. Out of the sports endorsed above, which **ONE** did you play the **most** in **elementary school**?

Soccer	❑	Extreme Intramurals (Mixed Sports)	❑
Hockey	❑	Martial Arts	❑
American Football	❑	Tennis	❑
Fencing	❑	Rowing/Kayak	❑
Figure Skating	❑	Lacrosse	❑
Volleyball	❑	Rugby	❑
Cheerleading	❑	Wrestling	❑
Baseball/Softball	❑	Curling	❑
Basketball	❑	Swimming	❑
Track and Field	❑	Indoor Soccer	❑
Other (Please specify):	❑		

cc. Do you exercise regularly? Yes ❑ No ❑

a. **If yes**, what type of exercise do you engage in (check all that apply)?

Weight training	❑	MMA/Martial Arts	❑
Powerlifting	❑	Circuit Training	❑
Jogging/Running	❑	Swimming	❑
Zumba	❑	Walking	❑
Spin Class	❑	Yoga	❑
Pilates	❑	Other Please specify:	❑

b. How many hours per week do you exercise?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

dd. When you ride a bike/skate/etc. do you wear a helmet? Yes ❑ No ❑

ee. Do you regularly engage in relaxation techniques Yes ❑ No ❑
(e.g., deep breathing or yoga)?

a. **If yes**, what relaxation techniques do you use (check all that apply)?

Deep breathing	❑	Meditation	❑
Guided imagery	❑	Massage	❑
Progressive muscle relaxation	❑	Other Please specify:	❑

b. How many hours per week do you engage in relaxation methods?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

ff. Was last night's sleep typical for you? Yes ❑ No ❑

a. **If no**, what was different?

Worse sleep	❑
Better sleep	❑

b. Please explain why last night's sleep was different for you (e.g., stress, temperature, noise, etc.):

c. Please rate how well you slept last night on a scale from 1 to 7 (circle one number):

Worst Possible Sleep						Best Possible Sleep
1	2	3	4	5	6	7

gg. Please indicate how you feel right now on a scale from 1 to 7 (circle one number):

Very Sleepy						Very Alert
1	2	3	4	5	6	7

hh. Are you currently employed? Yes ❑ No ❑

a. If yes, how many hours per week do you currently work?

0-1 hours	❑	5-10 hours	❑
1-2 hours	❑	10-12 hours	❑
2-5 hours	❑	12+ hours	❑

ii. Are you a shift worker (i.e., work hours outside of a traditional daily schedule)? Yes ❑ No ❑

jj. Have you had anything out of the ordinary occur in the past day or so? Yes ❑ No ❑

a. **If yes**, please explain:

kk. Check any of the following that apply to your experience over the past **6 months**:

Moved	❑	Death of a family member	❑
New Job	❑	Death of a close friend	❑
Loss of Job	❑	Financial difficulties	❑
Loss of Relationship	❑	Illness of someone close to you	❑
New Relationship	❑	Personal illness/injury	❑
Reconciliation with partner	❑	New Baby	❑
Reconciliation with family	❑	Wedding/Engagement (self)	❑
Divorce (of self or parents)	❑	Vacation	❑
Entered 1st year at University	❑	Disrupted Sleep	❑

Question 72 format adapted from Holmes, T. & Rahe, R (1967). "Holmes-Rahe life changes scale". Journal of Psychosomatic Research, Vol. 11, 213-218.

ll. Please indicate how your day has been so far by **circling one number on each** of the following three scales:

Pleasant									Unpleasant
1	2	3	4	5	6	7	8	9	10

Not Stressful									Very Stressful
1	2	3	4	5	6	7	8	9	10

Calm									Busy
1	2	3	4	5	6	7	8	9	10

mm. Please rate each of the following symptoms based on how you may have been affected during **the past 2 months** according to the following scale.

Frequency	Intensity	Duration
1 = Not at all	1 = None	1 = Not at all
2 = Seldom	2 = Uncomfortable	2 = A Few Seconds
3 = Often	3 = Irritating	3 = A Few Minutes
4 = Very Often	4 = Interfering	4 = A Few Hours
5 = All of the time	5 = Crippling	5 = Constant

	Frequency	Intensity	Duration
Headache			
Dizziness			
Irritability			
Memory Problems			
Difficulty Concentrating			
Fatigue			
Visual Disturbance			
Aggravated by Noise			
Judgment Problems			
Anxiety			

Question 66 from Gouvier et al. (1992)

Thank you for your time and consideration in completing this questionnaire!

CUDIT-m 2020

1. Which of the following best captures the average frequency you currently use cannabis?

1= less than once a year
2= once a year
3= once every 3-6months (2-4 times/yr)
4=Once every 2 months (6 times/yr)
5= once a month (12 time/yr)
6= 2-3 times a month
7 = once a week
8 = twice a week
9 = 3 – 4 times a week
10 = 5 – 6 times a week
11 = once a day
12 = more than once a day

2. Which of the following best captures how long you have been using cannabis at this frequency?

1 = less than 1 month
2 = 1 – 3 months
3 = 3 – 6 months
4 = 6 – 9 months
5 = 9 – 12 months
6 = 1 – 2 years
7 = 2 – 3 years
8 = 3 – 5 years
9 = 5 – 10 years
10 = 10 – 15 years
11 = 15 – 20 years
12= more than 20 years

3. Which of the following best captures the number of times you have used cannabis in your entire life?

1 = 1 – 5 times in my life
2 = 6 – 10 times in my life
3 = 11 – 50 times in my life
4 = 51 –100 times in my life
5 = 101 – 500 times in my life
6 = 501 – 1000 times in my life
7 = 1001 – 2000 times in my life
8 = 2001 – 5000 times in my life
9 = 5001 – 10,000 times in my life
10 = More than 10,000 times in my life

4. Which of the following best captures when you last used cannabis?

1 = over a year ago
2 = 9 – 12 months ago
3 = 6 – 9 months ago
4 = 3 – 6 months ago
5 = 1 – 3 months ago
6 = less than 1 month ago
7 = last week
8 = this week
9 = yesterday
10 = today*
11 = I am currently high*

4.b If you answer *10 or *11 in question 3 above, how impaired are you right now?

0 = I am not at all high
1 = I am a little bit high
2 = I am moderately high
3 = I am very high

5. How many days of the past week did you use cannabis?

1 = 1 day
2 = 2 days
3 = 3 days
4 = 4 days
5 = 5 days
6 = 6 days
7 = 7 days

6. Which of the following best captures your pattern of cannabis use throughout the week?

1 = I only use cannabis on weekends
2 = I only use cannabis on weekdays
3 = I use cannabis on weekends and weekdays

7. How many hours after waking up do you typically first use cannabis?

1 = 12 – 18 hours after waking up
2 = 9 – 12 hours after waking up
3 = 6 – 9 hours after waking up
4 = 3 – 6 hours after waking up
5 = 1 – 3 hours after waking up
6 = within 1 hour of waking up
7 = within ½ hour of waking up
8 = immediately upon waking up

8. How many times a day, on a typical weekday, do you use cannabis? _____

9. How many times a day, on a typical weekend, do you use cannabis? _____

10. Identify, in rank order, all the ways in which you use cannabis, beginning with 1 as the primary method

1 = Joints
2 = Blunts (cigar sized joints)
3 = Hand pipe
4 = Bong (water pipe)
5 = Hookah
6 = Vaporizer (e.g., Volcano, Vape pen)
7 = Edibles
8=other (please explain)

For question 11 below, clearly indicate the number of grams of cannabis you use with a number between 0 – 100. Do NOT include other forms of cannabis you may use (such as concentrates). You may use up to 3 decimals to indicate amounts under 1 gram.

11. In a typical session, how much cannabis do you personally use? _____

12. On a typical day you use cannabis, how many sessions do you have? _____

13 a. Are you aware of the average THC content (%) of the cannabis you use?

0=No
1= Yes

13 b. What is the average THC content (%) of the cannabis you typically use? Leave blank if you do not know.

0-1.99% (little to minimal)	12-16.99% (medium)
2-6.99% (very mild)	17-20% (strong)
7-11.99% (mild)	>20% (very strong)

14 a. Are you aware of the average CBD content of the cannabis you use?

0=No
1= Yes

14 b. Approximately what is the average CBD content of the cannabis you typically use? Leave blank if you do not know.

little to minimal	medium
very mild	strong
mild	very strong

15. How many years in total have you used cannabis? _____

16. How old were you when you FIRST tried cannabis? _____

17. Has there been a in your life when you used cannabis ***regularly*** (2 or more times per month for 6 months or longer)?

0 = No
1 = Yes*

**If response = 1 (Yes) then answer questions 17b and 17c below*

17b. How old were you when you FIRST STARTED using cannabis regularly (2 or more times/month, for 6 months or longer)? _____

17c. Has there been any time in your life when you used cannabis on a daily or near daily basis for 6 months or longer?

0 = No
1 = Yes*

**If response = 1 (Yes) then answer question 17ci below*

17ci. How old were you when you FIRST STARTED using cannabis on a daily or near daily basis? _____

18. Do you have a physician's recommendation to use cannabis for medicinal purposes?

0 = No
1 = Yes*
2 = Yes, but I use it for both medicinal and recreational purposes*

**If response = 1 or 2 (Yes) then answer questions 18b*

18b. Which medical condition(s) do you use cannabis for?

_____

19. Do you simultaneously use cannabis with any recreational substances? (e.g., alcohol, cocaine, LSD, energy drinks, steroids)

0=No
1=Yes

If so, please specify:

20. Has a relative, friend, or regulated health professional expressed concern about your use of cannabis or suggested you cut down over the past 6 months? Please check all that apply

1= Relative
2= Friend
3= Regulated health professional (e.g., Doctor, Psychologist, Nurse,.. etc..)

0= N/A

21. How often in the past 6 months have you had a problem with your memory or concentration after using cannabis?

0= Never
1= Once or twice
2=Monthly
3= weekly
4= almost daily
5= daily

22. Have you had symptoms **in the past** you believe were induced, increased, or reduced by cannabis use? Check all that apply.

Induced
Increased
Reduced
N/A

If so, please explain:

23.Do you **currently** believe that cannabis use induces, increases, or reduces symptoms? Check all that apply.

Induces
Increases
Reduces
N/A

If so, please explain: