Influence of Head Injury on Episodic Memory, Meta-memory, and Cannabis Use

By

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Abstract

Mild head injuries (MHI) are implicated in impairments of various cognitive constructs, including memory. Specifically, episodic memory performance is shown to be dampened post-MHI. Further, head injuries are also associated with problems in processing and reacting to emotional stimuli and, overall, research has shown that those with head injuries are less able to recall emotional stimuli compared to their No-MHI cohort. This literature is lacking in detailed measures of narrative episodic memory, especially in those with milder versus moderate or severe head injuries. Most studies implement word-list tasks to assess episodic memory, so the aim of the present study was to assess episodic memory using a story task, which is more reflective of memory usage required in day-to-day tasks. The goal of this research was to examine emotionally-valenced narrative recall in persons with MHI, while accounting for possible emotion effects. Subjective-memory, or meta-memory, was also of interest.

As head injuries are whole-brain events, various neurological structures can be impacted, but in particular, involvement of the prefrontal cortex (PFC) has been acknowledged. Even minor disruption to the PFC is associated with impulse control and sensation-seeking behaviours, including substance use. Those with a history of MHI have been shown to be more vulnerable to substance use/abuse. Given the recent legalisation of cannabis in Canada and its increased medical and recreational use, in addition to its influence on memory and cognitive, this research also investigates the nature, and interaction, of cannabis consumption in relation to MHI.

This study recruited 134 Brock University students to assess the relationships between MHI and episodic memory, subjective memory, emotional processing, and cannabis use. Results indicated that the MHI group performed similarly to the No-MHI group in recall capacity, and with both groups demonstrating a potent valence-related effect. Further, cannabis use was reported to a

greater degree by those with an MHI, demonstrating that high-functioning university students have the facilities to overcome possible narrative episodic memory impairments attributable to a head injury, however, they remain disadvantaged in terms of substance use and are disproportionately affected by it.

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Influence of Head Injury on Episodic Memory, Metamemory, and Cannabis Use

In Canada, traumatic brain injuries (TBI) account for 23% of all injury related deaths (Kureshi et al., 2021) with mild traumatic brain injuries (mTBI) e.g., concussions, accounting for approximately 70-90% of all TBI cases (Ryu & Dawson, 2009). According to the public health agency of Canada (2014), TBIs are likely to be among the most common neurological conditions alongside Alzheimer's and epilepsy by the year 2031. As a result, the care and resources needed to diagnose and treat head injuries continue to take an extensive toll on the Canadian health care system; in Ontario alone, medical costs for hospitalised patients with a TBI were approximately $120 million in the first follow-up year (Chen et al., 2012). Furthermore, global costs attributed to TBI accumulate to more than CAD$500 billion annually (Maas et al., 2017); as incidence rates for mTBI are likely higher than reported due to missed diagnoses by physicians (Ryu et al., 2009) and general underreporting of concussions (Kroshus et al., 2014), the overall fiscal and socioeconomic impact of head injuries is also likely to be greater than the current estimate.

TBIs have been referred to as the silent epidemic due to the fact that much of the post-injury symptomology is not visually presented. For example, TBI is associated with impaired executive functioning, slower cognitive processing, and also difficulty in emotion regulation – all of which do not necessarily present overtly (Bedard, Steffener, & Taler, 2020; Gorgoraptis et al., 2019; McDonald, 2013). Further, TBI exists on a spectrum of severity categorised by mild, moderate, and severe, and assignment of the type of TBI is usually based on factors such as duration of loss of consciousness and duration of amnesia (Esselman & Uomoto, 1994). The criteria required to organise the spectrum into each category is heavily debated in the literature because depending on the TBI severity classification, the presentation, intensity, and duration of post-injury related symptoms are likely to vary.

Mild TBI symptomology is at the centre of that debate because it is still not clear how long symptoms present in mTBI cases (Tenovuo et al., 2021). Those that have suffered an mTBI report experiencing symptoms such as poorer declarative memory, attention, and overall cognition up to three months post-injury, commonly referred in the literature as the acute phase (Bedard et al., 2020). However, there is also a portion of individuals with mTBI who report experiencing symptoms well beyond the acute phase, characterised as post-concussive syndrome (PCS). Nelson et al. (2019) found that 53% of participants with an mTBI diagnosis reported having persistent symptoms such as headaches, fatigue, depression, and forgetfulness, one year after the injury. Therefore, the literature would benefit from further research into the symptomology resulting from injuries of a milder nature on the spectrum of TBI severity.

Definition of Brain Injury

The brain injury literature would also benefit from selecting a consistent definition of what constitutes a TBI. According to Tenovuo et al. (2021), there are at least 40 different definitions of mTBI/mild head injury (MHI) used in the literature, and that number only rises when accounting for TBI definitions altogether. For the purpose of this thesis, the definition by Caplan et al., (2016) most adequately captures the criteria required to diagnose a TBI: The individual must experience disrupted brain functioning from any force to the head as evidenced by altered or lost consciousness. For an mTBI specifically, there must be less than 30 minutes of loss of consciousness (LOC), and less than 24 hours of memory loss as a result of the injury (Hon et al., 2019). Notably, LOC to any extent likely raises severity of the injury, as there is a plethora of research demonstrating more severe consequences in those with LOC from their injury versus without.

The Glasgow Coma Scale

The Glasgow Coma Scale (GCS) is designed to evaluate an individual's responses to stimuli, in an effort to assess their level of consciousness on a scale of 0-15 (Teasdale et al., 2014). The scale has three categories: The degree of eye opening (four levels), verbal response (five levels), and best motor response (six levels). The categories' levels sum to a total score of 15 which represents little to no impaired consciousness. Using this scale, TBIs are categorized as mild when the GCS is 13-15, moderate when it is 9-12, and severe when it is 3-8 (Khellaf et al., 2019; Teasdale et al., 2014). Notably, a score of 13 was previously representative of a moderate injury until the Advanced Trauma Life Support (ATLS) changed it to represent a mild injury. As a result, there has been some research contesting the change; for example, a classification of 13 as moderate is more predictive of mortality in individuals with TBI, (Mena et al., 2011) and is also associated with more abnormal neuroimaging scans than scores of 14 and 15 (Shukla & Devi, 2010).

Mechanisms of TBI

Falls and motor vehicle accidents account for the two main causes of TBI, with the rest resulting from other incidences such as assault and gunshot wounds (Majdan et al., 2011). Although the portions vary globally and based on factors such as age and income, in Canada, approximately 45% and 29% of TBIs are attributed to falls and motor vehicle accidents respectively (Kureshi et al., 2021). A TBI is the result of contact and inertial forces (e.g., from a fall) that cause damage to the brain tissue (McAllister, 2022). Specifically, a contact injury occurs when an external force causes the brain to make an impact with surfaces inside the skull. Upon impact, cerebrospinal fluid (CSF) flows where the external force was applied to create a protective cushion for the brain. This leaves the opposite region of the brain vulnerable to the

rebounding forces of the impact (Ramzanpour et al., 2018). Thus, the initial impact results in a coup injury, and the possible rebounding impact on the opposite side results in a contrecoup injury (Drew & Drew, 2004).

In addition to contact forces causing coup-contrecoup injuries, inertial forces can cause further damage due to the rotational acceleration of the brain. Rapid acceleration and deceleration of the brain can cause overstretching of white matter tracts, leading to microscopic tears in axonal integrity (Ma et al., 2016). These tears can then lead to swelling along the axon, eventually causing axonal disconnection, and effectively slowing signal transmission. This process is often referred to as diffuse axonal injury (DAI), as the axonal lesions resulting from a TBI can affect multiple regions of the brain. The repercussions of DAI are most notably observed in white matter tracts in the cortical regions and brainstem, among others (Siedler et al., 2014). It is clear that cortical regions of the brain are involved in important cognitive domains such as memory and executive functioning, and evidently, research suggests that those domains suffer a decline in performance following even mild DAI (Grassi et al., 2021; Scheid et al., 2006). Therefore, depending on the nature of the TBI, even mild injuries can result in a pleura of physiological repercussions.

Pathophysiology of TBI

A metabolic cascade of brain injury is set off upon damage to the axons (primary injury), leading to further cell death (secondary injury). First, potassium (K^+) leaves the effected neurons causing the cell membrane to depolarise in a process known as impact depolarisation (Capizzi, et al., 2020). This depolarisation leads to depletion of the region's energy stores, triggering the release of excitatory transmitters such as glutamate. The ion influx caused by the binding of glutamate at its receptor cites is partly responsible for the swelling observed during DAI

(Wagner & Zitelli, 2013). As a result of the efflux of K^+, calcium (Ca^{2+}) and sodium (Na+) enter the cell in large amounts. This influx causes overexertion of the sodium-potassium pump in an effort to maintain homeostasis (MacFarlane & Glenn, 2015; Giza & Hovada, 2001). The sodium-potassium pump is dependent on Adenosine triphosphate (ATP) for energy, so as the pump is overloaded, the available ATP is also exhausted. Thus, hyper consumption of ATP leaves the effected regions in an energy deficit (2015). The energy deficit present following injury instates a window within which the brain is ill-equipped to respond to another TBI. This vulnerability may be why those with a history of multiple concussions have worse behavioural and cognitive outcomes than those with a single concussion (MacFarlane & Glenn, 2015; Iverson et al., 2004).

The energy imbalance increases the production of reactive oxygen species (ROS), which play a role in various physiological processes that damage the cell and eventually lead to cell death (Di Pietro et al., 2018). For example, ROS are implicated in the initiation of programmed cell death (i.e., apoptosis, necrosis), and microvascular hypoxia; the levels of hypoxia that cells can tolerate varies, so severe hypoxia as a result of ROS being present can cause further cell death (Capizzi et al., 2020; Li & Jackson, 2002). Hypoxia interferes with proper functioning of mitochondria in cells, leading to an increased amount of lactate build-up, as damaged cells are not able to utilize the lactate being produced (Carpenter et al., 2015; Raghupathi et al., 2000).

In addition to impact depolarization, the force expelled upon the cerebral tissue as a result of the injury changes the permeability of the blood-brain barrier (BBB), causing extracellular accumulation of fluid due to vascular leakage (Di Pietro et al., 2015; Michinaga, & Koyama, 2015). The permeability allows certain microphages and microglia to flow through and initiate the release of pro-inflammatory cytokines (Di Pietro et al., 2015). Specifically, the cytokines involved in the pro-inflammatory process include tumor necrosis factor (TNF), interleukin (IL)

peptides, nerve growth factor (NGF), and transforming growth factor-β (TNF-β) (Lenzlinger et al., 2001). It is evident that the end of the cascade of TBI results in an inflammatory response, however, whether that inflammation is entirely negative is unknown. As Lenzlinger et al. (2001) suggest, it is possible that despite the cell death caused by inflammation, neuronal swelling may also be paving the way for mechanisms that have neuroprotective properties.

Neuroimaging of TBI

Computed tomography (CT) scans and magnetic resonance imaging (MRI) are useful tools for detecting lesions and hemorrhaging that results from moderate to severe TBI, however, diagnosing and identifying a history of mild brain injury through traditional neuroimaging techniques is difficult. The axonal alterations that occur as a result of long-term DAI cannot be easily detected by CT scans, MRI, and electroencephalogram (EEG) (Belanger et al., 2010), especially when the injury does not result in cerebral hematomas or lesions. Therefore, diagnoses of mTBI are commonly reliant on measures other than neuroimaging (e.g., GCS scores), however, some imaging techniques do aid in identifying signs of short-and long-term consequences of the injury. One such method is diffusion tensor imaging (DTI), which maps the organisation of white matter tracts in the brain to identify the strength of connections between various brain regions (Jones & Leemans, 2011; Tournier et al., 2011). DTI imaging can be used to track the long-term changes that occur as a result of brain injury as demonstrated by June et al. (2020), who found that participants with a history of concussion consistently had greater temporal lobe, hippocampal, and other microstructural white matter atrophy at multiple timepoints of the longitudinal study. This suggests that DTI is useful for not only identifying obvious injury markers of TBI for various vulnerable structures, but also the small-scale microstructural deficits that result from DAI.

Additionally, the ability to identify the connections between regions provides significant clarity into the behavioural and cognitive consequences that occur as a result of TBI; by identifying connections between regions of interest, weakening of those tracts as a result of DAI offers insight into their function and vulnerability. Inferences into the behavioural consequences tied to the degradation of certain regions can also be made. For example, a review by Jain et al. (2021) reported that although DTI scans completed 2-3 years post-injury did not show differences between mTBI and no-TBI participants, DTI done within six months following injury demonstrated differences in diffusion metrics between the two groups. This suggests that DTI can be a useful tool for specifying not only the initial damage as a result of TBI, but also the time period of neurostructural recovery.

Alternative imaging methods that provide further insight into mTBI include susceptibility weighted imaging (SWI) for detection of microbleeds, and functional magnetic resonance imaging (fMRI) for tracking relative changes in neuronal activity and connectivity (Ng et al., 2014; Sherer & Sander, 2014). With the use of SWI, Huang et al. (2015) found that individuals with mTBI were four times more likely to have microbleeds present than controls. Moreover, those with microbleeds suffered worse performance on a digit-span short-term memory task, demonstrating that microhemorrhage detection through SWI may aid in identifying injury severity and its resulting cognitive deficits.

With regard to fMRI, the ability to track neuronal activity changes between injured and non-injured individuals allows for a vast application of the technology. A prominent finding using fMRI suggests that those with brain injuries are more likely to have activation of regions outside the primary regions of interest during cognitive tasks (Zhang et al., 2010). Research on this discrepancy of activation suggests that due to damage and likely DAI in the region required

for a task (e.g., frontal lobe in an executive functioning task), the region's resources are drained, thus requiring activation from other regions to compensate for the loss in function (Medaglia, 2017). Behaviourally, this increased energy consumption contributes to a feeling of cognitive fatigue, commonly reported in those with TBI (Johansson, 2021; Wylie & Flashman, 2017; Kohl et al., 2009). These findings are made possible due to the excellent spatial resolution offered by fMRI relative to other measures, which is why the technology has drastically improved the literature on brain injury and its subsequent consequences. Generally, various imaging techniques are implemented successfully in the literature to explore the short-term and long-term consequences of TBI, however it remains difficult to diagnose mild head injuries through imaging alone.

Vulnerable Regions During TBI

Brain injuries are whole-brain events in that the short-and long-term physiological repercussions are often diffuse. Given this, understanding which areas of the brain are most vulnerable to the contact and inertial forces during an injury, offers more insight into the behavioural and cognitive consequences of TBI. Due to the boney protrusions inside the skull and the overall positioning of the brain, the cortical regions of the brain are most vulnerable to contact forces during an injury i.e., coup-contrecoup injuries. Generally, the anterior and inferior areas of the frontal and temporal lobes of the brain are most commonly susceptible to damage (Isokuortti, 2018; Fujiwara et al., 2008), and the behavioural and cognitive deficits that present following TBI are reflective of the functionality of these brain regions. For example, dorsolateral prefrontal cortex damage is associated with poor memory performance, and orbitofrontal cortex damage is associated with personality changes, such as increased irritability and mood instability (Salloway et al., 2008). Further, executive functioning difficulties from TBI are widely reported

throughout the literature and may be the most prominent symptom affecting day-to-day living post-injury (Gallego et al., 2022; Gioia & Isquith, 2004). As all of these deficits are among the most common symptoms reported following a brain injury and are substantially tied to frontal lobe functionality, they reflect its vulnerability to contact and rotational forces during an injury (McAllister, 2022).

Similarly, the functions of the orbitofrontal cortex (OFC) also reflect the symptoms that many with a history of head injury face. It is evident that the OFC is responsible for conscious olfactory perception (Mori et al., 2013; Li et al., 2010), so unsurprisingly, research suggests that those with even mild head injuries often report a weaker sense of smell compared to their non-injured cohort (Lecuyer-Giguère et al., 2019; Fortin et al., 2010). Further, the input of the OFC in affect-driven processes likely impacts some of the affect-related cognitive deficits associated with TBI. As previously mentioned, TBI impairs memory performance; so given that the OFC enhances the retrieval of emotional memories (Kumfor et al., 2013), damage in that region is likely involved in the emotional memory impairments reported by those with a TBI (Hebscher et al., 2016; Brand & Markowitsch, 2006).

In relation, the ventromedial prefrontal cortex (vmPFC) is located just below the OFC, and it contributes to various memory functions such as episodic memory retrieval (Bertossi et al., 2016). Additionally, it works to modulate autonomic physiological arousal (Zhang et al., 2014; Zald, 2008). Research from our Neuropsychology and Cognitive Research (NCR) lab at Brock University has shown repeatedly that those with MHI are physiologically underaroused as evidenced by relatively lower electrodermal activation (EDA) than their non-injured cohort (Baker & Good, 2014; van Noordt & Good, 2011). This underarousal supports research suggesting that the vmPFC is highly vulnerable during a TBI (McAllister, 2022). As the somatic

marker hypothesis (SMH) suggests, the vmPFC integrates visceral states and underlying emotions into higher cognitive functions, such as decision making and planning (Damasio, 1996). This is likely why physiological underarousal (as a measure of skin conductance) has been associated with riskier decision making (Critchley et al., 2001; Bechara et al., 1997), especially when decisions are reliant on emotional states like anxiety, sadness, and anger (Herman et al., 2018; Kreibig, 2010).

In addition to the frontal lobe, the temporal lobes can also face extensive strain depending on the direction of impact (Isokuortti, 2018; Niogi & Mukherjee, 2010). It is evident that the temporal lobe plays a key role in the recollection of memories (Wixted & Squire, 2011) so its vulnerability to a TBI is likely implicated in the various memory difficulties reported by head-injured individuals. Research on the acceleration and resulting impact of the brain during injury often implicates the temporal lobe; a simulation of 28 participants with football-related concussions found that in nine of those injuries, the impact force caused primary strain on the temporal lobe adjacent to the impact (Viano, et al., 2005). Due to acceleration forces, the primary strain can then migrate across to other regions such as the fornix and midbrain. The stretching and shearing of white matter tracts in these regions can lead to further difficulties in memory and cognition (Adamson et al., 2013; Niogi & Mukherjee, 2010; Viano et al., 2005). Further, although not as common as cortical injuries, structures in the hind brain are also vulnerable due to impact and DAI; for example, cerebellar damage is implicated in similar outcomes to TBI, such as motor and cognitive impairments (Wang et al., 2016; Park et al., 2007). Overall, it is evident that TBI is a whole-brain event in that despite initial damage to a particular region, the cascade of brain injury can result in impaired functioning of various sub-regions and structures.

Cognitive and Behavioural Sequalae of Mild Head Injury

Moderate and severe brain injuries have various negative behavioural and cognitive consequences; however, the literature would benefit from more research into the extent to which MHI symptomology presents itself post-injury. MHI events are often downplayed because of the belief that somatic symptoms from concussions last for 7-14 days on average . Unfortunately, there is a lack of awareness regarding the cognitive and emotional symptoms that take far longer to recover post-MHI. These symptoms can develop during the acute injury phase, but then linger for months, years, or sometimes present permanently (Polinder, 2018; King, 2014). Given the large variability in the extent and intensity of cognitive and behavioural post-concussive symptoms, this thesis will focus on key factors tied to the vulnerability of brain regions, and their relevant outcomes as observed in those with an MHI.

Memory Function Following MHI

The construct of memory is divided into multiple categories, with various brain regions playing a role in their overall functioning. The primary categories are sensory memory, short-term memory, and long-term memory. Of these categories, short-term memory has been studied extensively (as a function of working memory). An individual's working memory span is identified by testing how much information a subject can manipulate in their mind during an ongoing cognitive task (Wilhelm et al., 2013). There is a plethora of research (both in general cognitive neuroscience, and in the TBI literature) that assess both the spatial and verbal forms of working memory (Stone & Towse, 2015). Using tests like digit span and symmetry span, wherein the subject has to recall numbers or figures in a serial order, research has demonstrated significant differences in performance as a result of MHI; primarily, working memory performance is impaired following moderate to severe TBI (Dunning et al., 2016), but also MHI

(Chen et al., 2012; Gorman et al., 2012), and these deficits can be observed long after the initial injury (Hudac et al., 2017; Dean & Sterr, 2013).

Although the literature is populated with investigations into short-term memory function, long-term memory (LTM) research, especially in those with milder head injuries, is less extensive. LTM is divided into the explicit (conscious) recall of information, and implicit (unconscious) influences in behaviour (Mulligan & Besken, 2013). Furthermore, the explicit branch of LTM, specifically episodic memory, is particularly interesting because of the various factors that influence its function. Episodic memory is defined as any recollection of past events, including details attributed to time, place, and chronology. This conscious recollection requires one to mentally re-live a narrative e.g., events that took place on a holiday trip, in order to correctly recall the information stored in their LTM (Mahr & Csibra, 2018; Klein, 2015). Episodic memories are more-so summaries of experience rather than exact duplications, however, the extent to which they are accurate and fulsome differs based on multiple factors.

One such factor is head injury, which has been implicated in impairing the recall of episodic memory throughout the literature. Often in episodic memory research, word list tasks are presented to subjects, wherein they must correctly recall a list of previously presented words after a certain period of time. The California Verbal Learning Test (CVLT) developed by Delis et al., (1987) and the later revised CVLT-II (Delis et al., 2000) (is an example of a standardised and validated measure of assessing verbal memory in the form of word lists (Jacobs & Donders, 2007). Using the CVLT, various studies have consistently reported deficits in performance in those with a previous TBI diagnosis, relative to controls e.g., Davis (2016), Wiegner and Donders (1999), and Jacobs and Donders (2008). Interestingly, deficits in word-list tasks are also observed in those with milder head injuries in an undergraduate sample; Wammes et al. (2017)

implemented the Affective Norms for English Words (ANEW) test and found that those with a history of mTBI recalled significantly fewer words than healthy participants. These findings are particularly interesting because undergraduate students are presumed to be cognitively proficient yet nuances in memory performance attributed to MHI are still observed.

Word list memory offers a glimpse into an individual's ability to recall previously presented stimuli, however, those tasks lack the ability to measure a fulsome recollection of chronology, time, and location of events. These details, often reflected in autobiographical memory, utilise a more complex cognitive functioning of memory. To combat these deficits of evaluation, researchers can implement story memory tasks, wherein the subject is presented a narrative and is asked to recall as many themes and details of that narrative as possible after a certain period of time. The cognition required to recall stories captures the essence of real-world memory function more accurately than simpler word-list tasks (Gallagher & Azuma, 2018). Another trait of story tasks is that unlike word list tasks, stories have more organised structure and meaning. This allows participants to create a natural flow of events in their mind to potentially make recall less effortful (Perri et al., 2013; Wicklund et al., 2006). If narratives are fundamentally easier to recall because they require the implementation of more logical retrieval strategies, then it would be interesting to investigate the subtle effects on recall that even mild brain trauma can impose in cognitively capable individuals.

In measures of story memory, distinctions between TBI and healthy individuals are assessed as some combination of how many themes (sometimes referred to as main ideas or concepts) of the story are recalled, how many correct details associated with each theme are produced, and whether the order of event recollection is accurate. For example, Le et al. (2011) demonstrated that those with moderate to severe TBIs produced lower quality stories as a

measure of fewer components recalled, and worse overall organisational structure when compared to their non-injured cohort. More recently, Gallagher et al. (2018) found that although individuals with mTBI did not differ from healthy participants in terms of the number of details produced during immediate recall, they did produce significantly fewer correct details and fewer words during delayed recall. This suggests that although deficits in episodic memory are not as devastating in mTBI as they are in moderate to severe TBI, there are still impairments that deserve to be studied further. Specifically, further research needs to investigate recall of stories that are longer, more challenging (specifically targeted for the mTBI population), and thus more reflective of every-day event recall than standardized stories used in the literature.

Neurological Basis of Memory Function

Episodic memory is an immensely complicated construct that involves a multitude of cortical and subcortical structures, many of which overlap with working and semantic memory function. For the purpose of this thesis, structures critical to episodic memory will be outlined. As previously mentioned, TBI poses a particular risk to the frontal and temporal lobes of the brain (McAllister, 2022; Isokuortti, 2018), both of which are integral cortical regions for the encoding (Weis et al., 2011; Clément et al., 2010), retrieval (Rugg & Vilberg, 2013), and long-term consolidation of memory (Eichenbaum, 2017; Jeong et al., 2015; Sandrini et al., 2013). In fact, Strangman & Goldstein (2009) showed that individuals with a TBI had deficits in episodic memory encoding, likely attributed to decreased white matter in the dorsolateral prefrontal cortex. With regard to narrative memory tasks, Mar (2004) outlined specific subregions (e.g., the medial prefrontal cortex) within the aforementioned cortical regions of interest that play a role in comprehension and production of narratives. In support of this, innumerable studies have established activation of prefrontal and temporal regions during episodic memory tasks e.g.,

Kassel et al. (2016), Ezzyat and Davachi (2010), and Blumenfeld and Ranganath (2007). Therefore, the pre-established vulnerability of these regions during brain injury further amplifies the need to study changes in episodic memory performance after milder injuries.

In addition to the cortical structures, the most prominent sub-cortical structure involved in episodic memory functioning is the hippocampus; specifically, the CA1, CA2, and CA3 subfields located in the anterior portion of the structure (Zeidman & Maguire, 2016). In fact, episodic memory impairments have been associated with damage in the CA1 (Bartsch, et al., 2011), CA3 (Miller et al., 2020), and to a lesser extent the CA2 region (Alexander et al., 2016; Alexander, & Farris, 2016). Specifically, all three subfields play a role in the encoding of memories, with the CA1 spearheading retrieval processes (Aslaksen et al., 2018; Fouquet et al., 2012). Thus, the anterior regions of the hippocampus are particularly interesting in the scope of TBI, because the literature suggests that memory impairments in TBI are due to encoding failure more so than retrieval or consolidation failure (Tayim et al., 2016; Wright & Schmitter-Edgecombe, 2011).

Given its location within the medial temporal lobe, the hippocampus is prone to damage both during a TBI and after as a result of DAI (Atkins, 2011), likely contributing to why memory issues are commonly reported following head injury. In MRI studies of individuals with TBI, hippocampal volume has been found to be significantly decreased following moderate to severe injury (Serra-Grabulosa et al., 2005; Grady et al., 2003; Tate & Bigler, 2000), and to a lesser extent following mTBI (Leh et al; 2017; Girgis et al., 2016). Therefore, when considering the vulnerability of damage to key memory areas altogether, it is understandable why memory complaints are among the most commonly reported symptoms in the three months following a concussion (Gupta et al., 2019; Vassilyadi et al., 2015), but are also observed to persist well

beyond the acute phase (Rioux et al., 2022; Nelson et al., 2019; Dikman et al; 2010). In aggregate, the cognitive deficits tied to episodic memory function, such as encoding difficulties, are likely reflective of damage to the neuroanatomy responsible for them.

The Role of Emotion in Memory

A primary influence on the recall of stimuli is its emotional valence. It is well established that stimuli eliciting positive emotion (e.g., happiness, pleasure, hope, etc.) and negative emotion (e.g., anger, fear, grief, etc.) strengthen memory performance when compared to neutrally valenced stimuli (Kensinger & Ford, 2020; Gomes et al., 2013; Rasmussen & Bernstein, 2009). Additionally, subjects' recall is further advantaged by negatively valenced stimuli more than positive stimuli (Kensinger & Ford, 2020); for example, Van Bergen et al. (2015) presented subjects with positive, negative, and neutrally valenced stories and found that the total number of items correctly recalled was highest for the negative stories and lowest for the neutral stories.

The primary reason for negative stimuli strengthening recall is attributed to the neuroanatomy responsible for processing (primarily negative) valence; the main function of the amygdala is to process fearful or dangerous stimuli and generally negative information (Baxter & Croxson, 2012; Calder et al., 2001). Anatomically, the basolateral amygdala processes negative and positive stimuli through divergent neuronal pathways (Beyeler et al., 2016; Janak & Tye 2015); given this, positively and negatively valenced stimuli increase the efficiency to which information is processed by the brain, when compared to neutrally valenced information (Paz & Pare, 2013). Consequently, the memory advantage for negative stimuli is likely attributed to the increased attentional resources that the amygdala provides as a result of more efficient processing (Phelps 2004; Anderson & Phelps, 2001). Therefore, DAI to the amygdala resulting

from mTBI may alter emotional perception and its memory-related consequences (Hung et al., 2022).

Further complicating the neural processing of emotional stimuli is the role of physiological arousal. As previously mentioned, the vmPFC regulates physiological autonomic arousal (Zhang et al., 2014). The vmPFC also has connections to the amygdala and hippocampus, often serving as a moderator and inhibitor of amygdala activation (Andrewes & Jenkins, 2019); amygdala activity resulting from vmPFC input can then serve to modulate activity in other regions responsible for memory acquisition and retrieval, such as the temporal lobes and PFC (Steinmetz et al., 2010). In fact, the reason for advantaged recall for negative stimuli is attributed to increased arousal during encoding when compared to positive and neutral stimuli (Todd et al., 2013; Anderson, 2005). To further support the role of arousal in memory processes, Bertossi et al. (2016) showed that those with vmPFC damage produced less details when remembering past experiences. Also, evidence suggests that physiological arousal moderates vividness of negative memories (Kark & Kensinger, 2019) especially during cognitively demanding tasks of LTM (Choy et al., 2015; Burbridge et al., 2005); compiling this with findings from the NCR lab that establish chronic autonomic underarousal in those with MHI relative to non-injured individuals (Baker & Good, 2014; van Noordt & Good, 2011) the vulnerability of the vmPFC to head injury magnifies the need to study valence effects on recall in those with an MHI. Specifically, the comorbid relationship of the vmPFC's function in facilitating physiological arousal, and the impairment to emotional and memory related processes that can be associated with its injury.

Although TBI impairs memory retrieval, TBI individuals are still advantaged by emotional stimuli in comparison to neutral stimuli to a certain extent. A study by Czimskey and

Marquardt (2019) showed that individuals with a history of TBI recalled emotional words better than neutral words on a word list task. Interestingly, however, there was no advantage for valence on a story memory task in the TBI group, whereas the advantage did exist for the control group. The authors suggest that story memory may be eliciting a different emotional response than word memory, likely because narratives require more inferring of emotion than isolated words do; it is well documented that those with TBI have difficulty understanding emotional context and recognition (Rosenberg et al., 2019; Johnson & Turkstra, 2012) so the reason for deficits in story memory performance may be tied to difficulties in perceiving and inferring emotion that the stimuli is designed to elicit. Problems in correctly gauging contextual emotion are partly why those with TBI can struggle in social situations (McDonald & Flanagan, 2004), so assessing emotional perception deficits in narrative memory specifically in milder head injuries warrants investigation. From a psychometric measurement perspective, standardised episodic memory tests such as the CVLT-II are designed to avoid any significant effects of emotionality on recall by including words that lack positive or negative emotion (neutral valence). Thus, to expand upon the narrative memory research of Le et al. (2011) and Gallagher et al. (2018), research on MHI would benefit from investigating the additional variable of the emotional valence of stimuli.

Subjective Memory and Metacognition

Objective measurements of memory through standardised tests offer valuable insight into the cognitive consequences of head injury, however they do not necessarily assess the subjective feeling of one's perception of their memory ability. One's beliefs about memory or "metamemory" can be reflective of various quality of life factors; for example, those with a lower self-reported memory quality are more likely to report being depressed, anxious, and have

an overall worse quality of life (Schweizer et al., 2018; Mol et al., 2009). Subjective memory complaints are common in the acute phase of TBI, and unfortunately, they can also appear long after the injury (Draper & Ponsford, 2009).

Although subjective memory assessments are generally reflective of objective memory performance e.g., Samieri et al. (2014), TBI can alter the perception of one's metacognitive abilities. For example, in a sample of 504 individuals with TBI, Vos et al. (2020) found that objective memory measurement in those with TBI was reflective of self-reported subjective memory quality in 60% of participants, however 21% of participants overestimated their performance, and 20% of participants underestimated their performance. Given that 41% of brain-injured participants had impaired metamemory (and various other metacognitive shortcomings), it is evident that TBI complicates subjective assessment of one's cognitive functions. This impairment of self-awareness of one's cognitive abilities is defined as anosognosia (Pannu & Kaszniak, 2005) and has been observed in various studies of individuals with TBI, especially in those with right-hemispheric damage (Steward & Kretzmer, 2021). Of note, Vos and colleagues conducted their study with inpatients, who presented with severe injuries; research investigating metamemory is lacking in relation to those with milder injuries, so the extent to which this metacognitive impairment appears occurs in otherwise cognitively-capable individuals invites further investigation.

Behavioural Consequences of Brain Injury

As previously mentioned, the prefrontal cortex is implicated in various higher-order cognitive functions, such as decision making (Shallice & Burgess, 1991), with a plethora of evidence suggesting that those with a history of mTBI are more impulsive (Mosti & Coccaro, 2018; Berlin & Rolls, 2004) and make riskier decisions (Cotrena et al., 2014; Olson-Madden et

al., 2012). These impairments in decision making can be observed through behaviours such as substance use. The manifestation of substance use disorder in those with a history of head injury is of concern, particularly as a vessel for symptom control. In fact, a significant predictor of the existence of prolonged concussion symptoms is self-reported substance abuse (Newman et al., 2020; Iverson et al., 2015). Not only does increased sensation seeking following mTBI (Liebel et al., 2021) make it more likely that individuals seek out and develop addiction to substances, but the injury-associated disinhibition deficits likely drive the difficulties that injured individuals face when trying to overcome acquired addictions.

From the NCR lab, research on substance use in undergraduates has shown that those with a history of MHI report consuming a greater number of drinks per outing than their non-injured cohort (Alcock et al., 2018); this is perhaps tied to underlying mechanisms of physiological arousal. As previously mentioned, findings from the NCR lab have consistently demonstrated that those with a history of MHI are chronically underaroused relative to their non-injured cohort (Gallant & Good, 2019; Baker & Good, 2014). So, it is theorised that individuals may be seeking out substances (such as alcohol) that raise arousal in order to reach a pre-injury baseline arousal levels. Interestingly, alcohol consumption has been observed to raise physiological arousal (measured by skin conductance), but also, simply presenting pictures of alcohol to those with alcohol addiction can raise their physiological arousal (Laberg et al., 1992). Although alcohol is a nervous system depressant, it is important to consider its psychological effect as well. The significant dopamine release attributed to even low levels of alcohol consumption result in feelings of pleasantness and improvements in subjective mood states (Boileau et al., 2003), which may be why those with increased sensation-seeking qualities (including those with a history of MHI) are drawn to its use.

The literature on brain injury and its associations with substance use is saturated with studies focusing on alcohol, so its behavioural consequences and neural mechanisms are better understood than many other drugs. Conversely, cannabis research in North America is starting to gain popularity due to recent government regulations that make it more accessible to the general public. The recent legalisation of cannabis in Canada is of particular relevance to those that have a history of TBI, specifically because self-reported cannabis use is increased in the first year following a TBI (Grenier et al., 2020) and generally, those with a concussion history report greater cannabis use compared to their non-injured cohort (Gallant et al., 2019). Further, according to the 2020 Canadian cannabis survey, 27% of Canadians reported using cannabis (a 2% increase from 2019), and 22% of cannabis users increased their intake during the COVID-19 pandemic. Due to its increasing popularity, the effects of cannabis on the sequela of brain injury deserves further research.

Individuals with TBI may be drawn to cannabis over other drugs as an alleviant to various affective and somatic post-concussive symptoms, specifically due to its widespread psychoactive and physiological impacts. Cannabis acts on the endocannabinoid system and its cannabinoid receptors, which are among the most common receptors in the human body; specifically the CB1 And CB2 receptors. Chemically, the drug is divided into various components, with tetrahydrocannabinol (THC) being the main psychoactive component, and cannabidiol (CBD) being the main non-psychoactive component (Sharma et al., 2012). Therefore, depending on the proportion of THC and CBD content being consumed in a session, the individual can experience different levels of the psychoactive and physiological effects of the drug.

The psychological and behavioural consequences of brain injury are vast; however, commonly reported symptoms – both acute and long-term – include difficulties with sleep (Jain et al., 2014), increased anxiety and depression (Jorge et al., 1993), and prevalence of chronic pain (Lahz & Bryant, 1996). Given this, cannabis can be attractive to TBI sufferers because users often report that cannabis helps with falling and staying asleep, reduces feelings of anxiety, and reduces physical pain (Choi et al., 2020; Grenier et al., 2020). Further, as result of the multi-faceted properties of cannabis, there is increasing support in the TBI literature for its medicinal use to treat a variety of physical and psychological ailments e.g., Saulino et al. (2021).

Despite its growing endorsement, there is little clarity regarding the long-term side-effects of chronic cannabis use and its interactions with TBI symptomology. Cannabis effects have proven to be dichotomous in nature in terms of the user's experience and objective assessment of its intended effects. For example, Lawrence et al. (2020) found that although cannabis users reported consuming the drug for symptom relief in the acute phase following a concussion, there was no empirical evidence for accelerated recovery from symptoms following TBI. Additionally, although users report improved sleep quality as a result of cannabis consumption in the acute phase of injury, prolonged THC use is associated with greater sleep difficulties due to dependence and increased tolerance (Babson et al., 2017). This suggests that cannabis may serve a beneficial role only initially after brain injury, but the drug remains a risky option especially for those who may be prone to developing a dependence on it.

Neurocognitively, cannabis impairs various functions including attention (Broyd et al., 2016) and working memory (Smith et al., 2014; Bossong et al., 2012), and disrupts processes involved in the encoding and retrieval of episodic memories (Solowij & Battisti, 2008). Specifically, cannabis use in adolescence is associated with worse immediate recall on the CVLT

and memory subtests of the Wechsler Memory Scale, when compared to non-users (Duperrouzel et al., 2019; Lyons et al., 2004). Whilst the literature is lacking in the assessment of cannabis use and its impact on narrative memory performance, evidence suggests that in tests of autobiographical memory, cannabis users overgeneralise stories and have trouble recalling specific details of their experiences (Pillersdorf & Scoboria, 2019).

These objective memory impairments are also reflected in subjective memory reports: McClure et al. (2015) showed that while both groups performed worse than their age-normed cohort, chronic cannabis users who reported having no memory problems actually performed similarly to those who reported having significant memory problems. This suggests that cannabis may impair metamemory processes by contributing to memory function related anosognosia. This influence of cannabis on memory processes is further supported by neuroimaging. Structures within the temporal lobe house a high number of CB1 receptors relative to other areas of the brain, so overstimulation of those receptors as a result of heavy cannabis use can lead to atrophy in memory-relevant regions such as the hippocampus and amygdala (Burggren et al., 2019). Given that these structures are already prone to alterations as a result of brain injury, cannabis use following injury may accentuate memory impairment.

Another aspect of cannabis use is its influence on emotion perception. Consistent cannabis users rate emotional facial expressions as being less intense and have a more difficult time recognising emotions (Hindocha et al., 2014). Cannabis users also score higher on measures of alexithymia (inability to identify feelings). The inability to recognise and read the intensity of emotions efficiently, makes it more difficult to empathise with others (Besel & Yuille, 2010), and this may pose as a barrier to success in social settings. Therefore, considering that those with vmPFC damage suffer impairments in emotional responses such as empathy (Beadle et al., 2018)

the combination of TBI and cannabis use may exacerbate emotion processing consequences in the sequela of brain injury, possibly resulting in poorer recall of emotional stimuli.

The Present Study

Overall, the goal of this study was to expand on the research on narrative memory performance and metamemory, with a focus on those with mild head injuries. With the more recent legalization of cannabis in Canada, and the vulnerability of this population to substance use difficulties, the study also aimed to investigate the potentially interfering effect of self-reported cannabis use on free, and cued, recall.

***Hypotheses*:**

I. It was expected that the MHI group would be physiologically underaroused (as measured by HR) compared to their No-MHI cohort. For cannabis, research is mixed regarding baseline HR levels, so no directional hypotheses were made, only that use would impact performance, particularly for the MHI group.

II. As noted, those with a history of head injury and those with a history of chronic cannabis use demonstrate difficulties on various cognitive constructs, especially related to memory, however, narrative episodic memory has not been investigated extensively in the mild injury population. Based on existing literature, it is predicted that the MHI group would perform worse on the episodic memory test compared to the No-MHI group, and that regular cannabis consumption would further negatively impact memory performance.

III. Similarly, head injury and chronic cannabis use have been implicated in subjective metamemory deficits, but the research is limited particularly with respect to milder injuries. Therefore, as per existing literature on subjective memory, it was predicted that

the MHI group would be less reliable in their assessment of their memories compared to their No-MHI counterpart, and this unreliability would be greater when combined with Cannabis Use.

IV. Finally, head injury and chronic cannabis use have been implicated in subjective emotional control deficits as well and, again, the research is limited particularly with respect to milder injuries within the context of emotional reaction to narrative themes. It was expected that both MHI status and Cannabis Use status would result in greater emotional dysregulation and reactivity compared to their No-MHI/No-Cannabis Use cohorts, demonstrating less management for neurally-compromised individuals.

Method

Participants

134 (11 male and 123 female) English-speaking university students (M_{age} = 20.15, *SD* = 4.29) were recruited through Brock University's Psychology Department research website (SONA) and invited to participate in a single session on-line study conducted using the Qualtrics platform. To avoid diagnosis threat and demand characteristics (Nichols & Maner, 2008; Suhr & Gunstad, 2002; 2005), the recruitment statement informed participants that the purpose of the study was to assess the effect of emotional stimuli on episodic memory, however participants were not specifically informed about our interests in head injury and cannabis use data until after they completed the study, only that health and demographic information would also be collected as additional areas of interest.

Head injury status was assessed using The Everyday Living Questionnaire (ELQ) which surveys the participant on various demographic items, including details on their history, severity,

and consequences of head injuries. If the participant responded “yes” to experiencing disrupted brain functioning from any force to the head as evidenced by altered or lost consciousness (Belanger, Vanderploeg, McAllister, 2016) and/or responded “yes” to having a previous concussion diagnosis, they were assigned to the MHI group. In the present sample, 47 participants (35.1%) reported having at least one MHI (3 male, 44 female), of which 20 reported having more than one MHI in the past (Figure 1). The 35% incidence rate of an MHI is reflective of typical university student samples. Table 1 outlines details on the participants’ age, sex, and ethnicity; the sample was predominantly Caucasian (67.8% of No MHI, and 83% of MHI group).

Table 1

Demographics for No-Mild Head Injury and Mild Head Injury Groups

	No MHI (n = 87)	**MHI** (n = 47)
Mean Age (SD)	19.9 (3.97)	20.6 (4.86)
Sex (Female/Male)	79/8 (90/10%)	44/3 (94/6%)
Ethnicity	Percentage (n)	
Caucasian/European	67.8 (59)	83.0 (39)
Black/African American	8.0 (7)	0.0 (0)
Asian	10.3 (9)	6.4 (3)
Indigenous	2.3 (2)	0.0 (0)
Middle Eastern	2.3 (2)	2.1 (1)
Other	9.2 (8)	8.5 (4)

Note: The category of “Other” prompted a self-report specification, for which answers included Latin/Hispanic, South American, Mixed/Biracial/Multiracial, Guyanese, and Portuguese.

Furthermore, Table 2 outlines the self-reported location of the participant’s most recent MHI. Most reported involvement of the front (31.9%), and back (40.4%) of the head (includes

those with multiple regions struck), which supports previous research outlining the vulnerable location of injury during a head injury (Isokuortti, 2018; Wang et al., 2016).

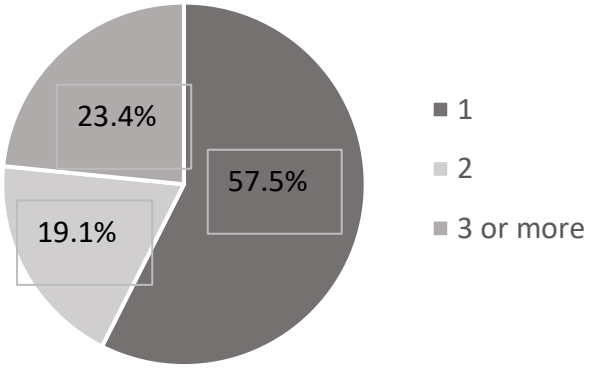
Table 2

Location of Most Recent Mild Head Injury

Injury Location	*n*	*% of total*
Front of head	15	31.9
Back of head	19	40.4
Left side of head	8	17.0
Right side of head	6	12.8
Top of head	6	12.8
Neck/Whiplash	10	21.3
Indirect Force	4	8.5
Unknown	4	8.5

Note: Table includes participants that had multiple regions impacted during the injury

Figure 1. History of Past Head Injuries in Mild Head Injury Group (n = 47)



Note: The "3 or more" group included three participants with more than 3 head injuries, with the rest having a three total injuries each.

Lastly, Table 3 identifies the reason for their most recent head injury; falls (29.8%) and sports (38.3%) are responsible for the majority of injuries in this sample. Soccer accounted for 27.7% and hockey for 22.2% of all sports-related injuries. Of interest, although hockey is considered to be more high-risk, research finds that impact forces to the head are up to 180% greater when heading a soccer ball, than during any routine hockey impact (Naunheim et al., 2000).

Table 3

Cause of Most Recent Mild Head Injury

Cause of Injury	n	% of total
Motor Vehicle Accident	4	8.5
Fall	14	29.8
Fight/Assault	1	2.1
Sports-related activity	18	38.3
Soccer	5	10.6
Hockey	4	8.5
Basketball	2	4.3
Dance	3	6.4
Trampoline	1	2.1
Surfing	1	2.1
Rugby	1	2.1
Power Tumbling	1	2.1
Other	10	21.3

Note: The other category was largely comprised of incidents of the participant being struck by an object

Materials

The materials in this study consisted of a self-report physiological measure, followed by a narrative memory test, and multiple self-report questionnaires to conclude – each described below. Some of the measures used are protected and normalised neuropsychological tools. Narrative materials and unprotected questionnaires are provided in Appendix A.

Physiological Autonomic Arousal Measure. To assess physiological arousal within the confines of COVID isolation regulations imposed by the government of Ontario, participants' autonomic status was not tested in-person as typical practice. As an alternative, participants were provided guidelines and asked to measure their heart rate (HR) in beats per minute (BPM) three consecutive times at the beginning of the study and enter each number when prompted on the Qualtrics survey. Participants had the option of using a HR measuring device such as an Apple watch, Samsung watch, or Fitbit, because the literature suggests that they are accurate in assessing HR with a miniscule margin of error (Falter et al., 2019; Weiler et al., 2017). If they did not own any of these devices, they were asked to measure their HR manually by following specific instructions provided in the program (see Appendix A). Instructions were available for each collection option.

Narrative Episodic Memory Task.

Neutral and Emotional Paragraphs. To assess episodic memory, participants were tasked with reading and listening to four distinct stories and then asked to report as much of the story as possible from their memory. Each story was an average of 225 words long (range = 214-231) and premiered one of four characters: Sam, Reese, Andy, or Jamie. All characters had gender-neutral names to minimize the influence of participant-related bias in memory encoding and retrieval. Each story had a neutral version and an emotional version. The neutral version was

designed to be mundane and lacking any evocative text. For example, the neutral version of Sam's story describes a normal day at the laundromat doing chores, with details regarding Sam's interactions and observations. The emotional version was designed to evoke feelings of empathy, often including tragedy and generally negative emotional and/or physical states. For example, the emotional version of Sam's story describes a normal day doing chores gone wrong when an earthquake occurs at his location, leading to destruction and trauma.

Free Recall of Stories. In total, eight stories were crafted (two versions for each character); however, participants would be given only one version of each character for a total of four (two neutral and two emotional) in the memory task. All stories contained five targetted themes, with two details attributed to each theme. For example, one theme for Sam's emotional story was "natural disaster" and the two details associated with that theme were "store windows started to shatter" and "everyone rushing to exit in panic." Story recall was graded out of a maximum score of 15, one mark for each accurate recollection of a detail or theme. The details were designed to be more difficult to recall than general themes to allow for sufficient challenge and minimize ceiling effects due to the fact that university students are accustomed to participating in memory assessments (exams and quizzes) on a regular basis.

Cued Recall of Stories. After all four stories had been presented, participants were asked to recall specific information from the stories in response to three 'cues' (questions) that were presented – with a total of two details to be described per question. For example, one cue for Sam's emotional story was "during the chaos, what happened to Sam?" with the accepted answer included an indication that 'Sam was crushed by the ceiling', and 'a bloodied Sam was carried out during the rescue'. Cued recall is often considered easier than free recall because the retrieval process is supported by associative information, so the purpose of presenting cues was to aid in a

more fulsome recollection of the stories and potentially draw out information that may have been missed during the free recall portion of the task. Each cued recall answer was graded out of two for a total of six possible marks on the cued recall task.

Self-report Questionnaires.

The Mental Fatigue Scale (modified) (MFS). A modified version of the MFS developed by Johansson et al., (2010) designed to assess mental and cognitive fatigue symptoms was used and is a subjective measure of an individual's arousal level. The participant rated 10 statements on a seven-point Likert-scale ranging from 0 to 3 (increases in increments of 0.5), where 0 is "No", 1 is "Slight", 2 is "Fairly serious", and 3 is "Serious" problems.

The Squire Subjective Memory Questionnaire (SSMQ). Developed by Squire, Wetzel, and Slater (1979), the SSMQ has been shown to be a valuable psychometric tool for assessing awareness and acknowledgement of one's general memory complaints. The 18-item questionnaire assesses metamemory, wherein participants are asked to rate their everyday memory abilities on a five-point scale ranging from "very poor" to "excellent." Items range from inquiries on the cognitive effort required for retrieving memories, to questions about the participant's general awareness of their environment. As demonstrated by van Bergen et al., (2010), the SSMQ has good reliability, construct validity, and internal consistency, allowing it to be a useful tool in assessing subjective memory compared to other (less efficient) questionnaires.

The Squire Subjective Memory Questionnaire – Modified (SSMQ-m). The SSMQ-m is a shortened, 13-item version of the SSMQ. The purpose of using the modified version was to investigate any changes in metamemory following the memory task. Therefore, items 2, 7, 10, 12, and 18 were removed from the original version of the SSMQ because they assessed

metamemory for events long in the past, for which participants were not expected to change their assessments.

The Profile of Mood States Questionnaire – Adult (POMS) 2nd Edition. The long adult version of the POMS (Heuchert & McNair, 2012) consists of 65 adjectives that describe feelings and mood state. Beside each word, the participant is prompted to rate themselves on how well each item describes them using a five-point scale ranging from "not at all" to "extremely." The POMS has seven subscales: Anger-Hostility, Confusion-Bewilderment, Depression-Dejection, Fatigue-Inertia, Tension-Anxiety, Vigor-Activity, and Friendliness. Of particular interest are the overall Mood Ratings (POMS total) as a global measure of emotional status after having read the emotive narratives, as well as the specific subscale mood ratings.

Behavioral Rating Inventory of Executive Function for Adults (BRIEF-A). The BRIEF-A (Roth et al., 2005) is a 75-item questionnaire consisting of statements related to self-regulatory abilities related to executive function. The participant is to rate themselves on each statement using a scale from 0 ("Never") to 5 ("Often"). The main summary scores include the Global Executive Composite (GEC – an overall total measure of executive ability), the Metacognition Index (MI – an index of one's awareness of one's executive abilities) and the Behavior Regulation Index (BRI) Subscales on the BRIEF are divided into distinct abilities of executive functioning: Inhibition, Self-Monitoring, Planning/Organising, Ability to Shift Cognitive Sets, Initiation, Task Monitoring, Emotional Control, Working Memory, and Organisation of Materials. The Working Memory subscale (part of MI) is of particular interest in this study due to the metacognitive nature of subjective memory, as is the Emotional Control subscale (part of BRI) due to the emotional composition of the memory task.

The Everyday Living Questionnaire (ELQ) and ***Cannabis Use Questionnaire*** (CUDIT-R). The ELQ is a 76-item demographic questionnaire that surveys the participant on their medical, health, educational, and lifestyle-related history. In the medical and health section, questions regarding their history of head injury are presented and identify who would be assigned to the MHI group. Further details are gathered regarding severity, frequency and symptoms experienced with respect to their head injury as part of the Postconcussive-Symptom Checklist (Gouvier et al., 1992). The ELQ also surveys details on substance use with a focus on alcohol and cannabis use. If participants reported having used cannabis in the past, additional details are gathered through the Cannabis Use Disorder Identification Test-Revised (CUDIT-R). Examples of such details include questions regarding frequency, severity, method of consumption, and reasons for use. For the present study, a participant was categorised as a regular user if they responded “yes” to the question “do you use cannabis regularly?” on the CUDIT-R. Comparisons for various categories to determine a regular user were conducted based on frequency of use, amount of use, longevity of use, etc., however they were found to not differ substantially from the self-reported responses.

Procedure

Upon approval from the Brock University Research Ethics Board (File 20-286-GOOD) a recruitment for the study was activated on SONA. Participants who signed up for the study were e-mailed a private Qualtrics link to access the study. A detailed consent form (with an accompanying voiceover) informing the participant that their data would be confidential was provided; important contact information was included in case participants had any questions or concerns regarding the study. If the participant decided to move forward with the study by confirming their consent, the collection of data commenced.

For the first phase of the study, participants were asked to provide three separate measures of their HR each preceded by a two-minute rest period. There were four options offered for them to measure their HR (Apple watch, Samsung watch, Fitbit, or manual), and depending on the option selected, step-by-step instructions on how to obtain their HR were provided (see Appendix A). The study next presented the MFS and SSMQ for assessment of fatigue and metamemory prior to the experimental (memory test) phase.

The memory test phase commenced with presentation of the first story. The story was presented in text and audibly. Once the voiceover finished (to control for exposure time), the study advanced to a screen where the participant was asked to write down as much of the previously presented story as accurately as possible. There was no time limit for the recollection portion of the study. Via random selection (without replacement), two neutral stories were presented first, followed by two emotional stories (blocked presentation of emotional valence was set so as to avoid emotional contagion carry-over effects to the neutral stories). Thus, if participants received a neutral version of a character, they would not also receive the emotional version of that character. Once presentation and free recall were complete for one story, the process was repeated three more times. The study then advanced to the cued recall phase and participants were prompted to answer three questions for each of the four presented stories (see Appendix A for stories and cued recall questions). The SSMQ-m was presented immediately following the cued recall to assess whether the experience of recalling had an influence on one's metamemory judgements.

Finally, participants were to complete all remaining questionnaires in the following order: POMS, BRIEF-A, and ELQ. To conclude the study, participants were presented a debriefing script (and form for download) informing them about all key variables under investigation (e.g.,

head injury, cannabis use), support services as needed, and access to the results of the study. Participants received 1.5 hours of research course credits on SONA for their participation.

Statistical Analyses

Analyses were conducted using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS; versions 28 and 28.1, 2021). Data was extracted from Qualtrics into an Excel file for initial data inquiry and organisation purposes, and then transferred to SPSS for detailed analyses. Data analyses included ANOVAs as a function of MHI status (no MHI/MHI), cannabis use status (regular user [yes/no]) and, as appropriate, valence (Neutral/Emotional), with additional independent, and paired samples, t-tests as appropriate for follow-up testing (e.g., HR differences, subjective metamemory changes as a result of the experimental manipulation, free recall, cued recall) and post-hoc Tukey Least Significant Difference (LSD) tests. Lastly, Pearson correlations were computed to assess relationships between various factors (e.g., severity of injury and performance) and subscales.

Results

Hypothesis 1: Physiological Arousal

Heart rate data was collected and averaged across all measurement methods as a measure of autonomic physiological arousal. An independent samples t-test (equal variances not assumed) resulted in no significant differences in baseline heart rate (in BPM) between the MHI (M = 75.97, SD = 8.57) and No-MHI (M = 75.30, SD = 9.49) groups; $t(109) = -.38$, $p = .71$, 95% CI (-4.17, 2.84)[1], see Figure 2. HR was also not correlated with Injury Severity ($r(103) = -.41$, $p > .05$).

[1] Six participants refrained from providing their HR data

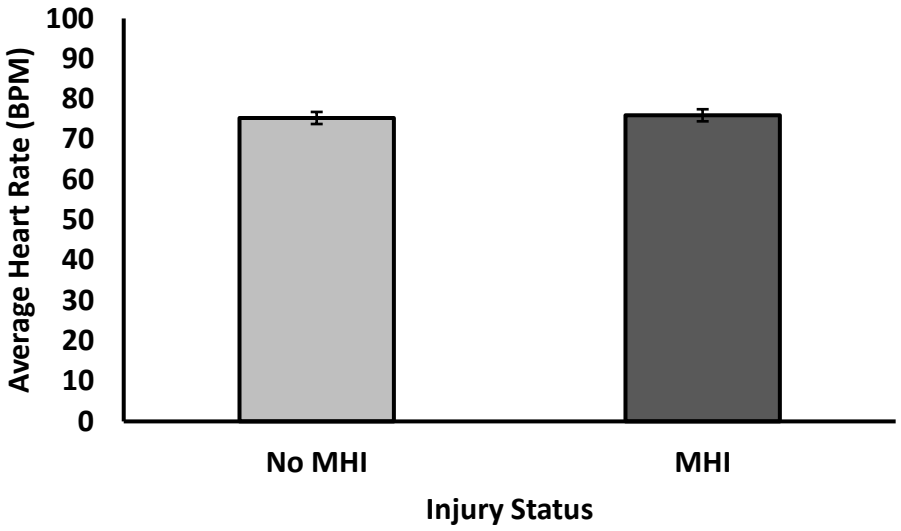


Figure 2. Average heart rate (BPM) for the MHI and No-MHI Groups. Error bars represent standard errors.

Behavioural Measures of Arousal

Pre-test behavioural autonomic underarousal was measured with the mental fatigue scale. An independent samples t-test (equal variances not assumed) resulted in a nonsignificant difference, but a trend in baseline fatigue ratings (MFS) between the MHI (M = 9.51, SD = 4.86) and No-MHI (M = 10.58, SD = 3.56) groups, $t(112.7) = -1.38$, $p = .08$, 95% CI (-2.59, 0.46) – see Figure 3.

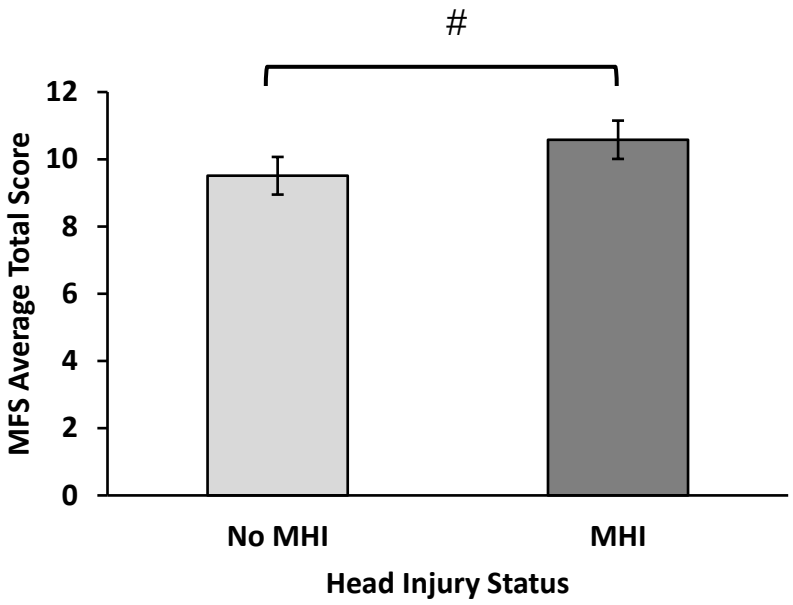


Figure 3. Average ratings on the Mental Fatigue Scale (MFS) as a function of Head Injury status, with standard errors *(*#p = .08).

A bivariate correlation matrix was produced to analyse any relationships between self-rated fatigue (as an indicator of underarousal), post-concussive symptoms, subjective metamemory ratings, injury severity, and cannabis use. The results indicate that greater experience of fatigue (as measured by the MFS) was associated with worse self-reported metamemory ability (SSMQ ratings) for both the No MHI group, $r(87) = -.56$, $p < .001$, and the MHI group, $r(47) = -.53$, $p < .001$. Similarly, greater self-reported post-concussive symptoms (PCS total) were associated with lower self-reported memory ability (SSMQ ratings) for both the No MHI, $r(85) = -.42$, $p < .001$, and MHI group $r(47) = -.32$, $p = .03$. However, as outlined in Table 4, there was no significant association between subjective memory assessment ratings and cannabis use or injury severity. The same analyses were conducted for post-test memory assessment ratings (SSMQ-m), however, no significant relationships were observed.

Table 4

Metamemory (Squire Subjective Memory Questionnaire) Ratings and Injury-Related Relationships

	No MHI (n = 87)		*MHI (n = 47)*	
	SSMQ Average		SSMQ Average	
Variables	*r*	*p*	*r*	*p*
Cannabis Consumption Degree	-.201	.062	.037	.805
Injury Severity			-.182	.220
Mental Fatigue Scale	**-.564**	**<.001**	**-.531**	**<.001**
Post-Concussive Symptoms	**-.415**	**<.001**	**-.317**	**.030**

Note: Two participants in the No MHI group had incomplete responses for the PCS scale, so they were removed from the analyses.

Hypothesis 2: MHI, Cannabis, and Recall Interaction

Consistent with previous research, and as depicted in Figure 4, a t-test examining cannabis use behaviour (as measured by the Cannabis Consumption Degree Score [CCDS] – see Appendix B)[2] identified significantly higher cannabis use for the MHI group (M = 13.57, SD = 10.57) as compared to the No-MHI group (M = 8.83, SD = 8.40), $t(132) = -2.66$, $p = .01$, 95% CI (-8.30, -1.19). Additionally, participant severity of injury scores (see Appendix B) significantly predicted cannabis use, such that those with greater head-injury related indices also reported using more cannabis ($r = .23$, $p = .007$). This relationship is depicted in Figure 5.

[2] The equations used for the Cannabis Consumption Degree Score and the Injury Severity score are presented in Appendix B.

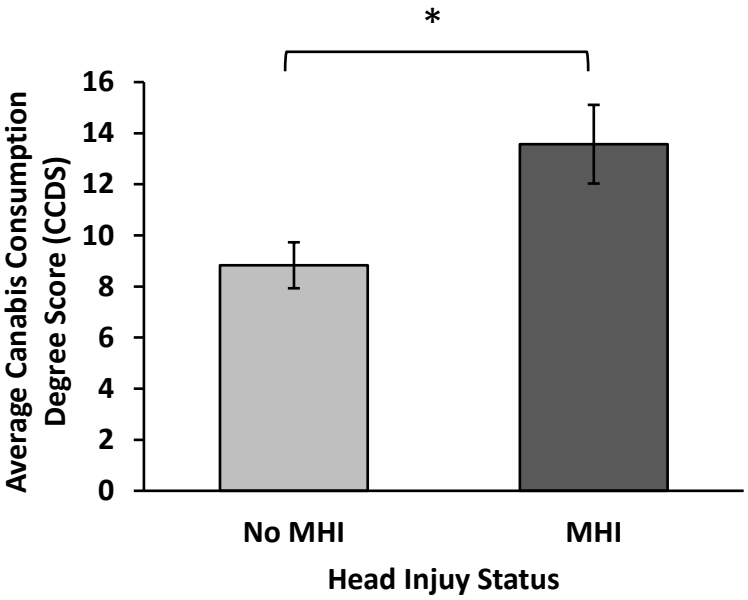


Figure 4. Average Cannabis Consumption Degree Score (CCDS), with standard errors, as a function of Head Injury status (*$p < .05$).

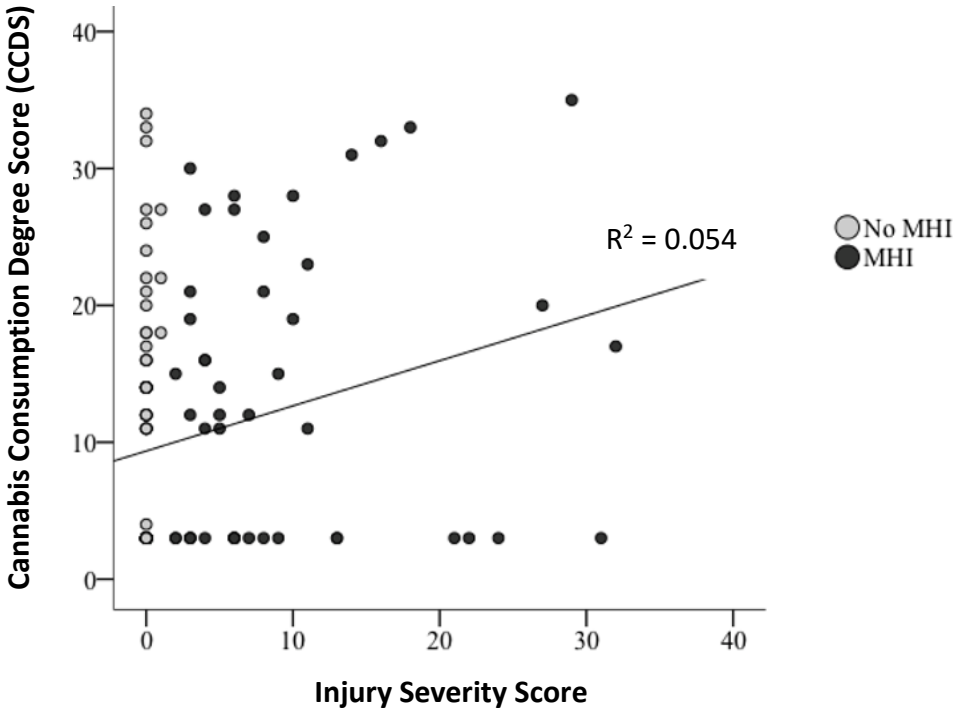


Figure 5. Scatterplot depicting the relationship between Injury Severity scores and Cannabis Consumption ($p < .01$).

A 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User] x 2 (Valence [Emotion/Neutral]) mixed model ANOVA with repeated measures on the third factor (Valence) was conducted. Results revealed a significant main effect of valence, $F(1, 124) = 52.93$, $p < .001$, $\eta^2 = .299$[3] such that participants had better recall for emotional stories compared to the neutral stories. No other significant main effects or interactions were revealed by the analysis. Figure 6 displays the main effect of valence, along with average free recall scores for both the cannabis use group and Head Injury Status. In addition, the same analyses for cued recall mirrored free recall results; there was a main effect of valence resulting in better cued recall for emotional stories, with no accompanying significant main effects or interactions, $F(1, 129) = 31.40$, $p < .001$, $\eta^2 = .196$[4]. The cued recall results are represented in Figure 7.

[3] There were six participants absent from the analysis due to missing free recall data.
[4] One participant was absent from the analysis because they did not provide data for cued recall.

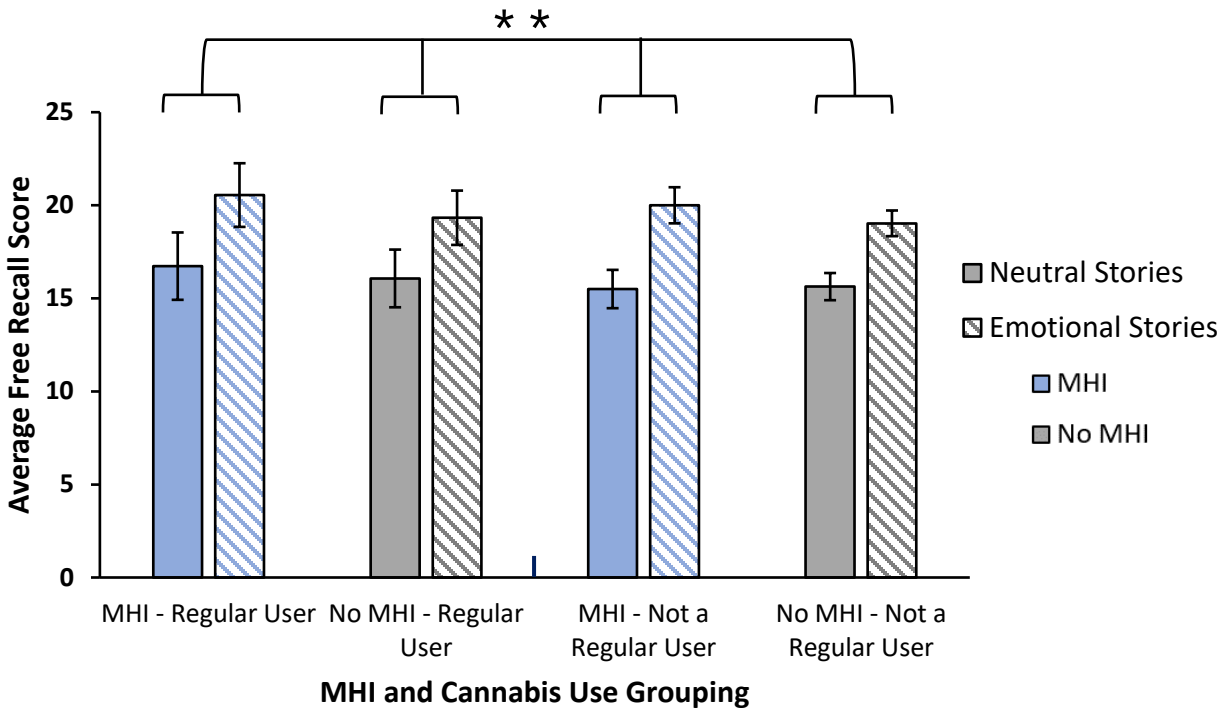


Figure 6. Average total Free Recall score, and standard errors, as a function of Head Injury status, Cannabis Use status, and Story Valence are presented (**$p < .001$).

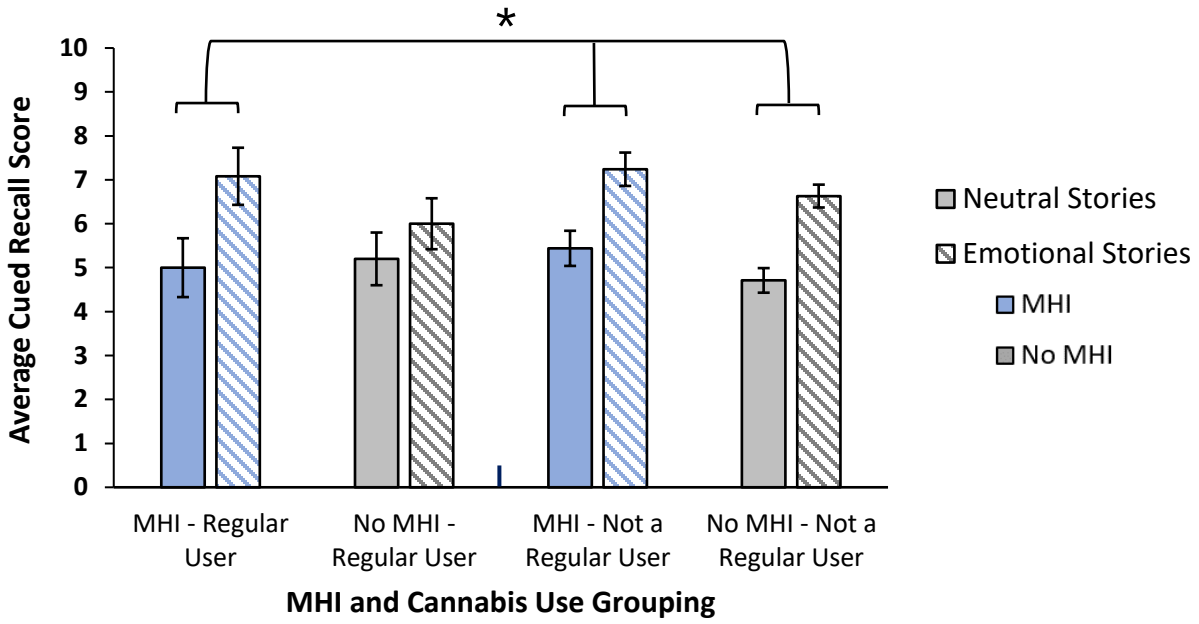


Figure 7. Average Cued Recall total score, and standard errors, as a function of Head Injury status, Cannabis Use status, and Story Valence are presented (*$p < .01$).

Hypothesis 3: MHI, Cannabis, and Subjective Metamemory Ratings

A 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User] x 2 (Time [Pre-test vs Post-test]) mixed ANOVA with repeated measures on the third factor was conducted examining Subjective metamemory [SSMQ/SSMQ-m]. Results revealed no significant main effects or interactions (Figure 8), however a follow-up paired samples t-test revealed an overall significant decrease in metamemory ratings from the SSMQ ($M = 6.40$, $SD = 1.12$) to the SSMQ-m ($M = 6.09$, $SD = 1.12$), $t(133) = 2.53$, $p < .05$ (two-tailed), 95% CI (.07, .56), as depicted in Figure 9).

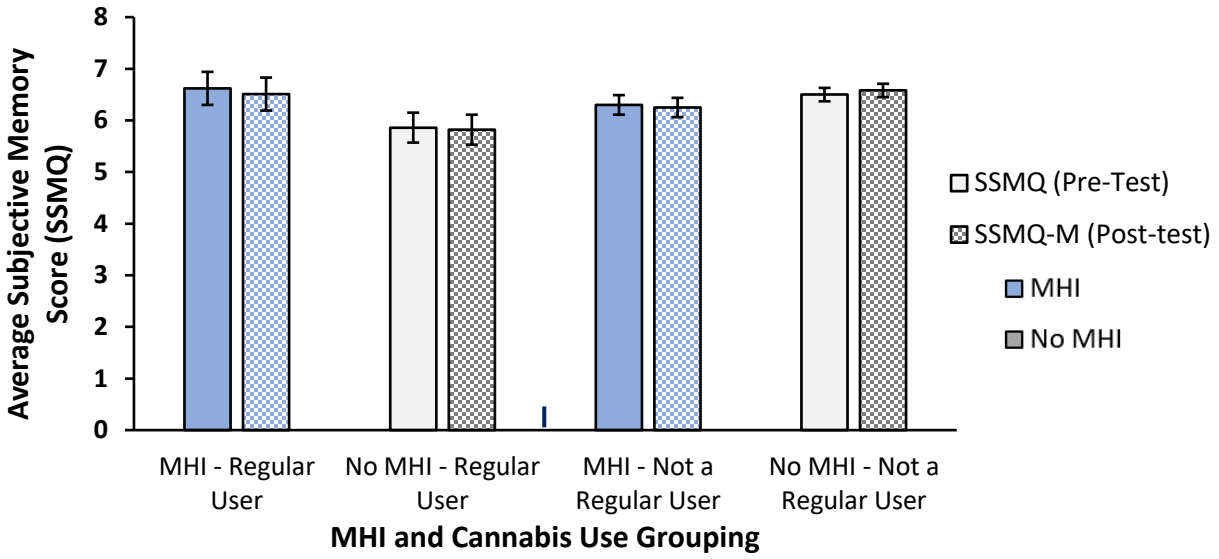


Figure 8. Average total, with standard errors, of the subjective metamemory ratings before and after the memory tests, are displayed for the Head Injury and Cannabis Use status variables.

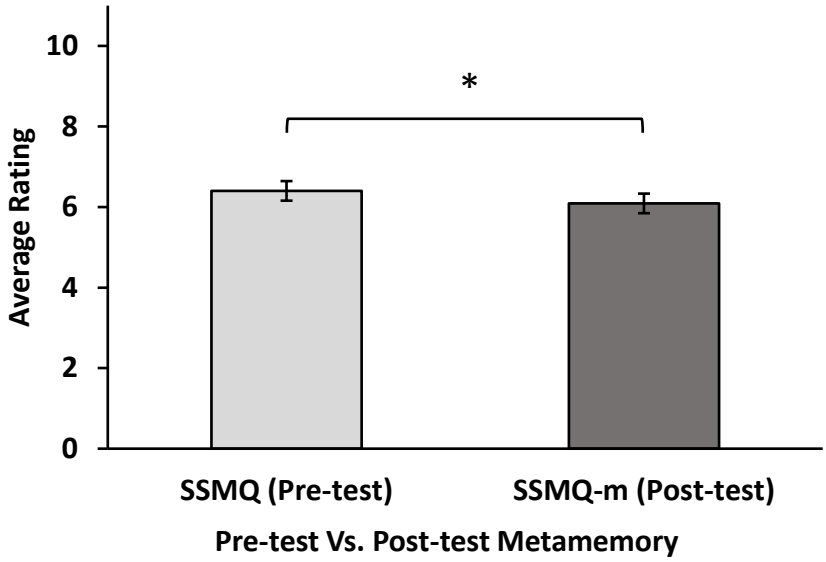


Figure 9. Average total metamemory rating on the subjective memory questionnaires before and after the recall test (*$p < .05$; Error bars represent standard errors)

A 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User] ANOVA was also conducted on the Metamemory Index of the Behavioural Rating Inventory for Adults (BRIEF-A [MI]). Results revealed no significant main effects or interactions (Figure 10). Examination of the Working Memory subscale produced a nonsignificant interaction, $F(1, 122) = 3.23$, $p < .07$, $\eta^2 = .03$, with follow-up analyses demonstrating that No-MHI Regular Cannabis Users reported having less difficulty with working memory than any of the other groups ($p < .003$; see Figure 11).

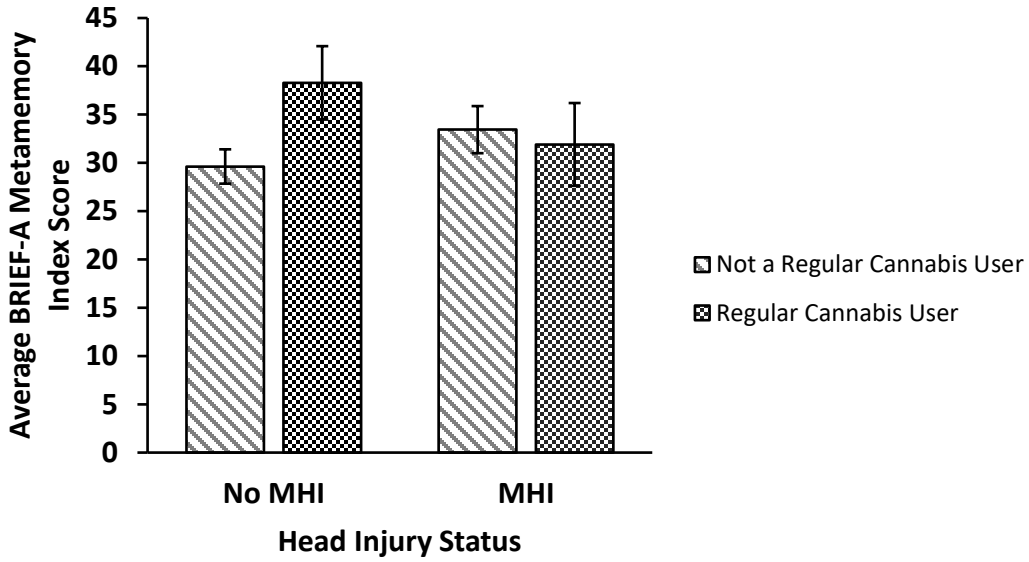


Figure 10. Average scores on the Metamemory index of the Behavioural Rating Inventory for Adults (BRIEF-A), with standard errors, as a function of Cannabis Use status and Head Injury status.

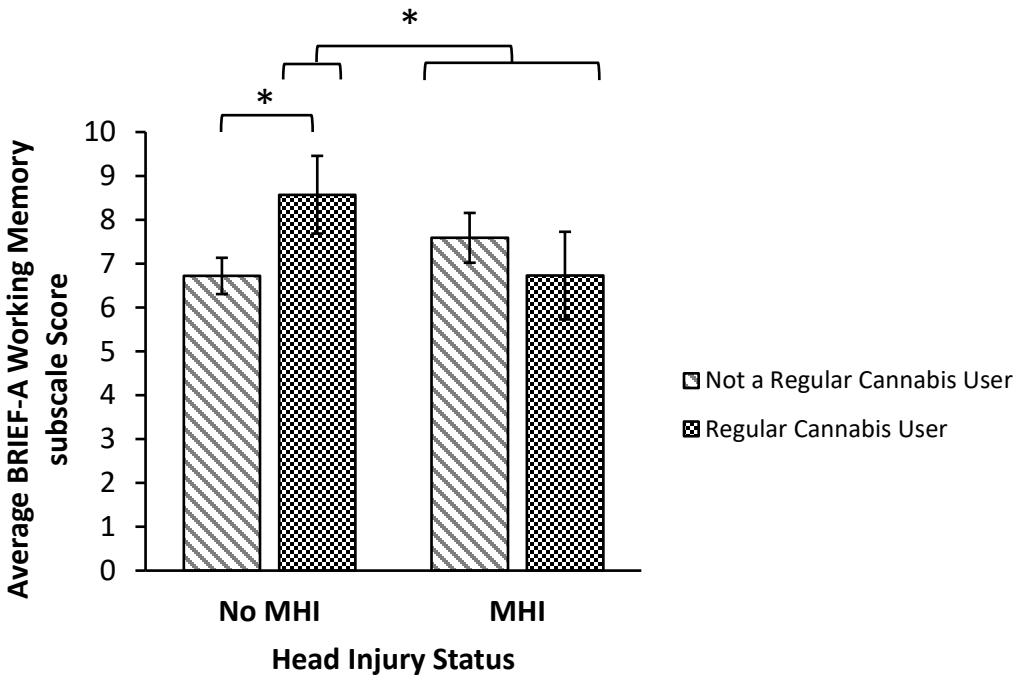


Figure 11. Average scores on the Working Memory subscale of the Behavioural Rating Inventory for Adults (BRIEF-A), with standard errors, as a function of Cannabis Use status and Head Injury status (*$p < .01$).

Hypothesis 4: MHI, Cannabis, and Mood Ratings

A 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User]) ANOVA was conducted examining overall subjective mood ratings post-test using the Profile of Mood States Questionnaire 2 (POMS-2) total. Results revealed no significant main effects or interactions (Figure 12). However, an examination of the mood subscales with a 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User] x 7 (POMS-2 Subscales) produced a significant main effect of the various subscales, $F(1, 122) = 69.10$, $p < .001$, $\eta^2 = .37$, and also a significant interaction with MHI Status, $F(1, 122) = 11.03$, $p < .001$, $\eta^2 = .09$. Follow-up analysis demonstrated that the tension-anxiety subscale was

significantly greater for MHI participants as compared to No MHI participants ($p < .001$, see Figure 13). No other main effects, interactions or simple effects were significant.

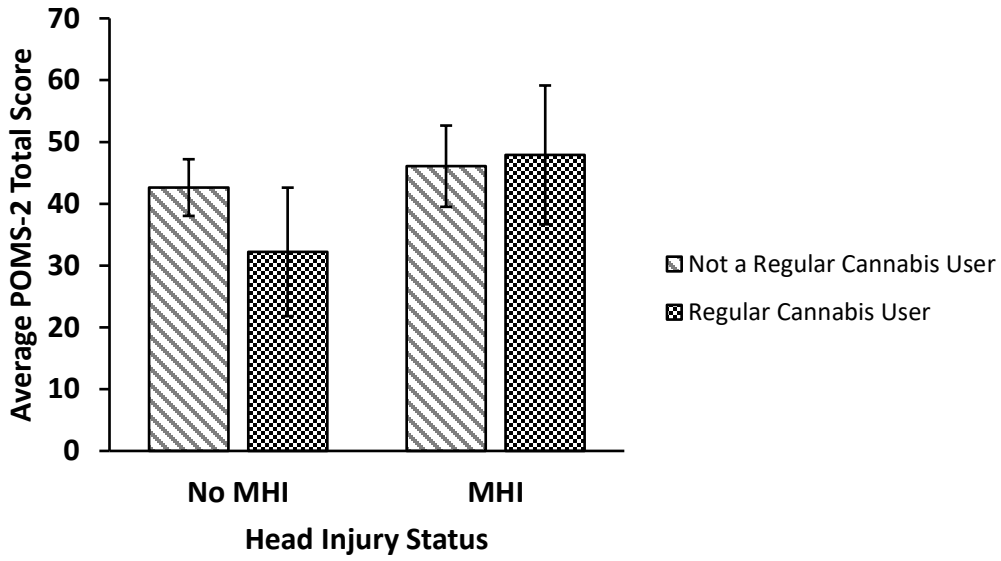


Figure 12. Average total scores on the Profile of Mood States Questionnaire 2 (POMS-2), with standard errors, as a function of Cannabis Use status and Head Injury status.

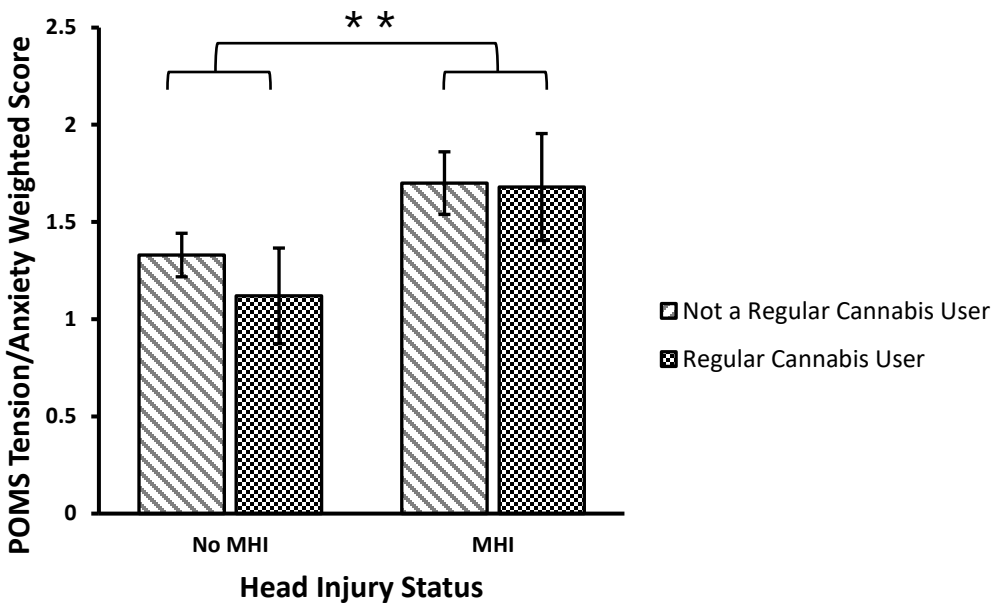


Figure 13. Weighted average totals for the Tension/Anxiety subscale of the Profile of Mood States Questionnaire 2 (POMS-2), with standard errors, as a function of Head Injury status (***p* < .001).

A 2 (MHI Status [MHI/No MHI]) x 2 (Cannabis Use [Regular User/ Not a Regular User] ANOVA was also conducted on the Behavioral Regulation Index of the BRIEF-A [BRI] demonstrating a significant interaction, $F(1, 123) = 4.15$, $p < .04$, $\eta^2 = .03$ (Figure 14). Further testing showed that this effect was a function of the No MHI Nonregular Cannabis User group reporting better (lower) Behavioral Regulation than the other three groups ($p < .02$). Of additional interest was the Emotional Control (EC) subscale produced a nonsignificant interaction, $F(1, 123) = 3.39$, $p < .07$, $\eta^2 = .03$, with follow-up analyses demonstrating that No MHI Nonregular Cannabis Users reported having better ability controlling their emotions compared to the other groups ($p < .004$; see Figure 15).

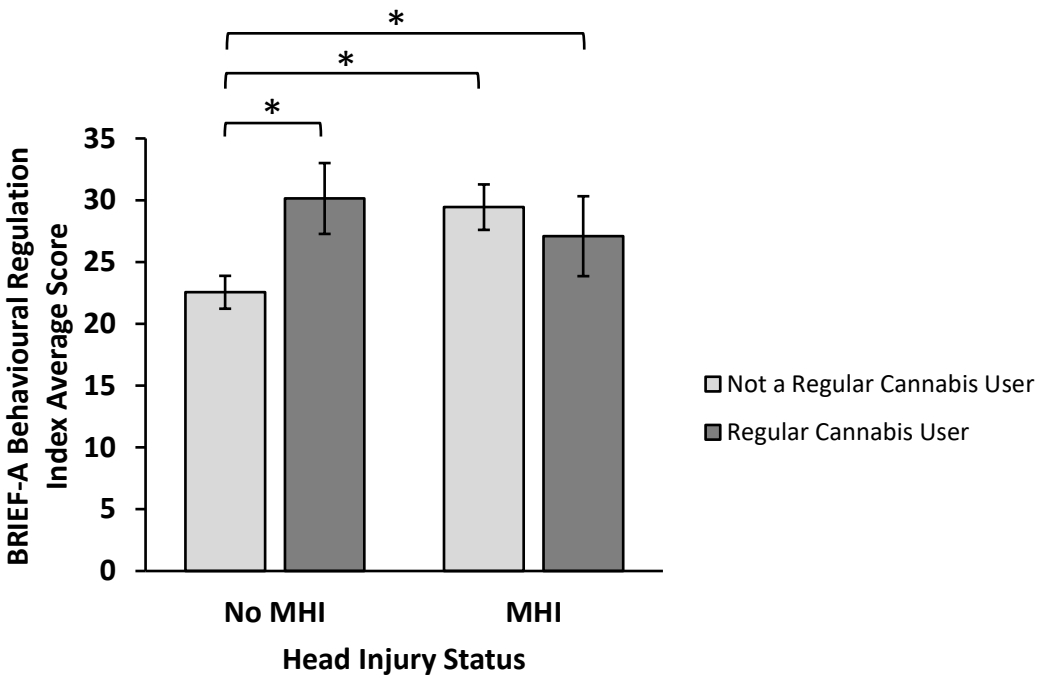


Figure 14. Average scores on the Behavioural Regulation index of the Behavioural Rating Inventory of Executive Function for Adults (BRIEF-A), with standard errors, as a function of Cannabis Use status and Head Injury status (*$p < .05$).

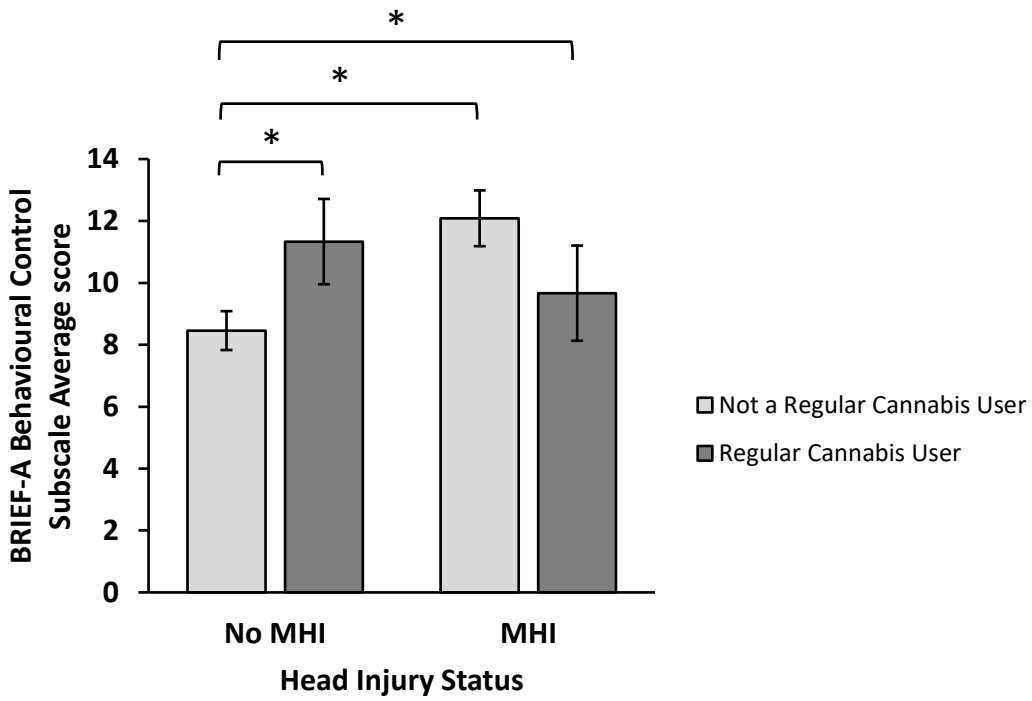


Figure 15. Average scores on the Behavioural Control index of the Behavioural Regulation index of the Behavioural Rating Inventory of Executive Function for Adults (BRIEF-A), with standard errors, as a function of Cannabis Use status and MHI status (*$p < .01$).

Discussion

Many studies have examined head injury and its consequent impact on cognitive constructs, such as memory; however, there has not been a study that investigated memory performance using newly developed narrative memory stimuli, while also investigating possible changes in self-reported metamemory ratings. Studies investigating episodic memory performance often implement word-list tasks (e.g., Wammes et al., 2017), which do not necessarily reflect how one recalls memories on a daily basis. Instead, the present study assessed narrative episodic memory, which reflects day-to-day memory function more accurately. Narrative memory tasks require the subject to retrieve multiple bits of connected themes and

concepts, rather than isolated words. Specifically, the purpose of this study was to investigate any impact of head injury on recall, and whether it differs in conjunction with other factors of interest: emotional valence of stimuli, subjective memory ratings, and degree of cannabis use.

It is clear that individuals with moderate and severe injuries struggle with detection and identification of emotional stimuli (Rosenberg et al., 2019; Johnson & Turkstra, 2012), however, it was interesting to examine the degree of this effect in a milder injury sample. Importantly, this study addressed differences between processing of emotional stimuli based on head injury status and found that a mild head injury in cognitively adept university students is not necessarily detrimental to narrative memory performance. Further, subjective memory influences on actual memory performance were explored. There is a gap in the head injury literature with regards to exploring meta-memory and narrative memory performance, so the goal of this study was to examine possible interactions between memory processes, while also accounting for head injury status. Lastly, this study investigated the role of cannabis in the sequelae of brain injury. With the growing accessibility and consumption of cannabis in Canada, it was important to address the effects of its use specifically in individuals with a history of head injury. Considering that those with a head injury are more susceptible to substance use and abuse (Newman et al., 2020; Iverson et al., 2015), this study built upon previous findings with an emphasis on investigating cannabis use.

This study aimed to identify any deficits in cognition and behaviour tied to a history of brain injury. By implementing a complex narrative memory task, findings from the present study highlight the ability of high-functioning MHI individuals to recall previously observed neutral and emotional stimuli on par with their No-MHI cohort. Although no difference was observed in physiological arousal as a measure of heart rate, the MHI group reported a higher degree of

cannabis use on average and reported greater post-concussive symptomology. In sum, the present research found that those with mild head injuries did not demonstrate significant declines in episodic memory function, potentially indicating a resilience of, and advantage for, cognitive functioning in university students at least when examining performance for tests that are more reflective of everyday memory use (i.e., narration). Those with an MHI did, however, differ in some constructs related to sequelae of brain injury and injury severity, validating the importance of studying mild head injuries along the brain injury spectrum.

Physiological Arousal

The standard measure for physiological arousal, both in the literature and in past NCR lab studies, has been EDA as a function of skin conductance. Unfortunately, this present study was forced to resort to self-reported heart rate as a measure for arousal. Although EDA is the most reliable measure, it is also correlated with heart rate as a determinant of arousal. Various findings from the literature suggest that those with an MHI are relatively underaroused compared to their no-MHI cohort (Baker & Good, 2014; van Noordt & Good, 2011). Therefore, it was predicted that those with an MHI would have a lower average heart rate than those without. Heart rate data from this study demonstrated that there was no significant difference between groups as a function of head injury status.

Average heart rate as a function of measurement device showed that individuals with a manual heart rate measurement reported lower heart rates on average compared to both Apple Watch and Fitbit users, however this did not vary as a function of MHI status, indicating that the method used did not thwart any potential effect of head injury. The observed variability of heart rates by method exemplifies the importance of assessing arousal using a consistent method such as EDA. In this study, individuals with an MHI were not underaroused relative to their no-MHI

cohort, likely because heart rate is immensely variable, and changes depend on a multitude of factors unrelated to brain injury (e.g., caffeine intake, physical activity). Further, considering the subtlety of differences in arousal between MHI and non-MHI groups in past NCR lab studies, heart rate was likely not sensitive enough to capture any subtlety that may have existed in this sample.

Interestingly, scores on the MFS showed a trend such that those with an MHI reported greater baseline fatigue levels compared to their No-MHI cohort. The MFS is demonstrated to correlate with physiological arousal in numerous studies by the NCR lab (e.g., LaRiviere, 2021), so the existence of this finding suggests that the MHI group in the present study may be underaroused, albeit to a lesser extent.

Memory Measures

The narrative episodic memory task was designed to capture the essence of everyday recall, requiring participants to recall themes and details from eventful stories as accurately as possible. As previously mentioned, research has shown that word-list tasks are successful in detecting differences in recall based on a history of head injury (e.g., Davis, 2016; Jacobs & Donders, 2008). This study intended to explore whether the TBI-related deficit in episodic memory exists even in well-functioning university students with a history of head injury. Consequently, the memory stimuli were designed to reflect what a typical student may encounter in a university setting; numerous courses require memorization of ideas and concepts, in addition to details and facts. In relation to word-list tasks, narratives may pose an easier challenge, especially to university students accustomed to such stimuli, because stories pose a chronological timeline of events. If one can recall an item or event from a story, they can then relate that event

to subsequent or preceding events for easier recall (Bower, 1976). In such tests, the chronology poses as a cue for further recall, whereas the isolation of words in a list task poses no such cues.

Based on previous episodic memory literature, it was hypothesised that those with an MHI would be disadvantaged in recall compared to those without. The current study found no difference between the MHI and no-MHI group. Both groups recalled details and themes of the narratives in a similar fashion, potentially indicating that the designed stories were not sensitive enough to replicate any MHI-related episodic memory deficits previously found in the literature, or its narrative nature can compensate for any memory disadvantage imparted with mild injuries. Interestingly, Ho and Bennet (1997), also found no effect of MHI in story recall, however, they did find that those with an MHI performed worse on the CVLT word-list memory task. The narrative task implemented in the current study was far more detailed than tests used in the literature, because the intention was to avoid ceiling effects in a cognitively capable university sample. Students are generally accustomed to difficult memorisations; however, despite increased difficulty in the stimuli, the MHI cohort was not disadvantaged in their recall. Similarly, there were no significant differences in recall for cued recall based on head injury status. Cued recall was implemented to potentially draw out information that may have been missed in explicit recall, however it did not produce differential results based on MHI status.

Valence Effects

It was hypothesised that those with an MHI would perform worse on emotional recall than the no-MHI group, but they would still perform better on the emotional versus the neutral stories. Although there was no differential effect specific to injury status for the recall of neutral versus emotional stories, there was a main effect of valence overall. Both MHI and No-MHI

groups performed better recalling of emotionally-valenced stories as expected. Many studies have found the valence effect, such that those with a TBI demonstrate impaired emotional recognition for negative emotions, but not positive emotions (e.g., Rosenberg et al., 2014). Thus, it was predicted that those with an MHI would perform worse than their No-MHI cohort on the recall of the negatively-valenced stories. The results of the present study did not observe this. Interestingly, some studies have highlighted the inconsistency of the valence effect in those with TBI (Rosenberg et al., 2015). It is important to note that most of the valence effects have been observed in those with a moderate or severe TBI, and usually in emotion recognition experiments. The present study aimed to observe the valence effect in milder injuries, and in a recall task versus a recognition task, so it is important to note that these differences may have impacted the likelihood of observing the valence effect in this sample.

Despite the fact that there was no influence of MHI on recall, this study found that negatively-valenced stories were recalled significantly better than neutrally-valenced stories overall. This finding replicates the results from many previous studies outlining the benefit of negatively-valenced stimuli for recall tasks (Talmi, 2013; Sharot & Yonelinas, 2008). The advantage of emotional stimuli for recall as demonstrated in the literature was equally present in this study. It may be that for injuries that are mild in nature, individuals can advantage the valence effect that is otherwise not observed in those with moderate and severe TBIs. The lack of any MHI-based effect on recall suggests that those with a history of MHI were able to cope with any potential injury-related deficits adequately for a story memory task.

The lack of an effect may be occurring for various reasons. One such reason is that for this sample the injury was particularly minor or mild since our behavioural measures suggest some MHI-dependent differences as a function of severity. For example, the injury severity score

was positively correlated with post-concussive symptoms, total life stress, and cannabis use. Therefore, this finding served to show that fortunately, high-functioning university students are capable of overcoming potential MHI-related episodic memory deficits and/or have a cognitive system that is sufficiently effective that it permits a type of neuroprotective advantage.

Role of Subjective Memory

Results for subjective memory mirrored those of objective memory performance such that there were no significant differences between the MHI and no-MHI groups. Subjective memory complaints are common in those with a history of head injury (Cole & Bailie, 2015); however, it is evident that lower self-rated memory performance ratings do not necessarily reflect poorer objective performance on memory tests (Ly et al., 2023; Anderson, 2021). One reason for implementing the SSMQ was to assess whether subjective memory played a role in other behavioural facets. In doing so, the results indicated that metamemory ratings were significantly lower on the post-test survey compared to the pre-test survey, suggesting that the objective memory test served to reduce confidence in self-rated memory performance for all groups.

Supplementary analyses indicated that participants with poorer subjective memory also reported feeling more fatigue on the Mental Fatigue Scale. This result replicates studies from the literature, which have found that fatigue and subjective memory ratings deteriorate in conjunction (Aasvik et al., 2015). In fact, the findings from the present study are similar to those of Cockshell and Mathias (2014). Their research demonstrated that subjects with a diagnosis of chronic fatigue rated their subjective memory to be poorer, however, those ratings were not correlated with actual memory performance.

Self-reported poor memory function is also associated with increased depression diagnoses, a lower quality of life, and lower overall life satisfaction (Jamora et al., 2012). Our results mirrored this finding from the literature, as supplementary analysis showed metamemory ratings to be negatively correlated with the depression/dejection subscale of the Profile of Mood States questionnaire. Subjective memory scores were associated with increased depression even in cognitively capable university students. Further, metamemory was also correlated negatively with the number of post-concussive symptoms. Although having an MHI was not mandatory for reporting PCS due to their comorbid prevalence with other diagnoses, the correlation suggests that poor subjective memory plays a role among symptoms such as headaches, anxiety, and concentration, in addition to fatigue and emotional problems. Overall, although subjective memory ratings did not correlate with objective memory performance, other associations from supplementary analyses suggest that metamemory interacts with some behavioural constructs regardless of MHI history.

Role of Cannabis Consumption

It was predicted that cannabis would play a role in memory performance, especially because memory impairments are a commonly reported side-effect of using the drug (Prini et al., 2020). According to scores on the episodic memory test, it was found that cannabis consumption did not affect recall for any group of interest. It is important to note that the average cannabis consumption reported in this sample was milder than most studies in the literature, and also, the sample size of regular cannabis consumers was lower. As demonstrated by Mercury et al., (2018), episodic future thinking was impaired in regular cannabis consumers, but not recreational consumers. Episodic future thinking utilises similar mechanisms to episodic memory (Weiler et

al., 2010), so it provides insight into why our study showed no effect of cannabis on memory, as the sample in our study consisted mostly of recreational users.

To account for the variability in what is considered a regular user in the literature, we computed a cannabis use degree score to capture a consistent scale measure of cannabis consumption among the participants. In doing so, our analyses indicated that those with a history of mild head injury reported using significantly more cannabis compared to their no-MHI cohort. It is well documented in the literature that brain injury can increase the risk for substance abuse, and this increase may partly be due to the individual seeking the psychoactive and physical effects of substances as a coping mechanism for the injury (Graham & Cardon, 2008). For cannabis in particular, individuals may be using the drug as a coping mechanism for the various symptoms tied to head injury. In our sample, individuals reported using cannabis for reasons such as anxiety, stress, sleep, fatigue, and chronic pain; head trauma is implicated in the development of many of these enduring symptoms (e.g., Ponsford et al., 2012).

Symptom-mitigation as a primary reason for cannabis use in those with MHI is further supported by the fact that the cannabis use degree score was positively correlated with the injury severity score for this sample. With more severe injuries, it is likely that injury-related negative outcomes are also increased. As demonstrated by the present sample, further analyses showed that injury severity was also significantly associated with increased headache frequency and intensity, more visual disturbances, and an increase in overall life stress. Although the head injury may not be a direct cause for increased cannabis use, the analgesic properties of the drug make is easier to understand why cannabis use increases post-injury (Jacotte-Simancas et al., 2021). Further, those with even mild head injuries report having a more difficult time managing stressors compared to those without a head injury history (Strom & Kosciulek, 2007; Iverson,

2005). Thus, greater difficulty in management of stressors coupled with the presence of long-term post-concussive symptoms may influence an individual to use cannabis as a coping mechanism. It is entirely possible that the MHI-related increase in cannabis use may be due to psychological reasons separate from a head injury. For example, the influences of predispositional sensation-seeking personality traits and the presence of psychological factors, such as motivation or peer inclusion, unrelated to head injury may contribute to the increase in use for the MHI group.

In addition to memory performance, cannabis use did not significantly influence subjective memory ratings in this sample. However, there was implication that metamemory ratings decreased as the cannabis consumption increased in the No-MHI, but not the MHI, sample. Although there is little research on the possible mechanisms that could contribute to this, the lack of its presence in those with MHI may be due to the greater variability in their cannabis use overall. .

As mentioned previously, overall memory complaints are a common cognitive struggle in chronic cannabis users. Additionally, attention and working memory struggles are also frequently reported (Jager et al., 2006). Although both head injury and cannabis use are implicated in worse working memory performance, in this study, regular cannabis use and/or head injuries demonstrate a disadvantage for working memory, consistent with the findings by Cooke et al., (2023).

Emotional Repercussions of Brain Injury

Individuals with a history of moderate and severe head injury demonstrate a plethora of emotional repercussions attributed to the injury. In milder injury samples, long-term post-

concussive symptoms include emotional changes such as increases in anxiety, stress, and emotional regulation (King & Kirwilliam, 2011; Hou et al., 2012). Our results indicated that individuals with a MHI reported greater feelings of tension and anxiety, compared to their No-MHI cohort. As mentioned previously, those with an MHI reported a worse quality of life compared to those without, so it is plausible that the increased feelings of anxiety and stress likely reflect that decrease. Unfortunately, the relative increase in anxiety and stress poses a great risk, because an inability to manage stress may contribute to unhealthy coping strategies (e.g., substance use).

Of relevance, regular cannabis use and head injury interactions demonstrated that those without a history of either showed greater emotional control and emotion regulation ability. It is evident that mild head injuries are implicated in greater behavioural impulsivity, especially in the context of decision making (e.g., Robb, 2015). Therefore, the findings of the present study further accentuate the dampened ability of injured individuals to perform on par with non-injured individuals on emotional constructs.

Limitations and Future Directions

This study was largely limited by the format of its administration to participants due to social distancing guidelines implemented by the government to combat the COVID-19 pandemic. The studies in our NCR lab were previously conducted *in-person*. Unfortunately, the present study was conducted online using a survey program Qualtrics. Therefore, the design of this study required uploading questionnaires and programming stimuli in an online form so that testing can be done on an electronic device. This change in format disturbs the fluid testing experience that would be provided *in-person*, as it is incredibly difficult to manage testing (e.g., electronic) difficulties and answer questions while conducting the study online. Further, it

impedes the tester from controlling outside influences on the participant, such as breaks, errors, and distractions.

Physiological arousal for this study was measured via self-reported heart rate, as opposed to *in-person* EDA measurement. As a result, an extremely robust finding from our lab demonstrating the underarousal of MHI individuals (e.g., Baker & Good 2014, van Noordt & Good, 2011) was not replicated by this study. As such, it is important for future studies investigating underarousal in a mild injury sample to consider the variation of autonomic arousal measures so that outcome differences can be identified and reviewed. The importance of accurate autonomics measurements supported by findings from the literature indicating that higher levels of arousal is associated with better performance on memory tasks (Choy, Farrington, & Raine, 2015; Jung & Good, 2007). Further, particularly for heart rate, it is difficult to control for external influences such as caffeine intake, exercise, and consistency in manual measurement when self-reported, especially across a large sample of participants.

The online format also made it difficult to manage performance for the episodic memory stimuli. Qualtrics made it feasible to control for exposure time, however technological errors were more difficult to control. For example, approximately 5% of the participants reported having difficulty hearing the voiceover narration, despite various audio performance checks before presentation of the stories. In addition, there was no way to guarantee that screen shots weren't taken once individuals became familiar with the memory task. Notably, these discrepancies could have affected performance, and are examples of how conducting a controlled memory experiment can be difficult in an online format. Similarly, concentration and attending to the stimuli is very important for memory success. For this study, while we could control for exposure time, there was no tester present to ensure that participants were consistently paying

attention and engaging the task as intended. Therefore, in-person testing is recommended for future studies, especially for the episodic memory measures.

In this sample, the majority of participants (92%) were female. Sex differences were not the focus of this study, however, may have played a role. For example, in the reporting of cannabis use, the present study did not have a large number of regular cannabis users, as compared to other studies in the literature (e.g., Cuttler et al., 2016), and males report greater frequency and quantity of cannabis use compared to females. Thus, future studies examining cannabis use as a factor should aim to recruit a more even, proportionate number of males to improve and/or have more confidence in statistical power and representation.

Lastly, future research would benefit from investigating various episodic memory tests and materials. As demonstrated by the present study, episodic memory testing that reflects more day-to-day memory function did not reveal memory differences associated with a history of MHI; however, memory tests range from narratives to word-list tasks and differences as a function of the type of stimuli are beginning to emerge.

Conclusions

This cross-sectional study demonstrated that individuals with a history of head injury are able to perform equally as well as those without an injury on a novel narrative episodic memory task. The MHI group was also able to perform equally as adequately on cued recall and showed no impairment in subjective memory. In contrast to literature findings, there was no disadvantage regarding the influence of emotional valence of the stimuli observed in the MHI group, especially in individuals who have proved themselves to be cognitively capable (i.e., they were able to achieve the entrance requirements for university and to pursue academic advancement in this environment). Narrative memory is considered to have associative advantages (e.g.,

meaningfulness, predictable syntactic structure) compared to word-list tasks due to the cuing effects of chronological events in a story (Bower, 1976). Thus, it is likely that cognitively capable university individuals presumed to be accustomed to this style of learning are able to overcome, or compensate, the possible impairments in episodic memory that may have been induced by a previous MHI.

Further, this study was able to replicate the emotional advantaged effect noted in the literature, such that participants regardless of group status, performed better on free, and cued, recall of emotional, compared to neutral, stories. This implies the stories were designed adequately to capture the valence that they were intended to convey. Another factor of this study was to investigate the possible role of cannabis influences on episodic memory, however there were no significant findings attributed to cannabis consumption and recall. None the less, this study did replicate the finding of increased cannabis use for the MHI group commonly reported in the literature (e.g., Jacotte-Simancas et al., 2021). There are various factors that may influence increased substance abuse post-MHI, with symptom-mitigation being one. In this sample, the degree of cannabis use was positively correlated with injury severity and post-concussive symptoms; along with anxiety and other MHI-associated maladies being reported for reasons of cannabis use in this sample, a history of MHI plausibly makes it more likely that an individual will use cannabis for its analgesic properties. This study also replicated MHI literature on certain emotional constructs, with results indicating that head injuries, and cannabis use, impair emotional control and regulation. Of note, refraining from regular cannabis use aids individuals without a head injury in emotion control and regulation.

The aim of this study was to address whether a head injury impaired episodic memory, while accounting for the influence of metamemory, valence, and cannabis use. Overall, it was

found that MHI did not impact recall, metamemory, or emotion processes differentially. This research serves to provide a positive outlook on university students with milder injuries, as it provides evidence for their cognitive ability to perform as adequately on an episodic memory task as those without an MHI. Behaviourally, it was observed that those with an MHI reported greater cannabis use compared to their No-MHI cohort. The literature is still lacking in the long-term effects of cannabis use in those with injuries across the TBI severity spectrum, so currently practicing healthcare professionals should highlight the vulnerability of cannabis use and abuse in injured individuals when they seek treatment for their symptoms.

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Appendix A : Research Ethics Board Documents and Testing 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:	5/12/2021		
PRINCIPAL INVESTIGATOR:	GOOD, Dawn - Psychology		
FILE:	20-286 - GOOD		
TYPE:	Faculty Research	STUDENT:	Smit Patel
		SUPERVISOR:	Dawn Good

TITLE: Investigating memory performance and perception in persons with and without mild head injury

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 5/1/2022

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 **5/12/2021 to 5/1/2022.**

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 5/1/2022. 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.

SONA Advertisement

BROCK UNIVERSITY

Department of Psychology

Application for Access to the Psychology Research Pool

All studies posted to the Psychology Research Pool website must have Research Ethics Board (REB) clearance.

INSTRUCTIONS: Please complete the information below about your study and then email this form to (lindap@brocku.ca) with the subject line RESEARCH POOL. ATTACH A COPY OF YOUR INFORMED CONSENT FORM TO THE EMAIL.

****

NAME OF RESEARCHER(S): Smit Patel; Sunny Qureshi

RESEARCHER(S) EMAIL: sp16uy@brocku.ca; sq17vs@brocku.ca

FACULTY ADVISOR (if applicable): Dr. Dawn Good

TITLE OF STUDY: Investigating the effect of emotional stimuli on memory and recollection.

BRIEF DESCRIPTION: The primary purpose of this study is to investigate the effect of emotional stimuli on memory and recollection with a particular interest in episodic memory abilities. Participants will be asked to complete questionnaires about health, mood, and memory on the Qualtrics program site. Further, measures of physiological arousal (i.e., heart rate) will also be requested and self-recorded. Should in-person on campus testing resume, participants will be invited to complete further physiological testing at a later time. This session will take 1.5 hours of your time.

IS THIS A TWO PART STUDY? No

LENGTH OF STUDY (e.g. .5, 1, 1.5, 2, …. hours): 1.5 hours

SELECTION CRITERIA:

1) Must be fluent in the English language

2) Must be 17 or older

CREDIT/PAY

Credit (30 mins = .5 credit to a maximum of 1.5 credit hours)

Participants will receive one-half credit hours per half hour of their time for participation. This will permit a maximum of 1.5 credit hours.

Informed Consent

Investigating the effect of emotional stimuli on memory and recollection

INVITATION

You are invited to participate in a Qualtrics-based study that involves both survey and experimental research. The primary purpose of this study is to investigate the effect of emotional stimuli on memory and recollection.

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 engage in a number of tasks to examine emotionality. First, you will be asked to follow a set of detailed instructions that inform you on how to provide us with a measure of your heart rate. In addition, you will be asked to complete a number of self-report measures related to demographics (e.g., sex, age, medical history, lifestyle, including questions asking directly about your health and any history of substance use), metamemory and mood. 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. For the experimental portion of the study, you will be asked to view and read short story paragraphs with an emotional theme. You may find that this material gives rise to unsolicited emotions; however, you can choose to exit the study at any point. Detailed instructions will be provided to you throughout the testing session. Once you have completed the study, further details regarding the specific purposes of the study will be provided to you via 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 participation, 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 restricted access master list advising the Principal Researchers (Dr. Dawn Good and graduate student, Smit Patel) 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). The results of the study will be presented in statistical format and as a group - no individual participant information will be published or identified. The responses you provide (with only an alphanumeric code identifier) will be securely kept in digital form for ten years post-data collection (or, if you are a minor, 10 years after your 18th birthday) to which only researchers and research assistants have access. Data will subsequently be deleted. If you choose to withdraw from the study prior to completion, your data will not

be used in the analyses and will be deleted from the aggregate data. 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 signed 'Consent to Release Personal Information' form (consistent with the guidelines of PHIPA [2004]).

POTENTIAL BENEFITS AND RISKS

The current study requires you to listen to, and read, short stories some of which you may find sensitive in nature and may elicit unsolicited emotions which could result in discomfort. These stories are fictional and if you wish to discontinue, you are able to do so at any time. Should you experience any concerns or emotional responses that arise as a result of your participation in this research study, you can make use of the contact information provided 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, 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, PHIPA, legislation (e.g., https://www.ontario.ca/laws/statute/04p03). You will receive a detailed debriefing about the study at the end of testing. You may 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

All private information shared by the participant (e.g., illegal activities, health information) will be respected as confidential and held in confidence. Your name will be associated only with the initial e-mail contact and a master code list. All responses collected will be confidential and coded by alpha-numeric code assignment and as noted above, a master list will be kept linking data codes to individuals' data. Only Dr. Dawn Good and Smit Patel will have access to the master list which is necessary to link names to participant's data for data-file matching and possible post-study follow-up. All data will be kept in a secure database at all times and will be deleted after 10 years. Only Smit Patel, Dr. Good, and their research assistants will have access to the anonymized data. All research assistants have completed confidentiality agreements. In addition, any information gathered from this study that is presented at conferences or published is summarized and presented as grouped data which preserves confidentiality.

PUBLICATION OF RESULTS

This study forms part of 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 study completion (expected April 2022). Please contact the principal faculty or student investigators (Dr. Dawn Good or Smit Patel) via the contact information provided.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact Dr. Dawn Good at Brock University using the contact information provided. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University [File # 20-286-GOOD] If you have any comments or concerns about your rights as a research participant, please contact the Office of Research Ethics 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 investigating emotional effects on memory and recollection.

[ ] I have read and understand the above information regarding this study.

[ ] I understand that I can obtain a copy of this form for my records

[ ] 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

COMPENSATION

[ ] COURSE CREDIT to receive up to 1.5 research credits (1.5 hours of participation; 0.5 every 30 minutes; please identify only the relevant course):_____

THANK YOU FOR YOUR TIME AND PARTICIPATION IN THIS STUDY!

Principal Student Investigator:
Smit Patel, M.A. Candidate
Department of Psychology
sp16uy@brocku.ca

Principal Investigator
Dr. Dawn Good, PhD., C. Psych.
Psychology Department & Centre for Neuroscience
Brock University
St Catharines, ON L2S 3A1
dgood@brocku.ca

Honours Student Investigator:

Sunny Qureshi, H.B.Sc. Candidate

Neuroscience Program

sq17vs@brocku.ca

Participant Debriefing Form

Smit Patel & 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, Smit Patel and Sunny Qureshi in the Departments of Psychology and Neuroscience at Brock University. Our goal within this study is to investigate the effect of emotional stimuli on memory and recollection in university students who have, and have not, experienced a previous mild head injury (MHI; concussion) and do, or do not, endorse using cannabis. We were unable to advise you of our added interest in concussion and cannabis use 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 memory problems as a major symptom (Anderson, Heitger, & Macleod, 2006; Heitger et al., 2007) and since memory deficits are advantaged by the emotional valence of stimuli (e.g., Bower, 1981), particularly negatively-evocative material (e.g., Eich, 2000), this study examines how emotion influences memory performance in persons with MHI. Further, given the change in legalisation as of 2019 when Canada became the first G7 country to legalize cannabis (Potter & Weinstock, 2019), and the impact cannabis use has on memory and emotional processing (e.g., Kumar, Chambers, & Pertwee, 2008; Hindocha, Freeman, Schafer, Gardener, Das & Morgan, 2015), with the added outcome of greater cannabis access and use both in general, and particularly persons with MHI (e.g., Gallant, Luczon, Ryan & Good, 2020), investigation of these interactions is timely.

While considerable research has examined the psychological and neuropsychological challenges in persons with moderate and severe injuries, very little work has investigated emotion and memory following concussion and the interactive effects that cannabis may have.

Given that memory impairment is a common side effect of MHI, but also cannabis use, the extent to which these factors interact and/or differentially affect cognition is an important focus of our proposed research.

With the intention of, ultimately, providing those with a history of MHI valuable knowledge when considering using cannabis for recreational or medicinal use. To date, little research has investigated the effects of cannabis use on those with a history of MHI.

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 you 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

- Distress 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 participation in this study!!!

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

Principal Student Investigator:
Smit Patel, M.A. Candidate
Department of Psychology
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St. Catharines, ON L2S 3A1
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Principal Investigator
Dr. Dawn Good, PhD., C. Psych.
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Honours Student Investigator:

Sunny Qureshi, H.B.Sc. Candidate

Neuroscience Program

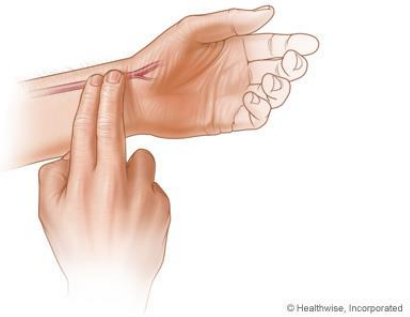
Brock University

St. Catharines, ON L2S 3A1

sq17vs@brocku.ca

Step-by-step guide for reporting heart rate without technology

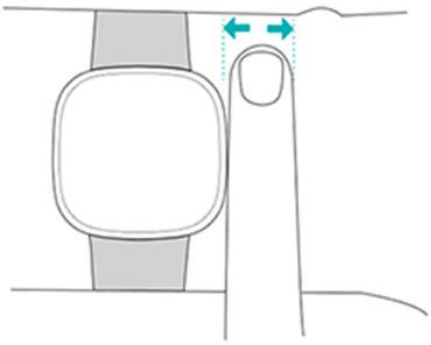
1. Using your phone, or a timer in the program, prepare to count the number of pulses you produce in a 30 second interval.
2. Make sure you are seated upright in a comfortable position
3. Gently pace your index and middle finger of your right hand onto the wrist of the left hand. Place the fingers to the left of the thick central nerve running down your arm. Make sure to feel around to find the exact spot where your beat is most strongly felt.



4. Once you have identified the spot where you can consistently feel your pulse, set up a timer for 30 seconds using any time-measuring device (timer, phone, clock etc.).
5. Start the timer and record the total number of pulses felt during those 30 seconds.
6. Multiply the total number recorded, by two. This will give you your estimated heart rate over the course of 60 seconds (1 minute).
7. Wait 2 minutes (as per the instructions on the screen), then repeat steps 3-5.
8. Wait 2 minutes again, then repeat steps 3-5 for the final time.
9. You should now have 3 measures of your heart rate. Take the average of these three measures by adding them all, and then dividing that total by three.
10. Record the average pulse rate across the three measurements and describe its strength and rhythm. Strength of the pulse is subjective, but can be described as ‘weak/faint’ vs. ‘strong'. In terms of rhythm – describe it as regular or irregular, and if irregular, in what way – e.g., missed beat, non-rhythmic).

Step-by-step guide for reporting heart rate with an Apple Watch

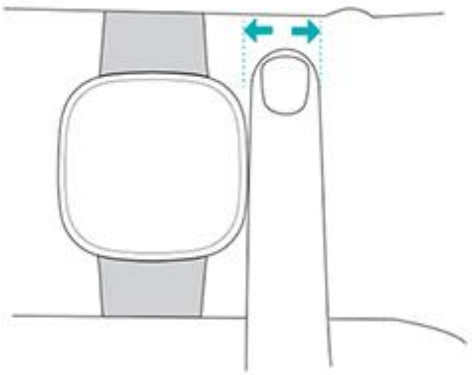
1. Make sure you are wearing your Fitbit a finger’s width above your wrist bone (See image below), and make sure the back of the device is in contact with your skin.



2. Make sure you are seated upright in a comfortable position
3. On your computer/mobile device, open a new tab on your browser and go to https://support.apple.com/en-ca/guide/watch/apda88aefe4c/5.0/watchos/5.0
4. At the top of the page, under select version, choose the apple watch operating software that is running on your device.
5. Follow the instructions for getting the apple watch to generate a heart rate measure.
6. Wait 2 minutes (as per the instructions on the screen) then prompt the apple watch to generate another heart rate measure (the numbers may not have changed)
7. Wait another 2 minutes, then prompt the apple watch to generate another heart rate measure.
8. You should now have 3 measures of your heart rate. Take the average of these three measures by adding them all, and then dividing that total by three.

Step-by-step guide for reporting heart rate with a Fitbit device

1. Make sure you are wearing your Fitbit a finger's width above your wrist bone (see image below), and make sure the back of the device is in contact with your skin.

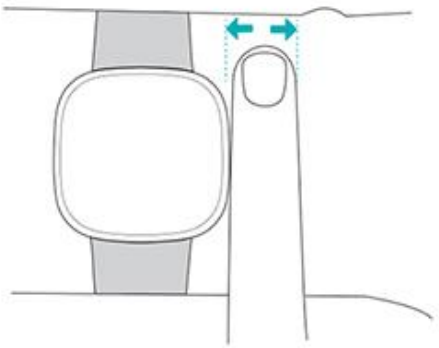


2. Make sure you are seated upright in a comfortable position
3. On your computer/mobile device, open a new tab on your browser and go to https://help.fitbit.com/articles/en_US/Help_article/1565.htm
4. Click "How do I check heart rate on my Fitbit device?" (second option in blue text)
9. Follow the instructions for getting the Fitbit to generate a heart rate measure.

10. Wait 2 minutes (as per the instructions on the screen) then prompt the Fitbit to generate another heart rate measure (the numbers may not have changed)
11. Wait another 2 minutes, then prompt the Fitbit to generate another heart rate measure.
12. You should now have 3 measures of your heart rate. Take the average of these three measures by adding them all, and then dividing that total by three.

Reporting heart rate with other physical activity monitors

Make sure you are wearing your Fitbit a finger's width above your wrist bone (see image below), and make sure the back of the device is in contact with your skin.



1. Make sure you are seated upright in a comfortable position
2. Prompt your band to generate a new reading for your pulse/heart rate.
3. Wait 2 minutes (as per the instructions on the screen) then prompt the device to generate another heart rate measure (the numbers may not have changed)
4. Wait another 2 minutes, then prompt the device to generate another heart rate measure.
5. You should now have 3 measures of your heart rate. Take the average of these three measures by adding them all, and then dividing that total by three.

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.

<u>If you experience 24-hour variations:</u>

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

Squire Subjective Memory Questionnaire (SSMQ)

Instructions:

We would like you to report your overall memory function pertaining to each statement. Using the following scale, please respond to the following statements.

1. My ability to search through my mind and recall names or memories I know are there is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

2. I think my relatives and acquaintances judge my memory to be:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

3. My ability to recall things when I really try is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

4. My ability to hold in my memory things I have learned is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

5. If I were asked about it a month from now, my ability to remember facts about this form I am filling out would be:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

6. My ability to make a past memory that is “on the tip of my tongue” available is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

7. My ability to recall things that happened a long time ago is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

8. My ability to remember the names and faces of people I meet is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

9. My ability to remember what I was doing after I have taken my mind off it for a few minutes is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

10. My ability to remember things that have happened more than a year ago is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

11. My ability now to remember what I read and what I watch on television is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

12. My ability to recall things that happened during my childhood is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

13. My ability to know when the things I am paying attention to are going to stick in my memory is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

14. My ability to make sense out of what people explain to me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

15. My ability to reach back in my memory and recall what happened a few minutes ago is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

16. My ability to pay attention to what goes on around me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

17. My general alertness to things happening around me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

18. My ability to follow what people are saying is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

Testing Stimuli: Narratives with Cued Recall Questions and Answers

A Day at the Laundromat: Neutral (words: 226)

One Saturday morning Sam decided to drive to the local laundromat to wash some clothes because he had some free time and was running out of things to wear. There was some traffic on the way, so the drive took longer than expected. After arriving, Sam headed over to the counter to meet a friend who had been working there for approximately three years, so the two would meet up almost every week. After some small-talk about a Junior-A hockey team, Sam pulled out two loonies – one was very faded, and the other looked new. After walking over to a vacant machine and inserting the loonies, Sam went on to load a few hoodies, jeans, and a towel.

Usually after loading the cycle, Sam would immediately head over to the local Country Style and order a vanilla latte to pass the time between loads. This time however, Sam walked over to a large poster on a nearby wall and took a picture of it. The poster was an ad for beginner's level origami lessons which were being taught in the same plaza as the laundromat. Since there was still plenty of time left on the laundry machine, Sam walked over to the address on the poster and signed up for the lessons, and there was enough time afterwards to pick up a drink at the café.

Themes/details

Theme	**Detail**
Went to the laundromat	1. Had to wash some clothes 2. Traffic on the way
Met friend	1. Friend worked at laundromat for 3 years 2. Talked about a Junior-A hockey team
Headed over to laundry machine	1. Two loonies – one faded and one new 2. Loaded a few hoodies, jeans, and a towel
During laundry routine	1. Would usually go to Country Style 2. Order a vanilla latte
Discovers an activity	1. Ad for origami 2. Went to sign up for lessons

Who did Sam meet at the laundromat and what did they talk about? A: friend of 3 years, talked about a Junior-A hockey team

What does Sam usually do after loading the cycle? A: Nearby Country Style, order a vanilla latte

What information was on the poster? A: address, origami lessons

A Day at the Laundromat: Emotional (words: 231)

One Saturday morning Sam decided to go to the local laundromat to wash some clothes because he was running out of things to wear. As Sam pulled out a phone to check the weather, a notification appeared stating that there was an earthquake nearby, but since each year there are about 10,000 earthquakes in California, Sam decided to continue to the laundromat unconcerned. After arriving, Sam noticed that the power had gone out in the entire plaza. Many customers heard a terrifyingly powerful rumbling of the ground and felt a sudden shaking of the floor. Realising the severity of the situation, Sam tried to contact family members and warn them of the disaster, but none of their phones had reception.

Moments later, the windows in the laundromat started to shatter. In a state of panic, everyone rushed to the exit. During the chaos, the ceiling began to collapse, and a segment of the plaster broke away crushing Sam beneath the debris. Some customers ran over to carry a bloodied and disoriented Sam outside of the building, where people were running around desperately looking for safety. During the ambulance ride to the hospital, Sam was in a state of shock and struggling to breathe, and eventually lost consciousness. After waking up on a hospital bed, Sam learned that the massive earthquake had killed many and left hundreds of people with gruesome injuries.

Themes/Details

Theme	**Detail**
Saturday morning activity	1. Notification that there was an earthquake nearby 2. 10,000 earthquakes each year in California
Arrive at laundromat	3. Power was out 4. Tried warning family, but no reception
Natural disaster	5. Store windows started to shatter 6. Everyone rushing to exit
Injury	7. Part of ceiling falls and crushes Sam 8. Left bloodied and disoriented
Aftermath of injury	9. State of shock, struggling to breathe, and LOC 10. Earthquake left hundreds with gruesome injuries

Who did Sam try to contact and why was he unsuccessful? A: family members, their phones had to reception

During the chaos, what happened to Sam? A: ceiling/plaster broke off and crushed Sam, bloodied Sam carried out

How was Sam feeling during the ambulance ride? A: state of shock, struggling to breath, LOC

Doctor's Appointment: Neutral (words: 219)

One evening, Reese was watching the final movie in the Lord of the Rings trilogy. Around the half-way point of the movie Reese felt an itch in the right ear, but it went away after some time. Soon after the movie ended, Reese decided to drink a glass of chocolate milk and eat a small snack before going to bed. After waking up early in the morning the itch was back, except now there was a small rash in the ear canal. This prompted Reese to book an afternoon appointment with Dr. May, who had been a family doctor for over 20 years.

After arriving at the local clinic, Reese was told to sit in the waiting room. The doctor was not busy given that it was a weekday, so there was an estimated wait time of only five minutes. Once Reese was called into the doctor's office, Dr. May was debriefed about the ear itch. Dr. May then did a thorough checkup of Reese's ears using an otoscope and came to the realisation that the ears needed to be flushed. The doctor reached for a blank piece of paper and wrote down the name and location of an ear specialist. The next day, Reese was able to schedule an appointment and have the ear treated without any complications.

Themes & Details:

Theme	**Details**
Watching Lord of the rings (movie)	1. Feel itch 2. Consume chocolate milk & snack before going to bed
Wake up early	1. Rash 2. Book an appointment with doctor
Arrive at clinic	1. Clinic was not busy 2. Wait time is only 5 mins
Debrief Doctor about issue	1. Doctor does thorough checkup of ears using otoscope 2. Realises ears need to be flushed
Write down info of physician	1. Schedule an appointment 2. Ears flushed next day

Q1: What action did Reese take just before going to bed? A: Ate food: chocolate milk, and snack

Q2: Why did Reese book an appointment with the doctor? A: Ear Itch and rash

Q3: How was Reese's medical issue resolved? A: Ears were flushed, ears treated by specialist

Doctor's Appointment: Emotion (words: 214)

One evening, Reese was watching the final movie in the Lord of the Rings trilogy. Around the half-way point of the movie, Reese started feeling extremely nauseous and felt a pulsating headache. The nausea and headache were overwhelmingly debilitating so Reese had to turn off the movie, take a pain killer, and sleep off the pain. This was not the first time these symptoms came up; over the course of a month, Reese had lost a significant amount of weight and repeatedly complained about general fatigue to family members.

Reese's mom noticed these changes and decided to book a doctor's appointment. She drove Reese to the local clinic but noticed that there was a long wait time of at least 45 minutes. At the end of an extensive checkup the doctor ordered a variety of tests, including an MRI, ultrasound, and multiple blood tests. In the coming weeks Reese awaited the test results, but continually felt drained because the symptoms were getting increasingly painful. Eventually, Reese was called back to the doctor's office and diagnosed with Adenocarcinoma – a form of stomach cancer with a low survival rate of only 20%. Since the diagnosis, Reese has completed multiple sessions of chemotherapy, however the prognosis remains uncertain due to a uniquely aggressive nature of the cancer.

Themes & Details:

Theme	Details
Watching LOTR (Movie)	1. Felt nausea and headache 2. Take a pain killer & sleep
Had been feeling symptoms for a while	1. Significant weight loss 2. Complaints of fatigue
Mom booked appointment	1. Drove to local Clinic 2. Long wait time (45 mins)
Doctor orders multiple tests	1. MRI, Ultrasound, blood tests 2. Wait for results while situation worsens
Diagnosis and prognosis	1. Stomach cancer with survival rate of 20% 2. Undergoing chemo with uncertain prognosis

Q1: Which symptoms caused Reese to go to bed early? A: Extreme nausea and headache

Q2: What are the symptoms that Reese had been feeling for the past month? A: Weight loss and fatigue

Q3: List the tests that the doctor ordered for Reese. A: MRI, ultrasound, blood tests

Night at the Bar: Neutral (words 228)

One evening Andy drove 90 minutes into the city of Hamilton. Andy went to meet three old college roommates. Andy and the roommates attended Mohawk College where they all acquired a diploma in business administration. They all work for different companies but decided to get together as it was one of their roommate's 25th birthday. They all decided to have a night out to celebrate. They went to a local bar called Chuck's Bar and Grill that held trivia night on Fridays and unlimited fifty cent wings with any order of drinks. After midnight, they had enough to eat so they all decided to split a taxi back home. As a birthday present, Andy decided to pay for the roommate's portion of the bill.

Andy and one of the roommates both decided to stay at the birthday roommate's house because it was close to the bar and the other lived further on the east side of town. Everyone was very tired and decided to split the taxi back home and slept in until noon. After lunch, Andy and the roommate got the car from the bar and drove back home because it was in the same direction of the highway. Andy returned to the city of St. Catharines just in time to pick up Andy's 8-year old daughter from soccer practice and they went to get ice cream.

Themes & Details:

Theme	Details
Met up with old college roommates from Mohawk	1. Drove for 90 minutes 2. Drove into Hamilton
Attended college together	1. All got a diploma in business administration 2. Got together for room mates 25th birthday
Decided to have a night out drinking	1. bar called chucks 2. held trivia night and unlimited 50 cent wings
Split a taxi to get home	1. room mates live further on the east side 2. slept in until noon
Leaving the next day to go home	1. returned to the city of St. Catherine's 2. pick up 8-year-old daughter from soccer practice

Q1: Which college did they attend and what which diploma did they acquire? A: Mohawk and business admin

Q2: What was Chuck's bar famously known for on Fridays? A: Trivia night and unlimited 50-cent wings

Q3: Why did Andy have to return back to St Catharine's? A: Pick up daughter from soccer practice, go get ice cream

Night at the Bar: Emotion (words 223)

One evening Andy drove 90 minutes into the city of Hamilton. Andy went to meet three old college roommates from Mohawk to celebrate one of their birthdays at Chuck's Bar and Grill. Andy did not plan on drinking a lot that night because of having to drive Andy's 8-year-old daughter to school in the morning, but the roommates did not take no for an answer and kept encouraging more vodka shots. After quite a few hours, they ended up drinking too much. The party died down around 2 am and they had to return home. None of them were in any shape to drive home as they were slurring their words, but the roommates convinced Andy to drive home drunk. Because of blurry vision, Andy could not see clearly and did not notice a vehicle merge onto the road. This caused Andy to turn the wheel quickly and lose control, causing a head on collision.

This resulted in Andy receiving traumatic injuries to the posterior and ventral areas of the brain. Since then, Andy needs a wheelchair and cannot move without assistance from others. Further, whereas Andy's daughter and Andy used to play soccer together everyday, now they can no longer enjoy playing sports together. Due to hearing loss, even simple things have changed; Andy cannot enjoy spontaneous conversations with friends and family.

Themes & Details:

Theme	Details
Met up with old college roommates from Mohawk	1. Drove for 90 minutes 2. Drove into Hamilton
Attended a room mates birthday party	1. At Chucks bar 2. Did not want to drink as he had to drive daughter to school the next morning
Andy drank with encouragement of his Roommates	1. too many vodka shots 2. party died down around 2 am
Room mates convinced Andy to drive drunk	1. His vision became blurry 2. Turned wheel quickly and got into a car accident
Injury to the brain	1. posterior and ventral areas of the brain 2. Andy cannot play sports or have spontaneous conversations with friends and family

Q1: Why did Andy not plan to drink? A: Had to drive his 8-year-old daughter, to school (emphasis)

Q2: What happened to Andy right before the other vehicle merged? A: Vision got blurry

Q3: How has Andy's senses changed? A: Andy cannot hear anymore, and has trouble having conversation with friends and family

University Life: Neutral (words: 231)

Jamie is a first-year university student pursuing a degree in Psychology. Throughout high school, Jamie has always planned to complete a PhD with the intention to become a therapist. Being involved in various extra-curricular activities at the university which includes a history club, art night, and intramural sports, Jamie's schedule stays busy. Jamie also spends several hours a month at the Giving Closet, which is a program that provides work experience for people in similar areas of study. Wednesday evening, Jamie would meet a group of friends to study for one of their psychology courses.

On a typical day, Jamie sets the alarm for 7:30 a.m., eats breakfast, and then walks to the bus stop in time to get to school. Jamie meets up with friends in the commons to have lunch and walk to their next lecture together. At the end of the day, Jamie spends two hours in the university library to work on outstanding assignments. After spending some time on course work, Jamie goes to the residence cafeteria to eat dinner and then returns to the main university campus to participate in a club or study group. Many evenings, Jamie would stay later to help tutor a friend in another class. The bus ride home is usually quiet, and Jamie arrives home in plenty of time to relax with housemates before preparing for the next day of classes.

Themes & Details:

Theme	Details
Jamie was in her first year of university	1. Majoring in Psychology 2. Wanted to pursue a PhD and be a therapist
Highly motivated and participated in extra-curriculars	1. History club, art night, intermural sports 2. Volunteering with Giving Closet
Jamie socializes often	1. Eats lunch in the commons with friends 2. Walks to lecture with friends
Jamie often assists others with their studies	1. Studies with a group a friends for their psychologist courses 2. Tutors a friend
Jamie has a structured schedule	1. Sets alarm for 7:30am 2. Walks to the bus stop in time to get to school

Q1: What was Jamie's ideal career path? A: Pursue a PhD with the goal of becoming a therapist

Q2: What type of off campus activity does Jamie do for several hours a month? A: with the Giving Closet, program that gives work experience to people in similar areas of study

Q3: How does Jamie frequently spend her evenings once she arrives home? A: Jamie relaxes with housemates, preparing for the next day of classes

University Life: Emotion (words 227)

Jamie is a first-year student majoring in Psychology and has always planned to pursue a PhD with the goal of becoming a therapist. Jamie, previously a straight-A student, struggles to achieve a passing grade in university. Jamie studies relentlessly and dedicated any free time to completing assignments. This leaves Jamie with no time to socialize which is difficult because Jamie is more than five hours away from home. Halfway through the semester, Jamie began to have panic attacks, but continued to study and attend office hours to ensure midterms would go smoothly. Despite significant effort, Jamie received a failing grade on a midterm. This failure was devastating to Jamie and brought on another severe panic attack.

Jamie still had a final essay to complete which could have improved the final grade but when Jamie received the essay back, it was yet another huge disappointment to learn that the essay received a grade of 45%. Feeling hopeless, overwhelmed, and worthless, Jamie called home to ask for help. Jamie's parents did not understand why their child was failing and questioned how much effort was being put into schoolwork. Deflated and angry, Jamie hung up the phone, stopped attending classes and refused to return anyone's calls. The university placed Jamie on academic probation which caused mental health issues to become unmanageable and led Jamie to drop out of university indefinitely.

Themes & Details:

Theme	Details
Jamie was in their first year of university	1. Majoring in Psychology 2. Previously a straight A-student
Jamie was highly motivated and wanted to purse graduate school	1. Wanted to pursue a PhD and be a therapist 2. studied relentlessly and dedicated any free time to completing assignments
Jamie was unable to socialize	1. No time 2. 5 hours away from her family
Struggling with her academics	1. failing grade on midterm 2. 45% on essay
Impacted her mental health	1. Hopeless, overwhelmed, and anxious 2. Became unmanageable and dropped out

Q1: What was Jamie's ideal career path? A: Pursue a PhD with the goal of becoming a therapist

Q2: What evidence showed Jamie was not doing well academically? A: Jamie failed the midterm and final essay

Q3: What happened when Jamie was put on academic probation? A: Jamie's mental health became unmanageable, and she dropped out.

Post-test Questionnaires

Squire Subjective Memory Questionnaire - Modified (SSMQ-m)

Instructions:

We would like you to report your overall memory function pertaining to each statement. Using the following scale, please respond to the following statements.

1. My ability to search through my mind and recall names or memories I know are there is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

2. My ability to recall things when I really try is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

3. My ability to hold in my memory things I have learned is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

4. If I were asked about it a month from now, my ability to remember facts about this form I am filling out would be:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

5. My ability to make a past memory that is “on the tip of my tongue” available is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

6. My ability to remember the names and faces of people I meet is:

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Very Poor		Poor		Fair		Good		Excellent

7. My ability to remember what I was doing after I have taken my mind off it for a few minutes is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

8. My ability now to remember what I read and what I watch on television is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

9. My ability to know when the things I am paying attention to are going to stick in my memory is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

10. My ability to make sense out of what people explain to me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

11. My ability to reach back in my memory and recall what happened a few minutes ago is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

12. My ability to pay attention to what goes on around me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

13. My general alertness to things happening around me is:

1 Very Poor	**2**	**3** Poor	**4**	**5** Fair	**6**	**7** Good	**8**	**9** Excellent

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 ❑

<u>If you were instructed to move ahead to question 38 please begin here</u>

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 ☐

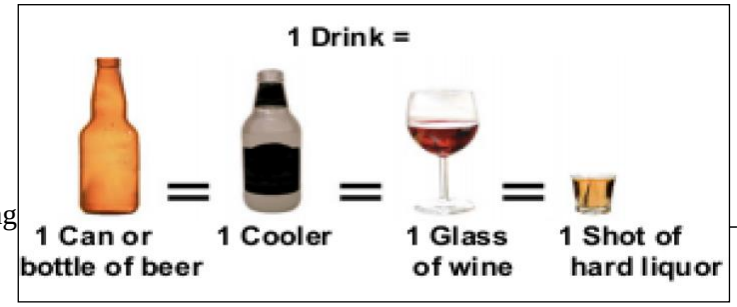
b. If **yes**, how long have you been drinking alcohol? _____

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 averag



_____ days/week

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.**

No use	☐	Weekly	☐
Once or Twice	☐	Daily	☐

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 ☐

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.

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

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

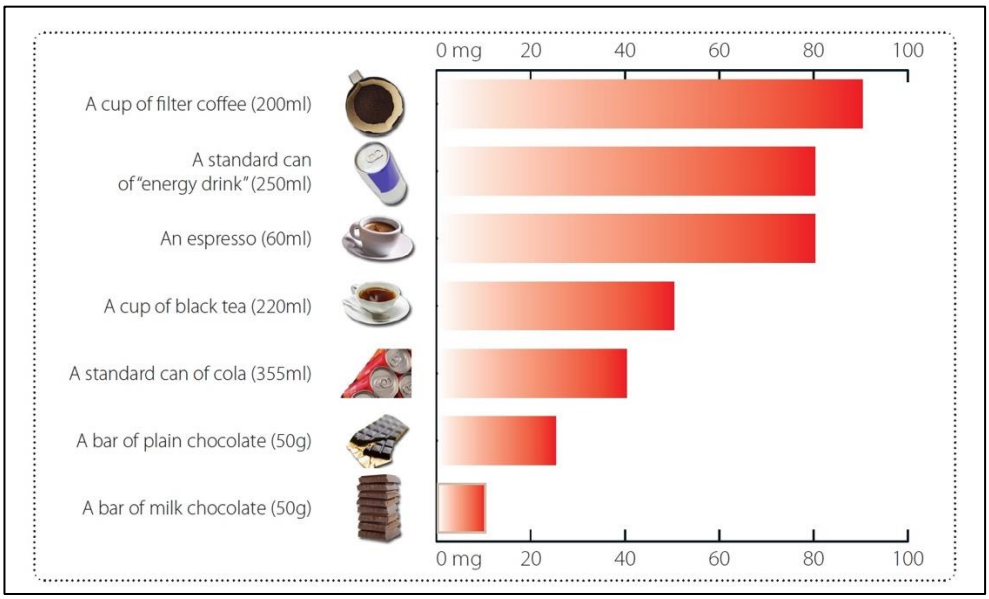
i. Do you take any performance enhancing drugs (e.g., anabolic steroids, hormones, stimulant drugs – **other than caffeine-based products** – such as amphetamine, ephedrine)? Yes ❑ No ❑

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 (e.g., deep breathing or yoga)? Yes ❑ No ❑

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):

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:

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

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

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

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

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

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

1 = less than 1 month	7 = 2 – 3 years
2 = 1 – 3 months	8 = 3 – 5 years
3 = 3 – 6 months	9 = 5 – 10 years
4 = 6 – 9 months	10 = 10 – 15 years
5 = 9 – 12 months	11 = 15 – 20 years
6 = 1 – 2 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	6 = 501 – 1000 times in my life
2 = 6 – 10 times in my life	7 = 1001 – 2000 times in my life
3 = 11 – 50 times in my life	8 = 2001 – 5000 times in my life
4 = 51 –100 times in my life	9 = 5001 – 10,000 times in my life
5 = 101 – 500 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	7 = last week
2 = 9 – 12 months ago	8 = this week
3 = 6 – 9 months ago	9 = yesterday
4 = 3 – 6 months ago	10 = today*
5 = 1 – 3 months ago	11 = I am currently high*
6 = less than 1 month ago	

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?

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

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

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

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	4= almost daily
1= Once or twice	5= daily
2=Monthly	
3= weekly	

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:

Appendix B. Equations for Analyses

Injury Severity (Scores collected from Everyday Living Questionnaire):

Injury severity was computed by aggregating the following responses: MHI Status [0 = no MHI, 1 = MHI], did they have symptoms lasting 20 minutes or more [0 = no, 1 = yes], was there loss of consciousness resulting from the injury [0 = no, 1 = yes], how long was the loss of consciousness [multiple options ranging from 1 = < 5 minutes, to 6= > 1 month], evidence for a skull fracture [0 = no, 1 = yes], memory loss prior to injury [0 = no, 1 = yes],memory loss length [multiple options ranging from 0 = no memory loss, to 8 = greater than 24 hours], memory loss after injury [0 = no, 1 = yes], post-injury memory loss length of time [multiple options ranging from 0 = no memory loss, to 8 = greater than 24 hours], Academic or employment accommodations required as a result of the injury [0 = no, 1= yes], medical emergency department visit [0 = no, 1 = yes], visit to family doctor [0 = no, 1 = yes], injury required stitches to face [0 = no, 1 = yes], injury required stitches elsewhere [0 = no, 1 = yes], injury required neuroimaging[0 = no, 1 = yes], received medical treatment [0 = no, 1 = yes], required overnight hospital stay [0 = no, 1 = yes],required 2+ nights of hospital stay [0 = no, 1 = yes], injury resulted in a bone fracture [0 = no, 1 = yes], injury caused soft tissue problems [0 = no, 1 = yes], required surgical intervention related to head trauma [0 = no, 1 = yes],required other surgical intervention [0 = no, 1 = yes],required additional follow-up [0 = no, 1 = yes], resulted in litigation [0 = no, 1 =yes], number of head injuries [multiple options ranging from 0 =none, to 6 = more than 5],and the same questions were aggregated for the second-most recent head injury as well.

Cannabis Consumption Degree Score (Collected from the CUDIT-R portion of ELQ)

The Cannabis Consumption Degree Score was computed by aggregating the following responses: self-reported regular cannabis use [no = 0, yes = 1], length of cannabis use [1 = not a regular user, 2 = less than a year, 3 = 1-2years, 4 = 3-5 years, 5 = 6-9 years, 6 = 10+ years], current cannabis use frequency [1 =less than once a year, 2 =once a year, 3 =once every 3-6months (2-4 times per year), 4 =Once every 2 months, 5 =once a month, 6 =2-3times 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], ever consumed cannabis regularly (2 or more times a month) for 6 months or longer [no= 0, yes = 1], ever consumed cannabis daily for 6 months or longer [no = 0, yes = 1],cannabis entire life occurrences [0 = never tried, 1 = 1-5 times in my life, 2 = 6-10, 3= 11-50, 4 = 51-100, 5 = 101-500, 6 = 501-1000, 7= 1001-2000, 8 = 2001-5000, 9 = 5001-10000, 10 = more than 10000 times], days cannabis was used in past week[1 = 0 days, 2 = 1 day, 3 = 2 days, 4 = 3 days, 5 = 4 days, 6 = 5 days, 7 = 6 days, 8 = 7 days].