The Effect of Chronic Cannabis Use on Visuomotor and Cognitive Performance

Ryan Cortez

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Abstract

The Canadian legalization of recreational cannabis use in 2018 has increased interest in the substance's impact on its users. This includes their visuomotor and cognitive abilities which are integral towards safely completing activities of daily living. The objective of this thesis was to determine if there are visuomotor and cognitive performance deficits related to cannabis use frequency. York University students (N~880) completed eight browser-based tasks that assessed their performance. Three tasks were analyzed: the task switching (assesses attention switching), tunnelling (assesses visuomotor acuity), and mirror reversed transformation (assesses goal-directed movement planning) tasks. The task performances of individuals with no prior use (N>=298), infrequent use (between once per 3 months & once per week; N>=71), and frequent use (once per week or more; N>=89) were compared. Our results demonstrated no significant performance deficits, suggesting that the frequency by which cannabis is used does not lead to persisting visuomotor and cognitive deficits.

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Chapter One: Introduction

Since the Canadian legalization of recreational cannabis use in 2018, there have been growing concerns regarding the potential impact of the substance on the daily lives of those who use it (Bourque & Potvin, 2021). Previous literature has indicated that adverse health effects exist related to both the acute and chronic use of cannabis (Crean et al., 2011; Nora et al. 2016). This effect extends to the brain, where it may affect visuomotor and cognitive functions which are important towards completing most activities of daily living (Grillner, 2013). Impaired functioning of either component can result in deficits in the ability to safely complete these tasks which may lead to potential harm or injury.

Despite these growing concerns, there has been insufficient research on the effects of cannabis outside of rehabilitation and clinical settings or jurisdictions where cannabis use is illegal. Participants in these settings commonly experience or are recovering from some form of cannabis use disorder (e.g. Rooke et al., 2013) which may be accompanied by demographic differences that harm the generalizability of the study to the general population that uses cannabis. Furthermore, findings in these studies face other limitations including small sample sizes and sampling biases related to rehabilitative environments. Hence, the legalization of cannabis in Canada has presented an opportunity for researching the effects of cannabis on a legal cohort outside of the rehabilitative settings. These individuals may use cannabis on a basis more alike to an average consumer and may be less likely to suffer from confounders such as polysubstance use.

The aim of this thesis is to determine the effects of cannabis use history and frequency on visuomotor and cognitive performance. Because most previous studies regarding the effect of cannabis on visuomotor and cognitive performance focus on the acute effects, it is important to address the knowledge gaps regarding potential deficits related to chronic usage during the non-acute phase.

To address this knowledge gap, we used a browser-based battery of tasks to assess if differences exist between individuals who use cannabis to those with no prior usage in several cognitive processes that are integral to daily activities. The battery was comprised of the following tasks and respective processes: the Tunnelling task which assesses motor acuity (Gonda et al., 2019) and goal-directed movements (McGrath & Kantak, 2015), the Iowa Gambling task which assesses decision making (Bull et al., 2015), the visuospatial N-back task which assess visuospatial working memory (Dores et al., 2017), the Mirror Reversed Transformation task which assesses goal-directed movement planning (Tippett & Sergio, 2006), the Visual Search task which assesses visual attention (Treisman & Gelade 1980), the Go/No-go task which assesses impulse inhibition (Gomez et al., 2007), the Task Switching task which assesses task-switching ability, inhibition (Mayr & Keele, 2000) and working memory (Rogers & Monsell, 1995), and the Trail Making task which assesses cognitive flexibility (Tombaugh, 2004).

Chapter Two: Literature Review

Cannabis is a psychoactive substance derived from the cannabis plant that is used for both recreational and therapeutic purposes. Even prior to the Canadian legalization of recreational cannabis in 2018, there had been a steady increase in cannabis use among several population cohorts and was the most widely used illicit drug in the country (Lowry & Corsi, 2020) and world (Figueiredo et al., 2020). From 2004 to 2017, cannabis usage increased among adults and decreased among youth (Rotermann & Macdonald, 2018). Since the legalization of recreational use, it appears that cannabis usage has continued to generally increase among adults

(Turna et al., 2021), yet has remained stable among youth (Zuckermann et al., 2021). The long-term trajectory of youth cannabis usage remains to be determined, however.

As stated previously, cannabis has both acute and chronic effects on health and brain function (Crean et al., 2011; Nora et al. 2016). These effects can be attributed to the principal psychoactive ingredient in cannabis, tetrahydrocannabinol (THC). THC exerts its effect by binding to CB_1 cannabinoid receptors. These receptors are expressed in high levels in neurons of the substantia nigra, basal ganglia, hippocampus, amygdala, and cerebral cortex and are important towards several components of executive functioning (Atakan, 2012). Activation of these receptors inhibits the release of neurotransmitters and amino acids from their host neurons and may interrupt processes involving cognitive-motor skills (Iversen, 2003). The other main ingredient in cannabis, cannabidiol (CBD) has been shown to have therapeutic benefits and may act as an antagonist to some of the adverse effects caused by THC (Niesink et al., 2013).

Some factors that can impact the degree of cannabis-related effects include the age of cannabis use onset, duration since usage onset, frequency of use, type/strain of cannabis, and amount of cannabis used (Aharonovich et al., 2008; Cohen & Weinstein, 2018). An empirical study conducted by Pope Jr. et al (2002) noted that acute cognitive impairments related to cannabis use may be temporary and reversible. The short-term cognitive effects within the acute timeframe of use may include impaired short-term memory, impaired motor coordination, and altered judgement. There is also evidence that other deficits may persist even after the discontinuation of the substance (Bolla et al., 2005). Long-term cognitive effects persisting past acute usage may include altered brain development, cognitive impairment, and diminished educational outcomes - these effects were strongly correlated when cannabis use began in early adolescence (Silins et al, 2014; Nora et al. 2016). The regular use of cannabis during adolescence is of particular concern since usage during this crucial developmental period is correlated with an increased likelihood of detrimental cognitive effects later in life (Volkow et al, 2014; Castellanos-Ryan et al., 2017). Lisdahl et al. (2014) suggest these detriments may be due to grey matter abnormalities associated with early onset of cannabis usage. Despite the previous literature, however, there is still a lack of a clear consensus on the effect of cannabis use on neurocognitive function (Figueiredo et al., 2020), highlighting the importance of future research on the substance.

The battery of experiments utilized in this study assessed several components of executive functioning and was used to determine if any differences exist between frequent, infrequent, and no prior use of cannabis. For this thesis, the task switching task, tunnelling task, and mirror reversed transformation task are described and analysed. The following processes related to the aforementioned tasks and literature regarding how they are affected by cannabis will be discussed: task switching ability, motor acuity, and goal-directed movement planning.

Task Switching

Task switching is a form of cognitive flexibility that involves the ability to switch attention between multiple tasks (Schneider & Logan, 2009). Within this study's battery of experiments, it was assessed by performance on the task switching task. It has been proposed that the neural mechanisms related to task switching are distributed between the frontoparietal cortical network and is related to processes regarding memory, attention, and impulse inhibition (Schneider & Logan, 2009). Task switching abilities are commonly used in daily life such as when driving a car. For example, it is used to switch attention between the colour of the traffic light and the presence/absence of pedestrians crossing the street when performing a turn at an intersection. A concept associated with task switching is the switch cost – the reduction in accuracy and/or slowing of response time to a stimulus after switching between tasks. The effect of various drugs on task switching performance has been measured by the relative difference in switch cost between those with and without a history of substance usage.

There are few studies regarding task switching ability that have used cannabis as its principal focus. An experimental study by Dafters in 2006 found that participants who used cannabis were not significantly impaired compared to those who did not in a task switching variant of the Stroop test, suggesting a lack of deficits in task switching ability as well as impulse inhibition. This study had 3 experimental groups: participants who have previously used both cannabis and MDMA (ecstasy) (N=33), participants who have only previously used cannabis (N=17), and participants who did not use either drug (N=18). The Stroop Colour-Word test was used to assess task switching based on their response time and accuracy. In the first block of trials, participants had to read out a set of colour words written in black ink. In the second block of trials, participants had to read of a set of colour words written in colours different than the word itself (E.g., Read the word 'blue' written in red). In the third and final block, participants had to indicate the colour the words were written in and ignore the word itself (E.g., Indicate the colour of the word 'blue' written in red). The difference in performance (switch cost) between blocks 2 and 3 was measured in all experimental groups. Only the MDMA cohort demonstrated significant impairments in task switching performance, while the cannabis-only cohort and no usage cohort experienced no significant impairments. These findings were interpreted as evidence that some components of executive functioning, such as task switching may not be significantly affected by certain drugs such as cannabis past the acute timeframe of use.

Motor Acuity

Motor acuity is defined as a component of motor skill learning that is quantified by shifts in speed-accuracy trade-offs (Shmuelof et al., 2013). The tunnelling task was used to assess motor acuity within this study. The contralateral primary motor & premotor cortical areas, and ipsilateral cerebellum are areas that are involved in motor acuity (Gonda et al., 2019; Shmuelof et al., 2013). It is used when completing activities requiring fine motor skills, such as when writing on a piece of paper. The effect of cannabis on motor acuity has not been significantly investigated. However, there have been a few studies discussing the effect of cannabis on linear and rotary movements that may integrate motor acuity.

For example, Kvalseth (1977) recruited 6 male participants with a history of prior cannabis use and evenly divided them into 4 cannabis dose conditions: 0 mg, 2.6 mg, and 19.5 - 26.0 mg of THC. The participants were then required to complete 3 movement-based tasks with the accuracy of responses and reaction or movement time as their performance measures. Experiment 1 required participants to respond to a set of stimuli as quickly as possible by pressing their respective buttons. The number of stimuli present varied in each trial, ranging from 1 to 8 stimuli. In experiment 2, participants were required to tap a stylus back and forth between two parallel metal plate targets distanced 12.7 cm apart. The objective was to minimize the linear movement time between plates and minimize error (defined as undershooting or overshooting a target). The distance between targets and width of targets varied across trials (distances of 10.16cm, 20,32cm, and 40.64cm; target widths of 0.64cm, 1.27cm, and 2.54cm). Similar to experiment 2, experiment 3 required participants to move a pointer between two targets. The main difference was that this movement was rotary instead of linear in nature and was controlled by turning a 5.7 cm round control knob at precise angular distances. The angular distance between targets and angular width of the targets varied across trials (angular distances of 45°, 90°, and 160°; angular target widths of 6°, 12°, and 24°).

The results demonstrated that cannabis dosage did not result in a significant difference in reaction time in experiment 1. Furthermore, while they found a significant difference in linear movement times between groups in experiment 2, this was not observed for rotary movement times in experiment 3. There was no significant interaction between the task difficulty (target distance and width) and cannabis dosage. While reaction and movement times did not generally significantly differ, cannabis did increase error rates for all experiments compared to the 0 mg dosage condition. It is important to note that this study did not have any participants who had no prior usage of cannabis. Hence, motor acuity performance differences between individuals with versus without cannabis usage histories in the absence/presence of acute usage have not been thoroughly explored.

Goal-directed Movement Planning

Goal-directed movement planning is the strategizing of volitional movement in order to attain a specified target/goal (Svoboda & Li, 2018; Echlin et al., 2020). An example of this is reaching your arm to pick up a bottle across your table. The mirror reversed transformation task was used to assess goal-directed movement planning in this study. Goal-directed movement planning utilizes multiple brain regions, including the anterior lateral motor cortex, premotor, supplemental, and primary motor cortex, striatum, superior colliculus, motor-related thalamus, and cerebellum (Svoboda & Li, 2018). Furthermore, dopamine plays a key role in goal-directed movement planning by affecting pathways related to the goal-based initiation of movement through the binding of D_1 receptors (Prashad & Filbey, 2017).

Only a few studies have explicitly investigated the effects of cannabis on goal-directed movement planning. Ramaekers et al. (2006) recruited 20 participants who use cannabis recreationally to conduct a study regarding the effects of cannabis on executive function and motor control. The three-way cross-over study required the 20 participants to receive treatments of 0 μg/kg, 150 μg/kg, and 500 μg/kg of cannabis per body weight over three different study periods. Their performance under each treatment was measured during their respective period. The researchers used the critical tracking test to measure motor planning and control. This task required participants to compensate for a horizontally deviated cursor on a horizontal scale to return the cursor to the midpoint. Throughout the task, the cursor deviation increased and required a larger compensation. The task included 5 trials and only the middle 3 scores were averaged into a final score. Participants completed this task at 4 time points for each cannabis dosage: 0.5, 1.5, 3.5, and 5.5 hours after consuming the dose. Although there were significant differences between the 0, 150, and 500 μg/kg doses in performance during the timeframe immediately after dose consumption (500 μg/kg performing the poorest and 0 μg/kg performing the best), these deficits appeared to reduce over time (yet remained significant until 5.5 hours post-consumption). No significant interaction was demonstrated between the amount of THC and the post-consumption time. These findings suggest that performance deficits related to motor planning may be transient and dissipate after the cessation of cannabis use. However, since all participants had a prior history of cannabis use, it is difficult to infer how these participants may compare to those with no prior usage outside of the acute effects. Hence, further research needs to be done on the comparison between those with a history of cannabis use versus individuals with no previous usage during cannabis-absent goal-directed motor planning.

Study Goals and Hypotheses

The goal of this thesis was to determine if there are deficits to visuomotor and cognitive function in persons who use cannabis compared to individuals who do not, especially within their task switching ability, motor acuity, and goal-directed movement planning. My hypotheses were that: there would be no detriments in the task switching abilities of the cannabis cohort compared to the no usage cohort, motor acuity performance would be worse in the cannabis cohort compared to no usage cohort, and goal-directed movement planning performance would be worse in the cannabis cohort compared to the no usage cohort. Furthermore, performance comparisons between males and females were completed as a covariate to determine if any interactions exist between sex and cannabis-use frequency.

Chapter Three: Methods

Participants

Participants were recruited from York University's Undergraduate Research Participant Pool (URPP) with the following exclusion criteria: 1) suffering from a neurological condition 2) currently using opiates or recreational drugs aside from marijuana 3) not using vision correction devices (if normally used) or indicating an inability to see the experiment screen properly, 4) the use of a phone or tablet to complete the study. Due to the different screening criteria between the tasks used in this study, there are a variable number of participants in each. The number of participants within the tasks ranged from 458 to 694, with the number of female participants ranging from 333 to 506 and number of male participants ranging from 125 to 188. The rationale for the large gap between the number of female and male participants is because York University's URPP population is 70% female. The average age of participants across all tasks was consistent at 21 to 22 years old. A detailed breakdown of the participants can be found on Table 1 within the Results section. All participants were required to complete an electronic informed consent form prior to the beginning of the study. Given the variable nature of data collection from online studies and the lack of expectation of a large effect size (due to the high-functioning legal cohort within this study), we aimed to collect as much participant data as could be achieved. The current study has received approval from York University's Human Participants Review Committee.

Apparatus

Participants were able to complete this study on their personal computers or laptops. As stated previously, participants who used phones and tablets were excluded since the browser-based tasks of this study were not yet adapted for these devices at the time of data collection. Qualtrics, a cloud-based survey platform, was used to provide the informed consent form, gather demographic information through a questionnaire, and provide instructions throughout the study. It also included URLs to the battery of browser-based tasks. Pavlovia, an online platform that launches and runs browser-based experiments using Gitlab, was used to host the battery of tasks and store the data on its server. Gitlab, an open-source software development platform, was the repository of all tasks which were coded in Psychojs.

Questionnaire

Participants were instructed to complete an online demographics questionnaire prior to completing the battery of tasks. The questionnaire required the participant to indicate their age, sex, ancestry/ethnicity, handedness, presence of neurological conditions, device used to complete the experiment, computer adeptness, and usage of corrective vision devices. Furthermore, additional questions related to level of fitness, language proficiencies, sleep history (Pittsburgh Sleep Quality Index), COVID-19 history and symptoms, concussion history, and other miscellaneous demographic information were included. However, these additional questions were not considered or used in the analysis of the current study's data. The main survey questions of interest were those related to cannabis use and include the following: whether the participant has had any prior usage of cannabis, method of ingestion (e.g. joint, hash oil, edible, etc.), rationale for usage (e.g. recreational, medical), estimated THC content per use, usage of cannabis in combination with alcohol, estimated time since last use, estimated time until next intended use, and age of first usage. A copy of the questionnaire utilized in the Fall 2021 data collection period can be found in the Appendices.

Tasks

As of March 2022, there are 8 tasks completed during this study over the course of 2 sessions. The order of tasks is randomized within each session. The tasks completed in the first session are the following: the Tunnelling task, the Iowa Gambling task, the Visuospatial N-back task, and the Mirror Reversed Transformation task. The tasks completed in the second session are the following: the Visual Search task, Go/No-go task, the Task Switching task, and the Trail Making task. For this study, only the Task Switching Task, Tunnelling task, and Mirror Reversed Transformation task will be further described and analysed.

Task Switching Task

The task switching experiment (adapted from Stoet, 2010) is used to assess task-switching ability, inhibition (Mayr & Keele, 2000); and working memory (Rogers & Monsell, 1995). In this task, participants were required to respond to a set of stimuli based on two different response rules in an alternating sequence. In total, there were four different variations of stimuli that could be presented in each trial: a diamond with either (1) two or (2) three dots inside the shape, and a square with either (3) two or (4) three dots inside the shape (Figure 1). The appearance rates of each of the four stimuli were randomized throughout the task. Participants used the ‘x’ and ‘n’ keys to respond to 2 different kinds of responses within each block. Block 1 required the participant to respond to the shape of the stimuli, regardless of the number of dots within the shape (denoted A). A diamond required an ‘x’ key response, and a square required an ‘n’ key response. Block 2 required the participant to respond to the number of dots in the stimuli, regardless of the stimuli shape (denoted B). Two dots required an ‘x’ key response while three dots required an ‘n’ key response. After blocks 1 & 2, participants were instructed to complete a third and final block that combined the rules of the first two blocks in an alternating trial sequence (denoted AABB). In block 3, stimuli appeared in a 2x2 grid in a clockwise fashion, beginning in the top-left cell.

Participants were instructed to respond to the presented stimulus as quickly as possible, with a set timeout time of 10 seconds per trial. Participants also received feedback for correct and incorrect responses. This feedback was presented as a change in the colour of the grid. When a correct response was made, the grid colour changed to green, while an incorrect response changed the colour of the grid to red. In blocks 1 & 2, following an incorrect response, a reminder screen with the instructions for the respective block was presented.

Prior to Fall 2021, blocks 1 and 2 each consisted of 12 trials, while block 3 consisted of 50 trials for a total of 74 trials. Beginning in the Fall of 2021, 2 additional blocks which are identical to blocks 1 & 2 were added after block 3 for a total of 5 blocks and 98 trials. This change was done in order to identify if learning effects were influencing the measured performance variables of the third block.

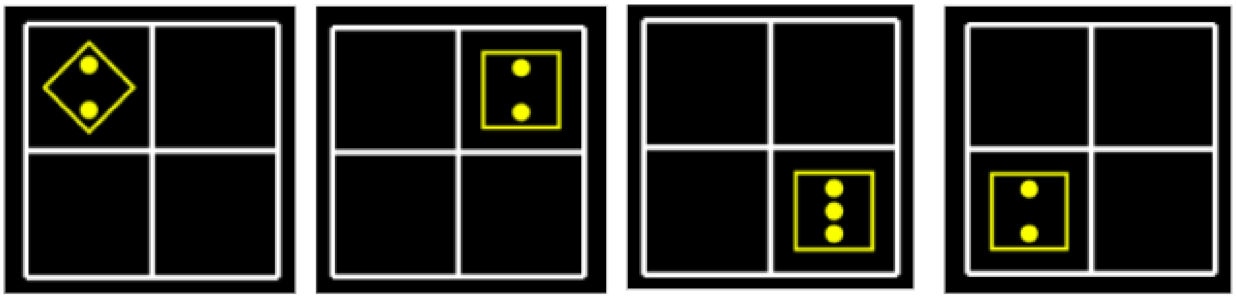

Figure 1. Task Switching task interface –Participants were asked to respond to the shape or filling of the stimuli in an alternating sequence depending on the stimuli location.

Tunnelling Task

The tunnelling task is a visuomotor task that is used to assess assesses motor acuity (Gonda et al., 2019) and goal-directed movements (McGrath & Kantak, 2015). The track used in this task has been adapted from McGrath & Kantak (2015) and Mirdamadi & Block (2020). Using their mouse or trackpad, participants were required to navigate their cursor through a standardized tunnel consisting of turns of fixed lengths and angles (Figure 2). Along with the original size of the tunnel, this standardized tunnel could appear in 3 additional smaller scaled versions: 40% of the original size, 60% of the original size, and 80% of the original size. Furthermore, the tunnel could appear rotated 180° in addition to having a different scaling. The objective of the task was to move the cursor through the tunnel as quickly as possible while minimizing cursor movement outside of the tunnel. Successful completion of a trial consisted of moving from the start position of the tunnel to the end position, then returning to the start position. This task consisted of 24 trials.

Figure 2. Tunnelling task interface – Participants were required to navigate their cursor as fast as possible through a tunnel from the home position (orange) to the target position (blue) and return to the home position while minimizing movement outside of the tunnel. The left tunnel demonstrates the track at its original size, whereas the right tunnel demonstrates 40% version of the original size and rotated 180°.

Mirror Reversed Transformation Task

The mirror reversed transformation task is used to assess goal-directed movement planning (Tippett & Sergio, 2006). In this task, participants moved their cursor from a home position to a series of targets at 30° and 60° angles and returned to the home position to complete the trial. The first 20 trials of the task had normal visual feedback, followed by 90 trials where visual feedback of the cursor was reversed on the y-axis, and ending with a wash-out phase of 20 normal visual feedback trials. Only the final 40 trials of the reversed trials were analysed since motor skill learning outcomes are not of interest. Prior to the reversed trials, participants were prompted that the cursor may move differently than expected but were not explicitly told that the cursor movement would be reversed on the y-axis.

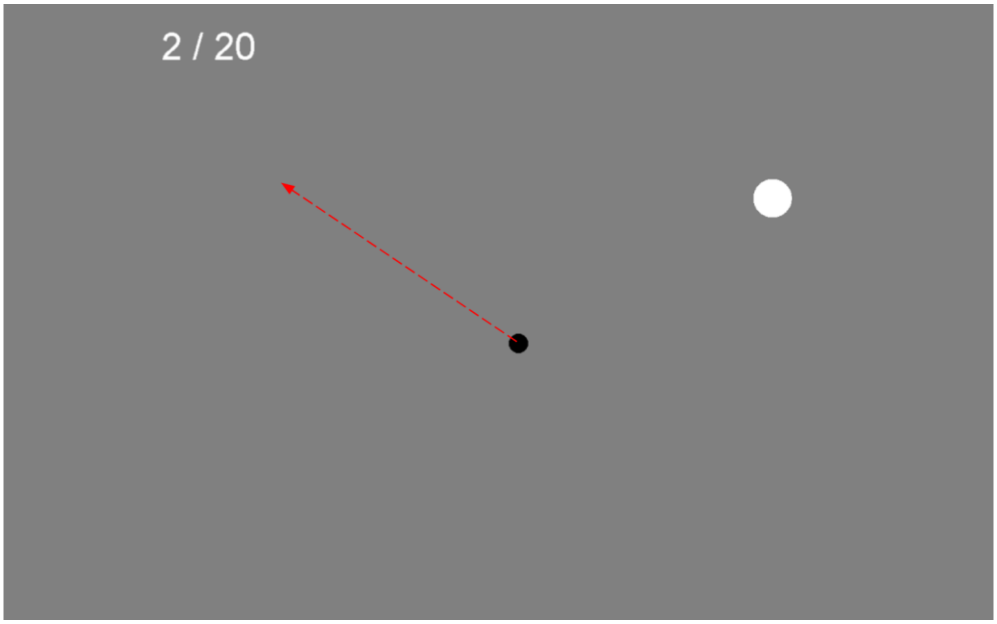

Figure 3A. Mirror Reversed Transformation task interface - the red line has been added for demonstration purposes. Participants were required to move their cursor (black dot) to a series of peripheral targets (white dot) with y-axis reversed visual feedback. The red arrow represents the mouse/hand path required to move the cursor to the target.

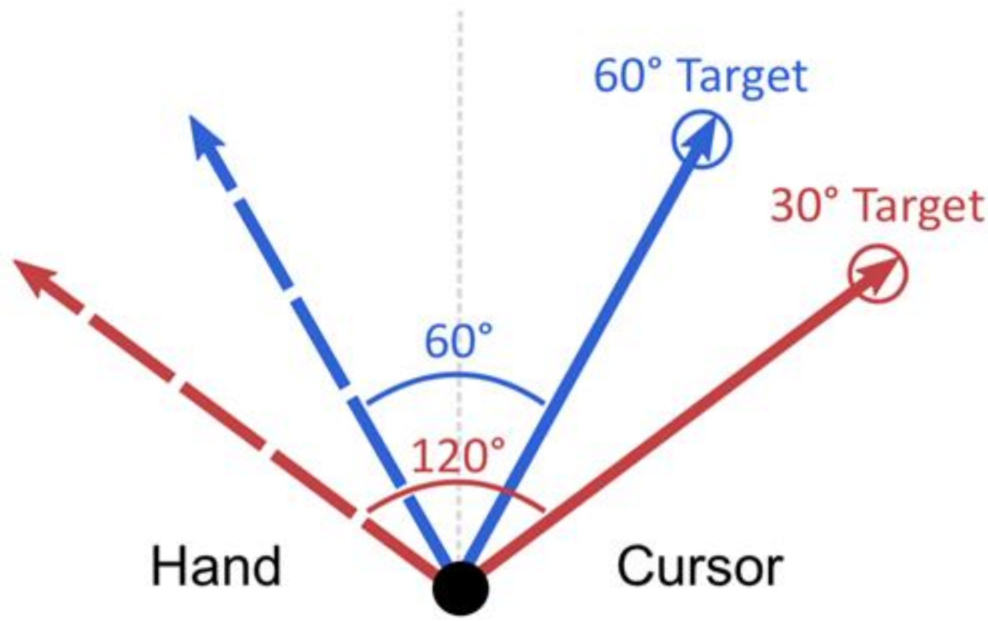

Figure 3B. Example movements of a mirror reversed trial. For a participant to correctly move their cursor to a target at 30° and 60°, they must move their hand at -30° and -60°, respectively.

Procedure

Participants completed the study in two parts which mainly differed in the tasks that were assigned to each. 4 tasks were completed in each part for a total of 8 tasks. To begin, participants were provided with a unique Qualtrics URL to access the study. At the beginning of the study, an electronic informed consent form was provided and was required to be signed. This was followed by the completion of a demographic questionnaire. Participants were then directed to complete the 4 tasks through embedded URLs within the questionnaire. After each task, they were asked to provide any comments/concerns and indicate if they made significant errors warranting the removal of their data (ex. misunderstood the nature of their task, etc). Participants were instructed to take a short break after each task, with a minimum of 20 seconds before being allowed to proceed. At the end of the study, participants were asked if they encountered any conditions that made it difficult to complete the study (Ex. distractions, technical difficulties).

Experimental Groups

Frequent use cohort

Participants who consume cannabis are categorized according to their frequency of use. They were not instructed to abstain or consume cannabis throughout the study. However, an indication of their most recent usage was asked in the questionnaire. The frequent use cohort was comprised of individuals who used cannabis at least once per week within the last three months.

Infrequent use cohort

The infrequent use cohort was defined by usage of cannabis at least once or twice within the last three months but less than once per week. This excludes any participants who have indicated they have not used cannabis in the last three months from the analysis.

No prior use

The no prior use cohort is comprised of individuals who have never used cannabis previously.

Data Analysis

The performance variables of these three tasks were analyzed using R and JASP, with a comparison made between frequent, infrequent, and no prior use of cannabis. The main objective of this analysis is to determine if any differences exist in the performance of frequent, infrequent, and no prior usage cohorts in the browser-based tasks. The method of how each task is analysed as well as their respective performance measures are described below. Furthermore, each task and their respective performance measures were compared between male and female participants to note if any sex-related differences exist. All statistical tests will be set to an alpha level of 0.05 and will use the Tukey post hoc test when required unless stated otherwise.

Task Switching Task

The variables being measured in this experiment are the reaction time (RT) and the proportion of correct and incorrect responses. Trials in baseline blocks (1 & 2 prior to Fall 2021, 1, 2, 4, & 5 after Fall 2021) were categorized as single trials because only one task is being assessed in each block. In block 3 exclusively, the reaction times and proportions of correct and incorrect responses were recorded for repeat and switch trials. Repeat trials are defined as trials where the stimulus position shifts from a left cell to a right cell, or from a right cell to a left cell of the grid (indicating no task switch, denoted by AA or BB). In repeat trials, the participant continued to respond based on the same task of the previous trial (Ex. shape>shape or filling>filling). Conversely, switch trials are defined as trials that occur after the stimulus position shifts from the top to the bottom row, or from the bottom to the top row which indicates a task switch, denoted by AB or BA. In switch trials, the participant must switch the task response from the previous trial (Ex. shape>filling or filling>shape).

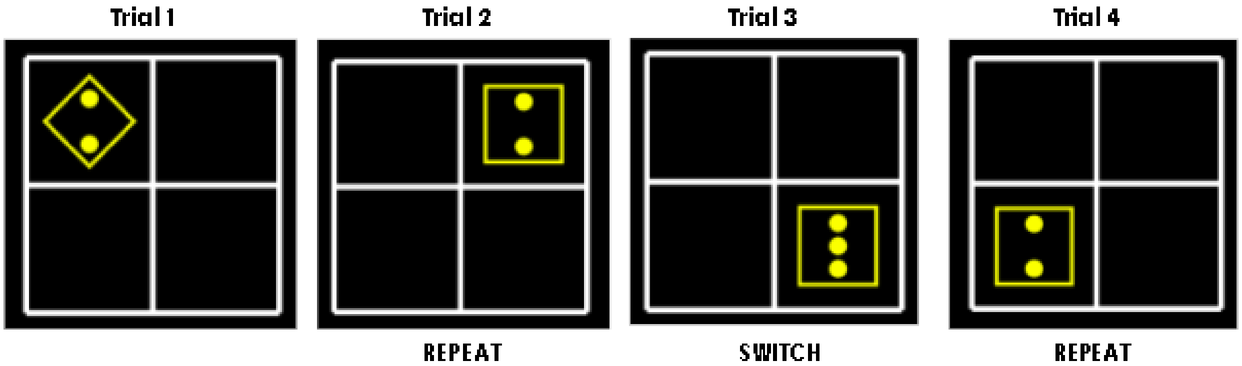

Figure 4. Demonstration of repeat and switch trials. A repeat trial stays within a given row and retains the same task as the previous trial. A switch trial moves between rows and switches tasks from the previous trial.

Performance on this task was measured by comparing the reaction times (s) and proportions of correct and incorrect responses between single, repeat, and switch trials. Reaction time onset is defined at the start of each trial when the stimulus appears. Improved performance is indicated by a lower reaction time and/or increased proportion of correct responses. It was expected that reaction time and proportion of incorrect responses would increase from single to repeat to switch responses due to the switch cost associated with the increasing difficulty of each trial type (Schmitz & Voss, 2014). A 3X3 mixed ANOVA was used to compare frequent, infrequent, and no prior usage of cannabis between the single, repeat, and switch trials.

Tunnelling Task

Performance on this task was measured by comparing the completion time (s) and accuracy between experimental groups. Completion time is defined as the time it takes to react to the peripheral target, move the cursor from the home position to the peripheral target, and return the cursor to the home position / the difference between completion time onset and offset. Completion time onset is defined at when the cursor enters the home position. Completion time offset is defined at the point when the cursor re-enters the home position. Since onset is defined when the cursor enters the home position and not when they leave the home position, it cannot be defined as movement time due to the potential time spent waiting within the home position. Accuracy is defined as the percentage of the total trial time within the tunnel track. The percentage of total trial time was measured as the percentage of total coordinate samples that occurred within the tunnel throughout the trial. A preliminary comparison between each track scale (40%, 60%, 80%, 100%) found near-identical completion times and was not used as an indicator of improved performance as a result. As a result, accuracy was used as the main measure of performance in this task. Accuracies were determined in all scale sizes and the difference between frequent, infrequent, and no prior usage of cannabis was determined through a 3X4 mixed ANOVA.

Mirror Reversed Transformation Task

Performance on this task was analyzed using the completion time (s) and cursor path length. Since motor skill learning is not of interest for this study, only the last 40 trials of the mirror reversed trials were analysed. Completion time is defined as the time it takes to react to the target and move from the home position to the target / the difference between completion time onset and offset. Completion time onset in this task is defined when the cursor is within a distance of 5% of the total screen height to the home position. Completion time offset is determined when the cursor is within a distance of 5% of the total screen height to the peripheral target. Cursor path length is defined as the length of cursor movement required to move from the home position to the target. A shorter path length indicates fewer extraneous movements and better performance. The path length unit is relative to the height of the screen, where a score of

1.0 indicates 100% of the total screen height. A straight-line path from the home to the target position would consist of 40% (0.4) of the total screen height. Completion time and cursor path length were compared between frequent, infrequent, and no prior usage of cannabis using an ANOVA.

Chapter Four: Results

Participants

The results of this study are based on the participant data collected between the period of Fall 2020 to Fall 2021. The number of participants per task varied due to different rates of completion for part 1 of the study (consisting of the tunnelling task, the Iowa gambling task, the visuospatial N-back task, and the mirror-reversed transformation task) and part 2 of the study (consisting of the visual search task, go/no-go task, the task switching task, and the trail making task). The completion of part 2 of the study requires the completion of part 1, but not vice-versa. Overall, 299 participants completed only part 1 of the study which meant their data for the part 2 tasks had yet to be collected or they had dropped out of the study before completing part 2. However, their task data from part 1 of the battery will be included and analysed in this thesis. Additionally, the number of participants per task varied due to task-specific screening criteria which resulted in the removal of uneven numbers of participants. A detailed breakdown of the participants across the tasks can be found in Table 1. The task-specific screening criteria will be discussed in the next section.

Table 1. General demographic information for no prior use, infrequent, and frequent use of cannabis cohorts within each task.

Task	No prior use	Infrequent use	Frequent use
Task Switching	n = 472 (68%)	n = 104 (15.0%)	n = 118 (17.0%)
Age (M, SD): Age of use onset (M, SD) Male: Female:	21.63 (6.67) N/A n = 130 n = 342	21.18 (4.48) 17.32 (2.73) n = 27 n = 77	22.44 (5.06) 16.93 (3.70) n = 31 n = 87
Tunnelling	n = 298 (65.1%)	n = 71 (15.5%)	n = 89 (19.4%)
Age (M, SD): Age of use onset (M, SD) Male: Female:	22.12 (7.03) N/A n = 85 n = 213	21.77 (4.87) 17.46 (2.47) n = 18 n = 53	22.89 (5.45) 17.01 (3.84) n = 23 n = 66
Mirror-reversed Transformation	n = 339 (64.6%)	n = 79 (15.0%)	n = 107 (20.4%)
Age (M, SD): Age of use onset (M, SD) Male: Female:	21.47 (6.72) N/A n = 93 n = 246	20.84 (4.08) 17.24 (2.05) n = 21 n = 58	22.29 (4.97) 16.74 (3.28) n = 30 n = 77

Data Screening

The browser-based nature of the study and the lack of researcher supervision during the experiment may have resulted in potential participant errors that harm the generalizability of their data (ex. Misunderstood experiment, lack of effort, etc.) To address this, several screening criteria have been applied to each task in order to mitigate these potential errors. The screening criteria for the task switching task, tunnelling task, and mirror reversed transformation task will be discussed below. Aside from these task-specific screening criteria, any incomplete tasks were also removed from the data analysis.

Task switching

The task switching task utilized screening criteria based on reaction time and accuracy. Any trials with reaction times <0.10 s was removed as this would indicate low effort rapid responses. In addition to this, a trial time limit of 10 s was implemented into the experiment. Participants with multiple and/or consecutive trials with reaction times <0.10s were removed entirely. Participants with a mean accuracy of 3 standard deviations away from the mean single, repeat, or switch trials were excluded, respectively. The task switching screening criteria resulted in the removal of 4.61% of participants.

Tunnelling

The tunnelling task was screened based on the completion time of participants. Based on a preliminary analysis of the task, any completion times above 12 s were excluded as beyond this point, there are no differences in our main performance measure of accuracy as observed in Figures 11 and 12. The tunnelling screening criteria resulted in the removal of 1.3% of participants.

Mirror Reversal Task

The mirror reversal task was screened based on completion time and path length. Participants with completion time averages above 10 seconds or path length averages above 6.0 (cursor movements of 6 times the height of the screen) were excluded, as this indicated they were not following the instruction to complete the trials as quickly as possible or were making excessive extraneous movements. Furthermore, participants who indicated that they switched their hand side between blocks were also excluded. The tunnelling screening criteria resulted in the removal of 11.4 % of participants.

Experimental Groups

Cannabis Use

The following reported comparisons are based on the task switching task because it has the largest sample size (n = 694). Across all tasks, there was a significantly larger proportion of people who identified as females (72.9%) compared to those who identified as males (27.1%). This percentage reflects our pool of participants where roughly 70% identified as female. As stated previously, participants who indicated they used cannabis less than once every three months were removed, resulting in 117 individuals being excluded from the analysis. Demographic comparisons were completed between participants with no prior, infrequent, and frequent use of cannabis across each task to determine if any significant differences exist. A one-way ANOVA was conducted and found no significant differences between the ages of the three experimental groups ($F = 1.278$, $p = 0.279$ $\eta^2 = 0.004$), where the average age remained consistent at 21-22 years old. No significant differences were found between the age of first cannabis use ($F = 0.313$, $p = 0.577$, $\eta^2 = 0.02$), with an average of ~17 years old.

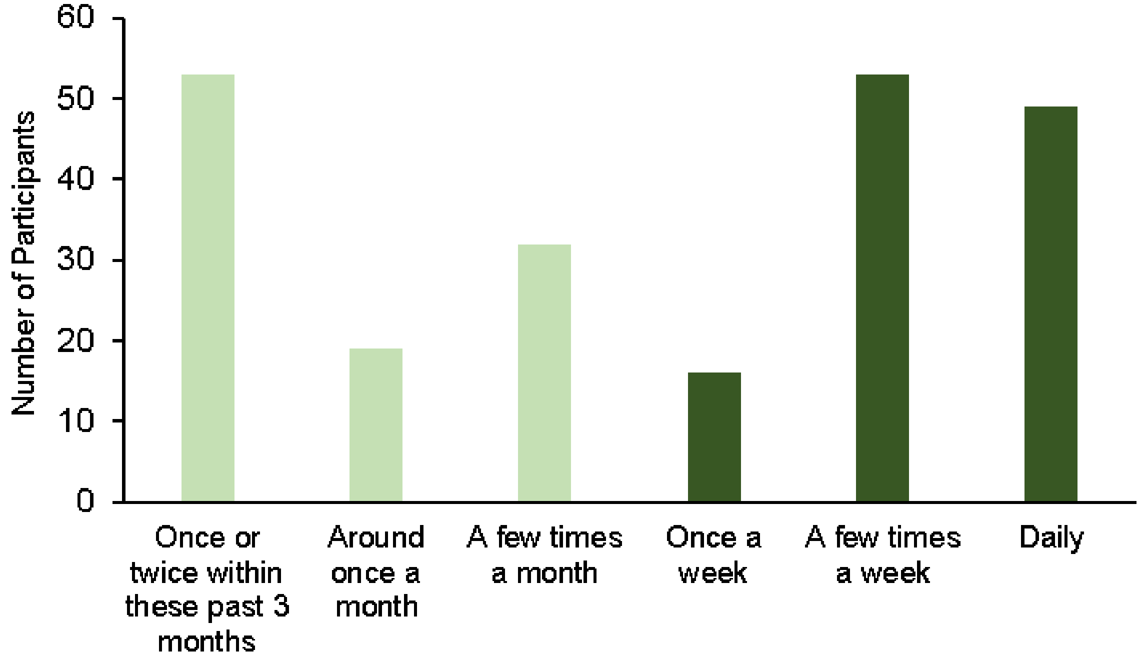

Figure 5. Distributions of cannabis use frequencies within the task switching task. Light green bars are sub-groups within the infrequent use cohort while dark green bars are sub-groups within the frequent use cohort.

Infrequent Use

The infrequent use cohort ranged from being 15.0% to 15.4% of the analyzed participants across tasks. The average age of first cannabis use was ~17 and the average number of years since first cannabis use ranged from 3.61 to 4.31 years. Participants were asked to indicate their primary methods of intake and could list as many methods as they liked. Across all tasks, the most frequently used method of intake for the infrequent use cohort were joints (67.1% - 67.3% of participants), followed by edibles (47.9% - 51.9%) and blunts (13.9% - 18.3%). The least common method of intake was through hookahs, which accounted for 1.4% - 2.9% of participants. Additionally, participants were asked to indicate their rationales for use, with no limit on number. The most common reason for infrequent use was as a social activity (68.4% -

72.1%), followed by general recreational use (40.5% - 41.3%) and anxiety relief (23.9% to 31.6%) across tasks. The least common rationale within the questionnaire options was for sleep aid, ranging from 8.7% to 17.7% of participants. A few other rationales for use were indicated under the 'Other' category as text responses, including as an entheogen and for reducing overthinking.

Table 2A. Cannabis use patterns of the infrequent use cohort across each task.

Characteristic	**Task Switching Task (n = 104)**	**Tunnelling Task (n = 71)**	**Mirror Reversal Task (n = 79)**
Methods of Intake:			
Blunt:	n = 19 (18.3%)	n = 13 (18.3%)	n = 11 (13.9%
Joint:	n = 70 (67.3%)	n = 45 (63.4%)	n = 53 (67.1%)
Bong:	n = 12 (11.5%)	n = 8 (11.3%)	n = 9 (11.4%)
Vaporizer:	n = 18 (17.3%)	n = 12 (16.9%)	n = 10 (12.7%)
Hand Pipe:	n = 9 (8.7%)	n = 8 (11.3%)	n = 7 (8.9%)
Hookah:	n = 3 (2.9%)	n = 1 (1.4%)	n = 2 (2.5%)
Edible:	n = 54 (51.9%)	n = 34 (47.9%)	n = 40 (50.6%)
Oil:	n = 10 (9.6%)	n = 8 (11.3%)	n = 10 (12.7%)
Rationales for Usage:			
Recreational:	n = 43 (41.3%)	n = 29 (40.8%)	n = 32 (40.5%)
Social:	n = 75 (72.1%)	n = 48 (67.6%)	n = 54 (68.4%)
Anxiety Relief:	n = 27 (26.0%)	n = 17 (23.9%)	n = 25 (31.6%)
Pain Relief	n = 12 (11.5%)	n = 10 (14.1%)	n = 14 (17.2%)
Sleep Aid:	n = 9 (8.7%)	n = 4 (5.6%)	n = 14 (17.7%)
Other:	n = 1 (1.0%)	n = 1 (1.4%)	n = 2 (2.5%)
Average age of use onset (M, SD)	17.33 (2.37)	17.46 (2.47)	17.24 (2.05)
Average years since use onset (M, SD)	3.86 (2.37)	4.31 (4.22)	3.61 (3.62)

Frequent Use

The frequent use cohort ranged from being 17.0% to 20.4% of the analyzed participants across tasks. The average age of first cannabis use was ~17 and the average number of years since first cannabis use ranged from 5.86 to 6.55 years. Like the infrequent use cohort, the most used method of intake across tasks were joints (68.6% - 71.0% of participants) and edibles (31.5% - 40.1%). However, unlike infrequent use, the third most common method of intake was through vaporizers (33.7% - 37.4%) instead of blunts. The least common method of intake was also through hookahs, which accounted for 0.8% - 1.9% of participants. In terms of rationales for usage, the most common reason was general recreational use (73.7% - 77.6%), followed by anxiety relief (58.4% to 64.5%) and social activities (55.9% - 61.7%) across tasks. The least common rationale within the questionnaire options was sleep aid, ranging from 21.2% to 25.2% of participants. A few additional text responses were indicated under the ‘Other’ category, including increasing appetite, religious reasons, as a depressive aid, escaping mental blocks, and general enjoyment.

Table 2B. Cannabis use patterns of the frequent use cohort across each task.

Characteristic	**Task Switching Task (n = 118)**	**Tunnelling Task (n = 89)**	**Mirror Reversal Task (n = 107)**
Methods of Intake:			
Blunt:	n = 31 (26.3%)	n = 23 (25.8%)	n = 29 (27.1%)
Joint:	n = 81 (68.6%)	n = 63 (70.8%)	n = 76 (71.0%)
Bong:	n = 34 (28.8%)	n = 27 (30.3%)	n = 35 (32.7%)
Vaporizer:	n = 44 (37.3%)	n = 30 (33.7%)	n = 40 (37.4%)
Hand Pipe:	n = 20 (16.9%)	n = 12 (13.5%)	n = 22 (20.6%)
Hookah:	n = 1 (0.8%)	n = 1 (1.1%)	n = 2 (1.9%)
Edible:	n = 44 (37.3%)	n = 28 (31.5%)	n = 43 (40.1%)
Oil:	n = 21 (17.8%)	n = 12 (13.5%)	n = 18 (16.8%)
Rationales for Usage:			
Recreational:	n = 87 (73.7%)	n = 68 (76.4%)	n = 83 (77.6%)
Social:	n = 66 (55.9%)	n = 52 (58.4%)	n = 66 (61.7%)
Anxiety Relief:	n = 74 (62.7%)	n = 52 (58.4%)	n = 69 (64.5%)
Pain Relief	n = 25 (21.2%)	n = 19 (21.3%)	n = 27 (25.2%)
Sleep Aid:	n = 48 (40.7%)	n = 36 (40.4%)	n = 48 (44.9%)
Other:	n = 7 (5.9%)	n = 6 (6.7%)	n = 6 (5.6%)
Average age of use onset (M, SD)	16.93 (3.7)	17.01 (3.84)	16.74 (3.28)
Average years since use onset (M, SD)	6.55 (3.70)	6.16 (5.39)	5.86 (5.63)

Task Switching Task

Reaction Time

To reiterate, reaction time in the task switching task is defined as the time required for a participant to respond to a stimulus after the stimuli appearance and is measured in seconds. A 3X3 mixed ANOVA was used to determine reaction time differences in the main effect of trial type (single, repeat, or switch), the main effect of experimental group (no prior use, infrequent, and frequent use of cannabis), the interaction between trial type and experimental group, the interaction between trial type and sex (male and female), and the interaction between experimental group and sex. Effect size was estimated using η^2.

The main effect of trial type on reaction time was significant and had a medium effect size ($F = 246.483$, $p<0.001$, $\eta^2=0.093$) A Holm post hoc test demonstrated significant differences between single, repeat, and switch. The single trials had significantly higher reaction times than the repeat trials ($SE=0.020$, $p=0.001$) and significantly lower reaction times than switch trials ($SE=0.020$, $p<0.001$). Furthermore, the repeat trials had a significantly lower reaction times than switch trials ($SE=0.020$, $p<0.001$). The higher reaction times of switch trials was expected due to the increased switch cost and difficulty associated with the trial type. However, the reduction in repeat trial reaction time was unexpected and may be attributed to learning effects due to the later appearance of repeat trials compared to single trials during the experiment. The main effect of experimental group on reaction time was not significant ($F = 0.231$, $p=0.794$, $\eta^2<0.001$). Furthermore, there was no significant interaction between trial type and experimental group on reaction time ($F = 1.284$, $p=0.274$, $\eta^2=0.001$).

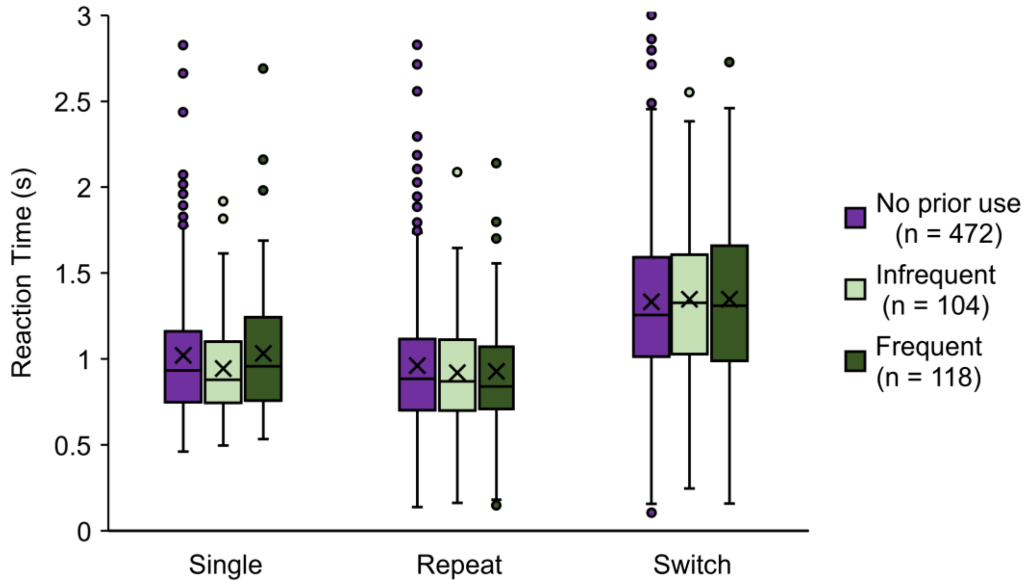

Figure 6. Box-and-whisker plot (median, first and third quartiles, interquartile-range, x = mean) of reaction times of single, repeat, and switch trials between no prior use, infrequent, and frequent cannabis use in the task switching task.

The interaction of trial type and sex on reaction time was not significant ($F = 1.652$, $p=0.192$, $\eta^2<0.001$). Furthermore, there was no significant interaction between the experimental groups & sex ($F = 0.084$, $p=0.919$, $\eta^2<0.001$).

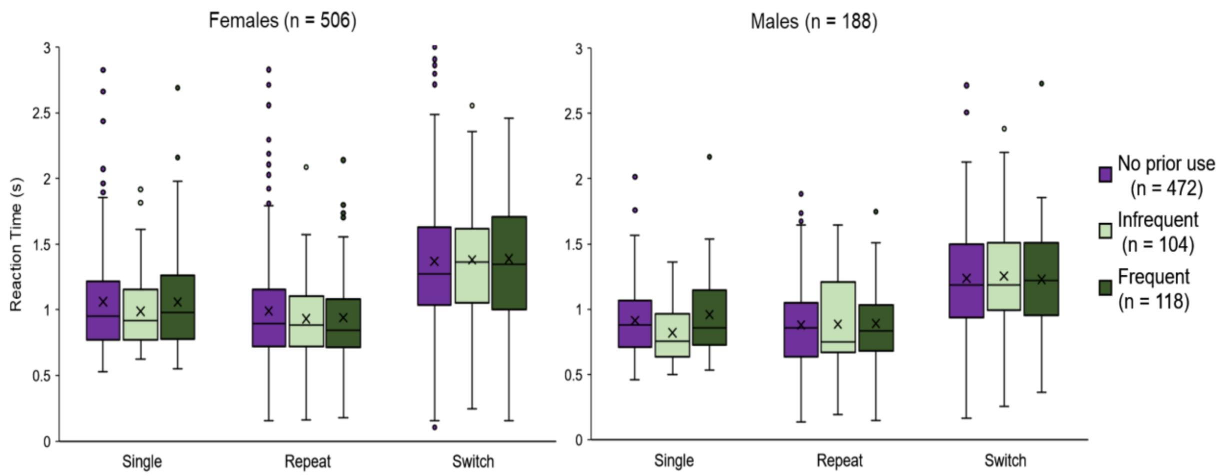

Figure 7. Box-and-whisker plot (median, first and third quartiles, interquartile-range, x = mean) of reaction times of single, repeat and switch trials between male and female experimental groups in the task switching task.

Accuracy (Percentage of Correct Responses)

Accuracy in the task switching task is defined as the percentage of trials that were correctly responded to and was measured within each trial type (single, repeat, and switch) independently. A 3X3 mixed ANOVA was used to determine accuracy differences in the main effect of trial type, the main effect of experimental group, the interaction between trial type and experimental group, the interaction between trial type and sex, and the interaction between experimental group and sex.

The main effect of trial type on accuracy was significant but had a small effect size (F = 45.398, $p<0.001$, $\eta^2=0.015$) A Holm post hoc test demonstrated significant differences between single, repeat, and switch trials. The single trials had significantly higher accuracy than the repeat trials (SE=0.650, p=0.032) and switch trials (SE=0.650, p<0.001). Furthermore, the repeat trials had significantly higher accuracy than switch trials (SE=0.650, p<0.001). Again, the lower accuracy of responses from single to repeat to switch trials was expected due to the increasing switch cost accompanied by each trial type. The main effect of experimental group on accuracy was significant but small (F = 4.643, p=0.010, η^2=0.010). A Tukey HSD demonstrated a significant difference in accuracy between the no prior use cohort compared to the infrequent use cohort, where the infrequent cohort was more accurate (SE = 1.535, p=0.010) Furthermore, there was a significant interaction between trial type and experimental group, albeit with a very small effect size (F=4.012, p=0.003, η^2=0.003). A Tukey HSD demonstrated that the no prior use cohort switch trials were less accurate than infrequent use cohort switch trials (SE=1.759, p=0.007).

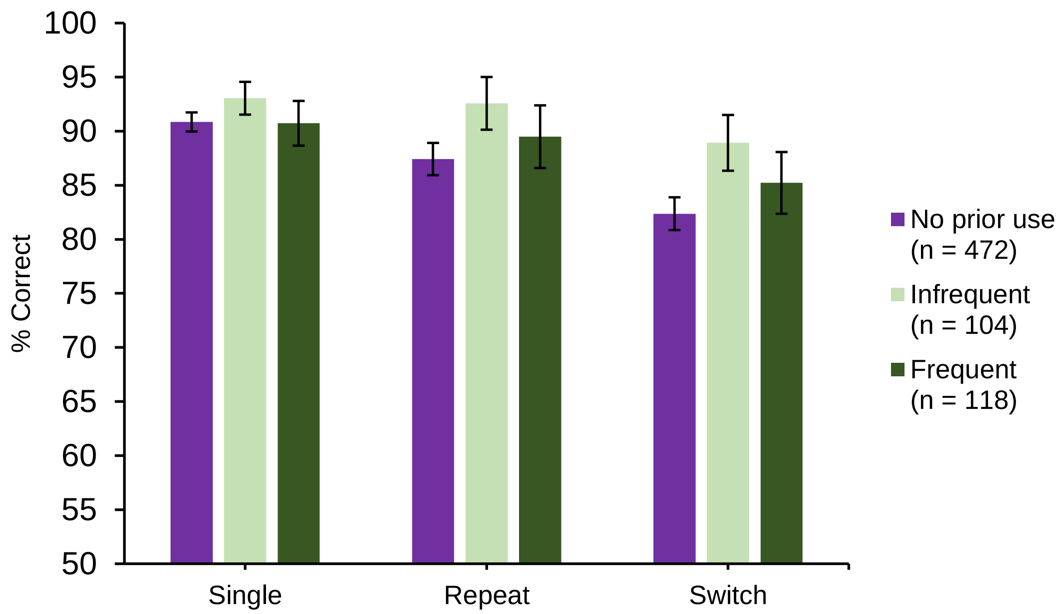

Figure 8. Percentage of correct single, repeat, and switch trials between no prior use, infrequent, and frequent use of cannabis. Y-axis begins at 50% correct responses. Error bars are 95% confidence intervals.

The interaction of trial type and sex on accuracy was not significant ($F = 0.014$, $p=0.986$, $\eta^2<0.0001$) and there was no significant interaction between the experimental groups and sex ($F = 0.180$, $p=0.835$, $\eta^2<0.001$).

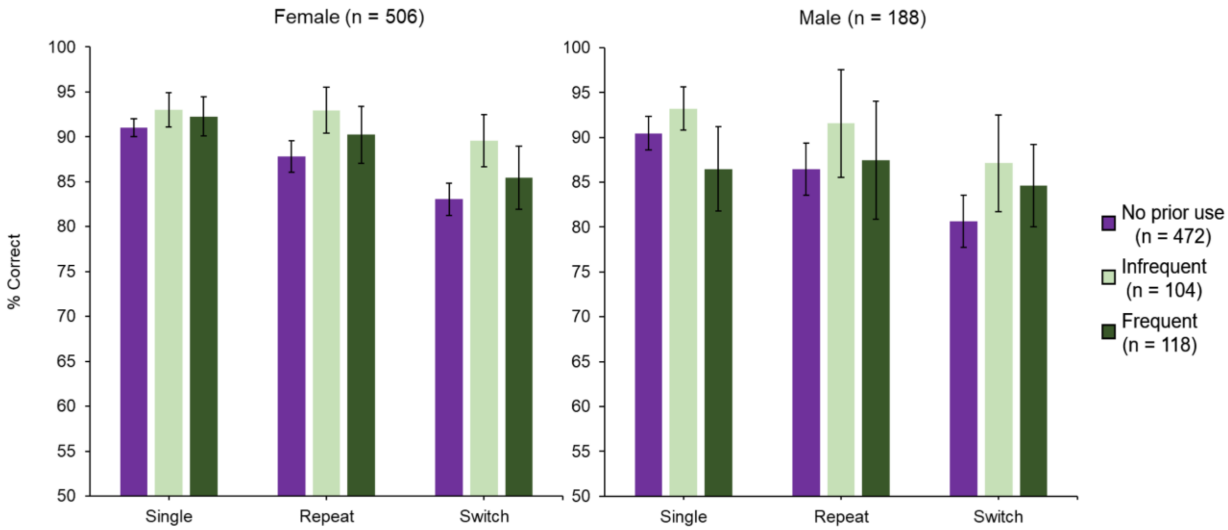

Figure 9. Percentage of correct single, repeat, and switch trials between female and male cannabis use frequencies. Y-axis begins at 50% correct responses. Error bars are 95% confidence intervals.

Overall, there were mostly no differences in performance between no prior usage, infrequent, and frequent use of cannabis. There were also no differences between male and female performance or interactions between cannabis use frequency and sex. The tasks demonstrated the expected pattern of performance between trial types, where single trials generally had the best performance and switch trials had the poorest performance.

Tunnelling Task

Completion Time

Completion time in the tunnelling task is defined as the time required for the participant to move their cursor from the home position through the tunnel to the target and return to the home position. Completion time is measured in seconds. A repeated-measures ANOVA of the completion times demonstrated no significant differences between the different track scales ($F = 1.780$, $P=0.149$, $\eta^2=0.004$). Furthermore, there were no significant differences observed between the completion times of no prior use, infrequent, and frequent use of cannabis ($F = 0.163$, $p=0.850$, $\eta^2<0.001$) or any interactions between experimental groups across any of the track scales ($F=0.113$, $p=0.995$, $\eta^2<0.001$). As discussed in the Methods section, due to the lack of differences in completion times between track scales or any experimental groups, completion time was not used as an indicator of performance differences. Instead, accuracy was used as the main measure of performance for this task.

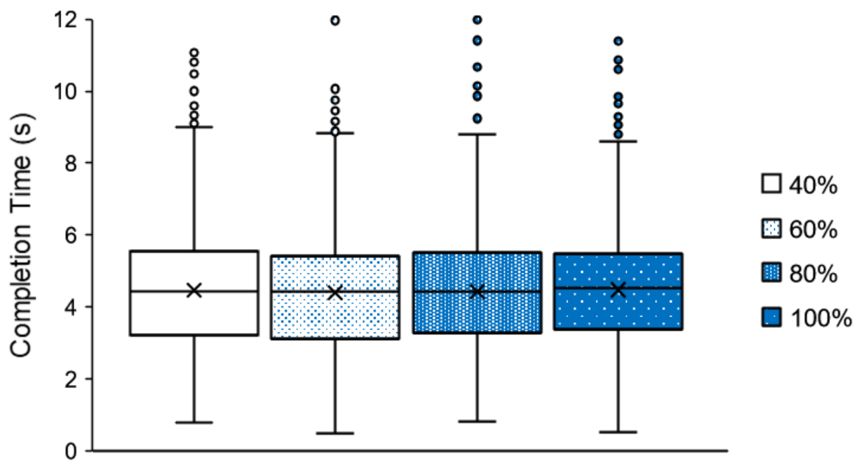

Figure 10. Box-and-whisker plot (median, first and third quartiles, interquartile-range, x = mean) of completion times of all participants across the 40%, 60%, 80%, and 100% scaled tracks in the tunnelling task.

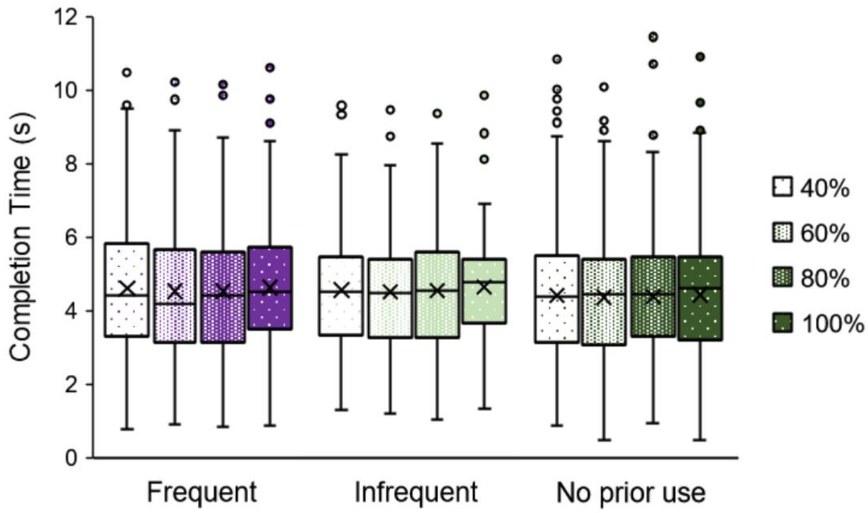

Figure 11. Box-and-whisker plot (median, first and third quartiles, interquartile-range, x = mean) of completion times for the different cannabis use frequencies across the 40%, 60%, 80%, and 100% scaled tracks in the tunnelling task.

Accuracy (Percentage of Trial Time Within Track)

Accuracy in the tunnelling task is defined as the percentage of total time within the track throughout the trial. A 3X4 mixed ANOVA was used to determine accuracy differences in the main effect of track scale (40%, 60%, or 80%, 100%), the main effect of experimental group (no prior use, infrequent, and frequent use of cannabis), the interaction between track scale and experimental group, the interaction between track scale and sex, and the interaction between experimental group and sex on accuracy.

The main effect of track scale on accuracy was significant and small ($F=26.485$, $p<0.001$, $\eta^2=0.006$). A Tukey HSD demonstrated the accuracy of the 40% track was significantly lower than the 60% track ($SE=0.005$, $p<0.001$), 80% track ($SE=0.005$, $p<0.001$), and 100% track ($SE=0.005$, $p<0.001$). Accuracy on the 60% track was significantly lower than on the 100% track ($SE=0.005$, $p<0.001$). Accuracy on the 80% track was also significantly lower than on the 100%

track (SE=0.005, p=0.026). This finding is expected due to the increased motor acuity required to move through a smaller track size.

The main effect of experimental group on accuracy was not significant (F=2.019, p=0.134, η^2=0.008). Furthermore, there was no significant interaction between the track scale and experimental group on accuracy (F=0.524, p=0.790, η^2<0.0001).

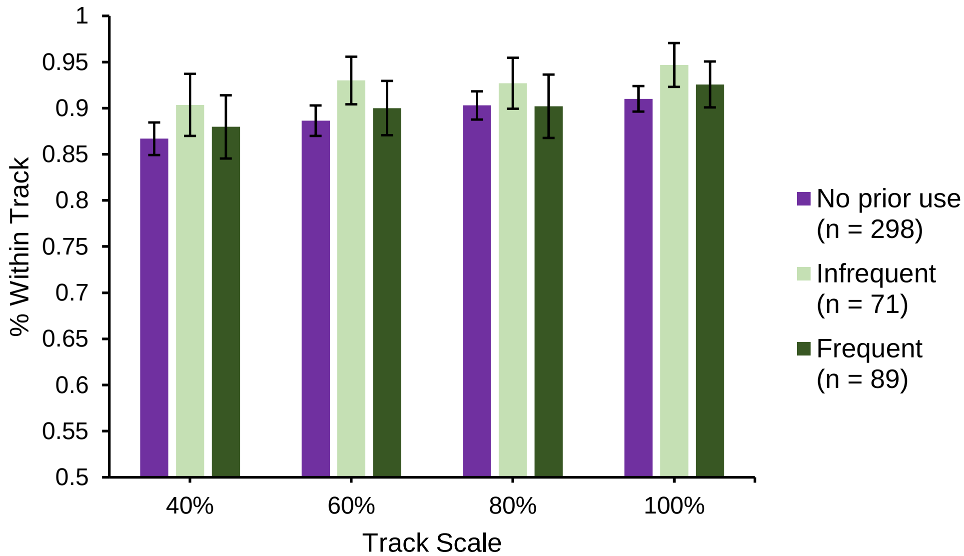

Figure 12. Accuracies of no prior use, infrequent, and frequent use of cannabis across all track sizes in the tunnelling task. Y-axis begins at 50% correct responses. Error bars are 95% confidence intervals.

The interaction of track scale and sex on accuracy was not significant (F = 1.958, p=0.118, η^2<0.001) and there was no significant interaction between the experimental groups and sex on accuracy (F = 0.256, p=0.774, η^2<0.001).

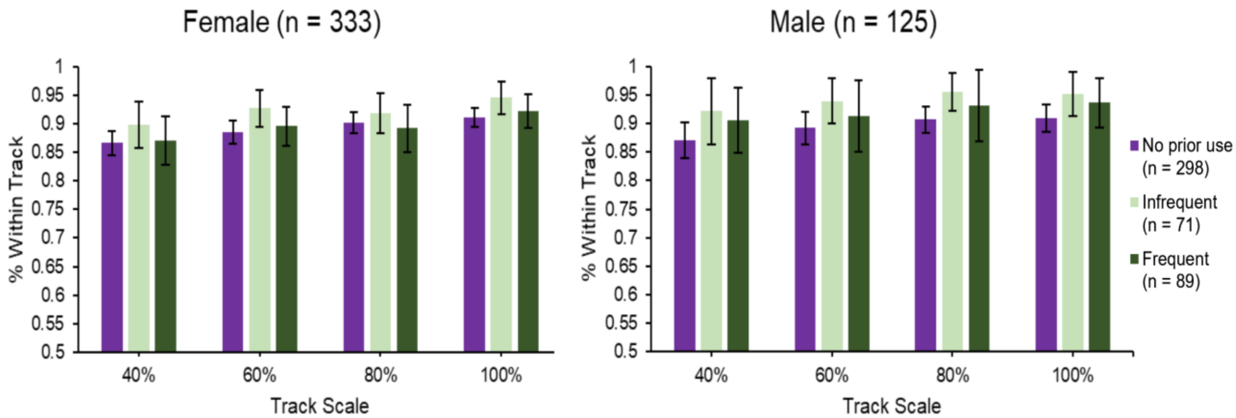

Figure 13. Accuracies of male and female no prior use, infrequent, and frequent cannabis use cohorts across all track sizes in the tunnelling task. Y-axis begins at 50% correct responses. Error bars are 95% confidence intervals.

As seen on figure 15, the speed-accuracy trade-offs of no prior usage, infrequent, and frequent use of cannabis largely overlap across the different track sizes and do not demonstrate prominent differences. Furthermore, although the completion time appears to be relatively similar across the different track scales, the accuracy of trials generally reduces in the smaller scaled tracks as shown by the increasing number of lower accuracy trials. Overall, there is little evidence to suggest performance differences between cannabis use frequencies or any sex-related interactions.

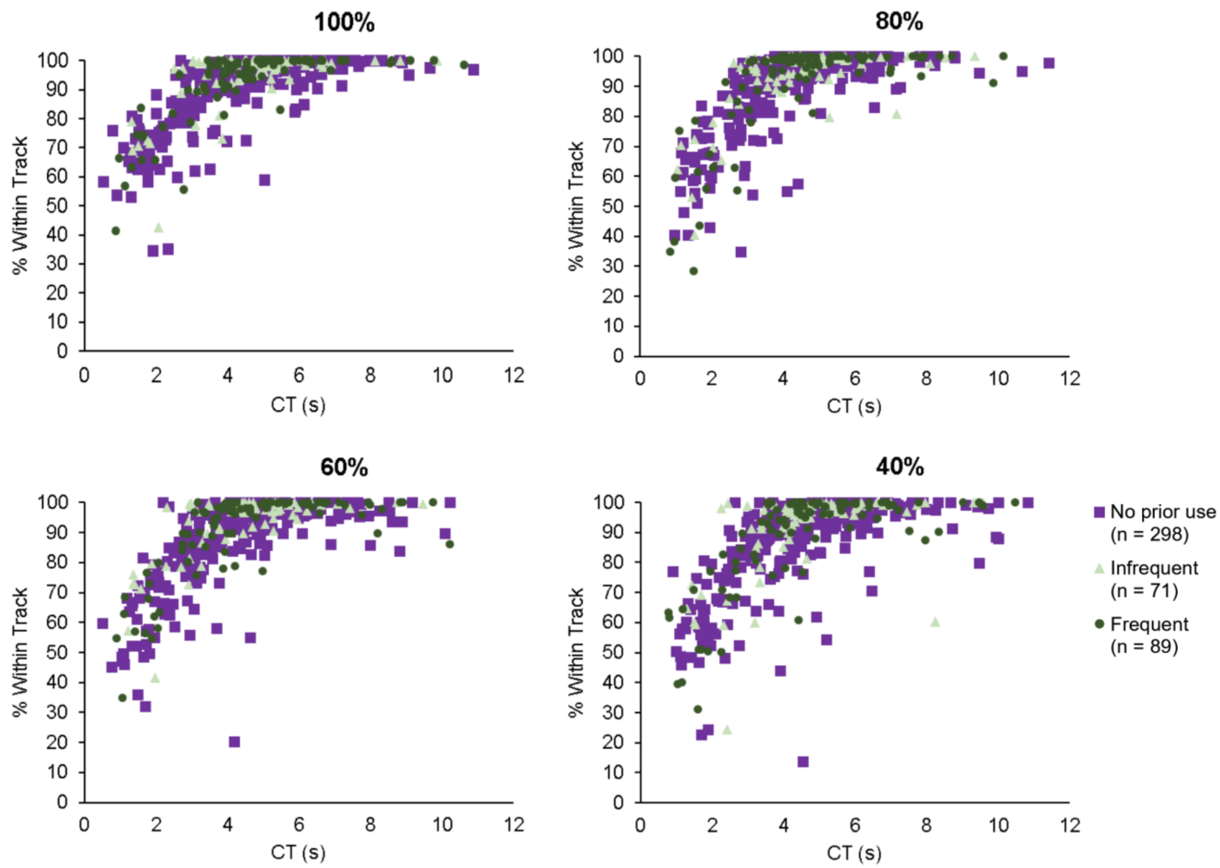

Figure 14. Speed-accuracy plots of no prior use, infrequent, and frequent use of cannabis in the 40%, 60%, 80%, and 100% scaled track of the tunnelling task.

Mirror Reversed Transformation Task

Completion Time

Completion time in the mirror reversed transformation task is defined as the time (in seconds) required to move from the home position to the peripheral target. A one-way ANOVA was used to determine completion time differences between the main effect of experimental group (no prior usage, infrequent, and frequent use of cannabis), the main effect of sex (male and female) and the interaction between experimental group and sex.

The main effect of experimental group on completion time was not significant ($F= 0.033$, $p=0.967$, $\eta^2<0.001$). Furthermore, the main effect of sex was significant but small ($F =16.402$, $p<0.001$, $\eta^2=0.032$). A Tukey HSD demonstrated that males had significantly lower completion times than females ($SE=0.106$, $p<0.001$). There was no significant interaction between experimental group and sex ($F=0.206$, $p=0.814$, $\eta^2<0.001$).

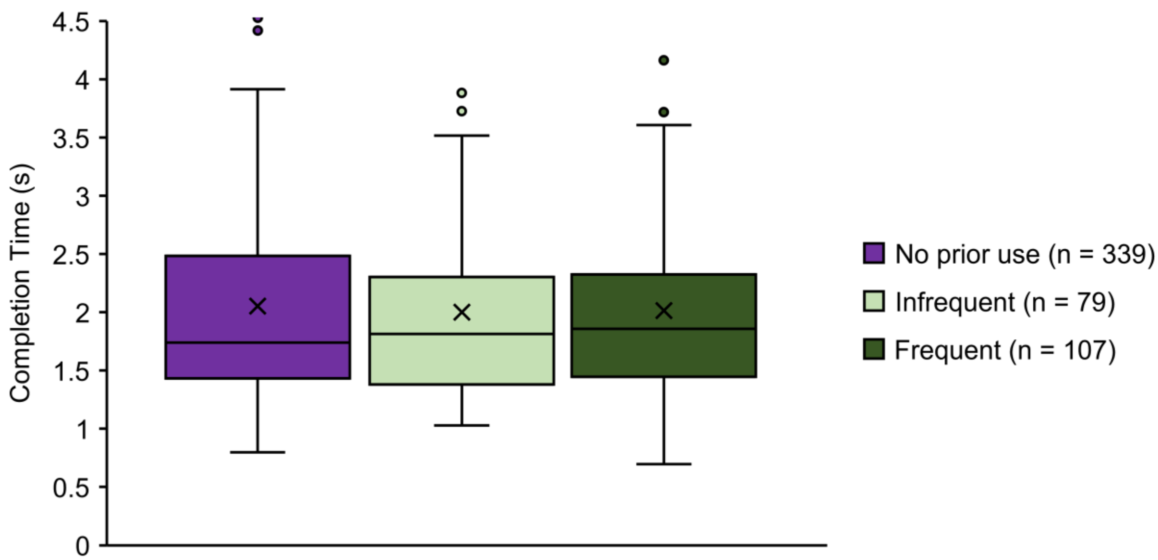

Figure 15. Mirror reversed transformation task completion times of no prior use, infrequent, and frequent use of cannabis.

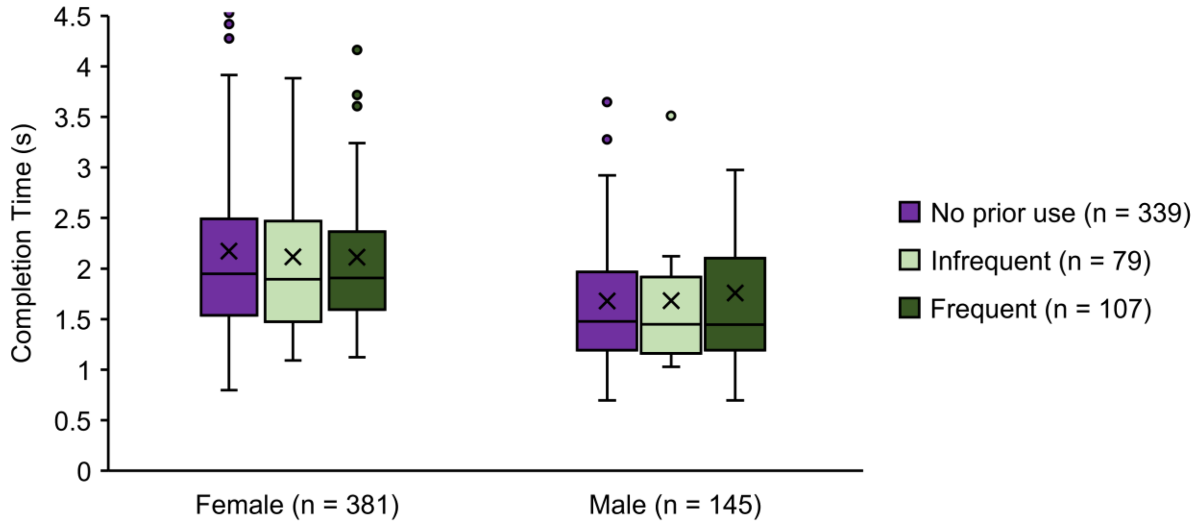

Figure 16. Mirror reversed transformation task completion times of females and males in no prior use, infrequent, and frequent cannabis use cohorts.

Path Length

Path length is defined as the length of cursor movement required to move from the home position to the peripheral target. A lower path length is indicative of more efficient reaches and improved performance. The path length unit is relative to the height of the screen, where a score of 1.0 indicates 100% of the total screen height. A straight-line movement between the home and the target position is 0.4 / 40% of the screen height. A one-way ANOVA was used to determine path length differences between the main effect of experimental group (no prior use, infrequent, and frequent use of cannabis), the main effect of sex (male and female) and interaction between experimental group and sex.

The main effect of experimental group on path length was not significant ($F= 2.041$, $p=0.131$, $\eta^2=0.008$). The main effect of sex was also not significant ($F =0.017$, $p=0.897$,

$\eta^2<0.0001$). Additionally, there was no significant interaction between experimental group and sex ($F=0.874$, $p=0.418$, $\eta^2=0.003$).

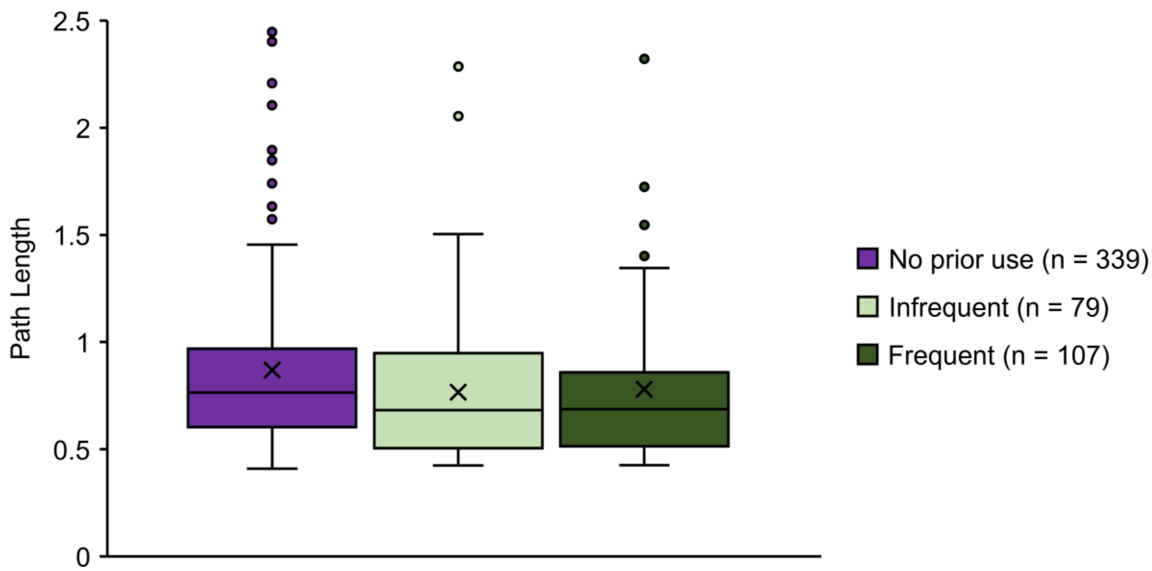

Figure 17. Mirror reversed transformation task path lengths of no prior use, infrequent, and frequent use of cannabis. A score of 1.0 indicates a path length of 100% of the total screen height. A straight-line movement to the target position is 0.4 screen heights.

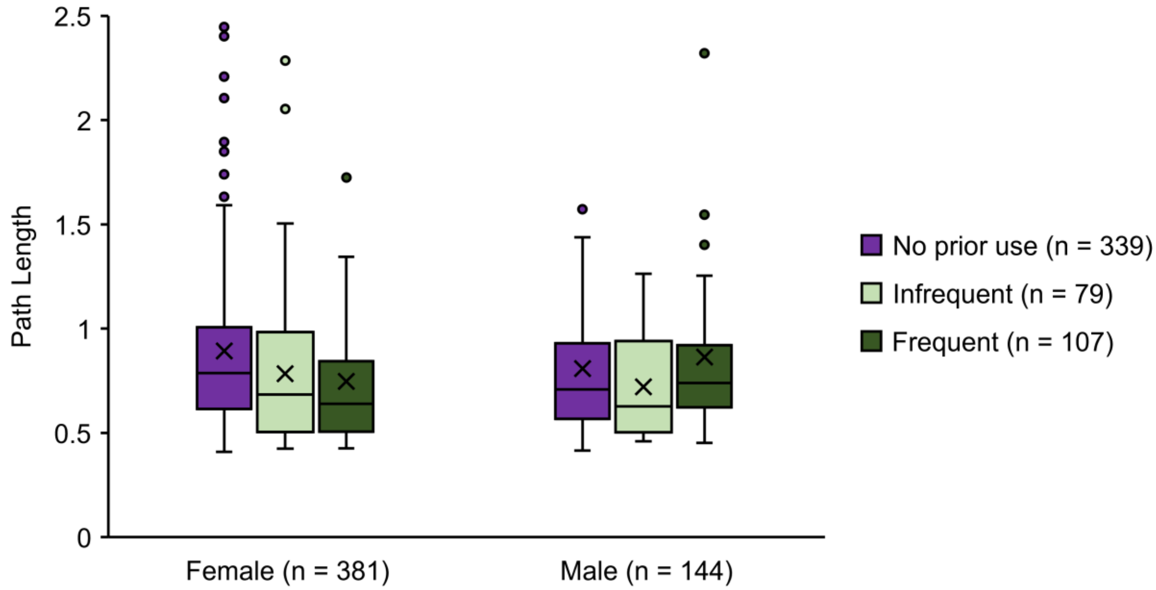

Figure 18. Mirror reversed transformation task path lengths of females and males in no prior use, infrequent, and frequent cannabis use cohorts. A score of 1.0 indicates a path length of 100% of the total screen height. A straight-line movement to the target position is 0.4 screen heights.

Overall, within the mirror reversed-transformation task there was a lack of performance differences between experimental groups in both completion time and path length suggesting a lack of group-related deficits in goal-directed movement planning.

Chapter Five: Discussion

To reiterate, the overarching goal of this study was to determine if frequency of cannabis use is associated with deficits in visuomotor and cognitive performance. I hypothesised that performance deficits would be observed in the motor acuity and goal-directed movement planning but not the task switching abilities of the cannabis use cohorts compared to no prior use cohort. Across all three tasks, there is little evidence to suggest impairments due to the lack of performance differences between no prior usage, infrequent, and frequent use of cannabis. This does not support my original hypothesis, as there were no deficits to any of the measured visuomotor or cognitive abilities assessed.

Furthermore, there is little support for sex-related performance differences across tasks or interactions between sex and experimental groups. Although there was a significant difference between the completion times of males and females in the mirror reversed transformation task, the effect size was small and unlikely to demonstrate a prominent difference in performance.

In the following section, I will discuss how the findings of the current study compared to the literature regarding these tasks or the visuomotor & cognitive processes that they assess.

Task Switching Task

The results of the task switching task suggest that cannabis use does not impair task switching ability, inhibition, and working memory. This was supported by the general lack of significant differences between reaction times and proportions of correct trials. Although there was a significant difference between the accuracies of the no prior use cohort compared to infrequent use cohort, the effect size was small. Furthermore, the infrequent use cohort had higher accuracies than the no prior use cohort which also does not support a performance deficit associated with cannabis use.

The absence of performance differences between cannabis use frequencies has been observed in other studies focusing on divided attention tasks, such as by Ramaekers et al. (2009). They assessed differences between cannabis use frequencies using a dual processing task which required attention to multiple stimuli like the task switching task. However, their task primarily measured signal detection and control but not reaction time. They found no significant difference in correct signal detections between chronic cannabis use (>4 times per week) and infrequent use

(<once per week) after ingesting cannabis compared to when consuming a placebo. This is in line with our findings that cannabis use frequency is not associated with a significant impact on task switching abilities.

Similarly, Cunha et al. in 2010 utilized a battery measuring the executive functioning of substance-dependent individuals (including cannabis). They compared 30 SDI participants to 32 healthy control participants after 2 weeks of substance abstinence. Notably within the battery was a Stroop Colour Word Test (also described in the Literature Review) which assessed task switching abilities. Akin to the current study, there were no significant impairments in the Stroop Colour Word Test between participants who used cannabis and the control group. Furthermore, Edgerton and colleagues (2005) found that although the acute administration of cannabis use may produce deficits in cognitive flexibility, the ability to shift attention between tasks may still be maintained. It is important to note that the study by Edgerton et al. was conducted on mice models and the overall generalizability to humans may be difficult to infer. However, attention shifting has also been shown to be unaffected by cannabis use administration in primates despite the accompaniment of deficits in other cognitive domains (Wright et al., 2013).

Although several studies have shown consistent findings to our own of a lack of cannabis-related deficits, other studies have observed the contrary. For example, Bolla et al. (2002) found that there were dose-dependent deficits related to cognitive flexibility / task switching abilities. Even after 28 days of cannabis-use abstinence, increased cannabis use dosage was associated with greater impairments compared to lighter usage of cannabis. However, it is important to note that the sample sizes within this study were small (n = 7 – 8 per experimental group) and none of the participants were excluded for using other drugs. Hence, the generalizability of this study to average person who uses cannabis may not be akin to the current study. As a result, although there are consistencies in the literature in terms of a lack of performance deficit, further research needs to be conducted on the effect of cannabis on task switching abilities.

Tunnelling Task

Like the task switching task, the results of the tunnelling task suggest that cannabis use does not impair motor acuity and goal-directed movements. There was no significant difference demonstrated in the main performance measure of accuracy between no prior use, infrequent, and frequent use of cannabis cohorts.

Although there are very few studies that explicitly look at the effects of cannabis use frequency on motor acuity and goal-directed movement planning, there are studies that look at general motor performance which may integrate these abilities. For example, Dahlgren et al. (2020) compared driving performance (a visuomotor-based task) between participants who used cannabis to those who did not. Contrary to our findings, they found that cannabis use was associated with impaired driving simulator performance compared to no usage, even with a lack of cannabis intoxication. This finding suggests that there may be residual effects that affect the visuomotor and cognitive abilities associated with driving. However, it was noted that these impairments were mainly observed in individuals with early onsets of cannabis usage (before age 16), where an earlier onset was associated with more severe impairments. The cannabis cohorts of the current study had an average age of use onsets above this threshold which may attribute to the lack of performance differences that was observed.

Similar to the findings by Dahlgren et al., Cunha and colleagues' (2010) study determined that motor programming was one of the cognitive domains impaired in persons who used cannabis compared to a control group. They assessed motor programming through a task that required the participant to successfully copy an examiner demonstrating 3 consecutive left-hand motor sequences (Luria's fist-palm-edge motor series) on their own right hand. Although both this task and the tunnelling task require motor acuity abilities, the findings of Cunha and colleagues' study may not align with one another due to the differing degree of working memory required between the tasks. The tunnelling task did not require the replication of motor movement and hence, it is difficult to infer how performance on either motor acuity task generalizes to one another.

Like the tunnelling task, an experimental study by Weinstein et al. (2007) compared the performance of a cannabis use cohort with a no usage cohort on a virtual reality task that required them to move through a maze while minimizing contact with the walls. The cannabis cohort was under the effects of 17mg THC while the no usage cohort had no THC in their system. The results found that participants who used cannabis hit the walls of the maze more often than participants who did not use cannabis. Furthermore, through PET scans and Fluorodeoxyglucose (FDG) usage, they found that while THC increased brain metabolism in brain areas associated with motor coordination, it also reduced metabolism in areas associated with visuomotor integration. The differences between these findings with the current study may be attributed to the relative absence of THC in the systems of our participants. In this study, we did not require participants to be immediately intoxicated on cannabis and many participants noted that their last use of cannabis was not within the last day of their study completion. Hence, additional research needs to be conducted on individuals under the immediate effects of cannabis intoxication to develop a more comprehensive understanding of cannabis use effects on motor acuity.

Mirror Reversed Transformation Task

Like the previous two tasks, the results of the mirror reversed transformation task suggest that there is no impairment of goal-directed movement planning associated with cannabis use. There were no significant differences between the completion times and path lengths between no prior use, infrequent, and frequent use of cannabis.

This finding is contrary to several studies regarding the effect of cannabis on movement planning and control, such as by Todd & White in 2017. They noted that cannabis usage may affect the integration of sensory and motor information used in rhythmical movement via long-lasting effects on brain regions associated with movement. Within their study, they specifically assessed control of rhythmic movement by comparing the patterns of a finger tapping task (ex. frequency, variability, tremor) between a cannabis use group and a group with no usage. Despite their findings of potential detriments, they addressed how different types of movements aside from the rhythmic type (ex. voluntary movements) had yet to be thoroughly investigated in terms of cannabis use. Although the mirror reversed transformation task requires repeated movements across trials, it is difficult to generalize it as rhymical in nature compared to Todd & White's task. Similarly, their task likely did not require the same degree of goal-directed movement planning as the mirror reversed transformation task due to the lack of any altered visual feedback. As a result, although there may be some overlap, the differences in the overall type of movement used in each task may mean that there are different brain regions involved in each. Hence, further research needs to be completed to determine potential cannabis-use related differences in goal-directed movements compared to other types of movement.

Strengths and Limitations

Study Strengths

One of the main strengths of this study was the recruitment of legal participants outside of clinical/rehabilitative settings where cannabis and other substance use disorders are common. As a result, the findings in this study may be more generalizable and akin to the average person who consumes cannabis that is not be suffering from some form of substance use disorder. Furthermore, the large sample size in this study helps ensure that our findings have enough power resulting in a reduced probability of committing a type-II error. The large sample size also enabled us to screen our participants more strictly (i.e., removal of participants with neurological conditions and drug use aside from cannabis) which is not always possible in studies with small sample sizes of participants who use cannabis. The final strength of this study to mention is the diversity of visuomotor and cognitive abilities being assessed through the different tasks. Several components of visuomotor and cognitive abilities are assessed, such as task switching, motor acuity, and goal-directed movement planning which may provide a more holistic understanding of their overall performance as opposed to a single task. The consistent findings of non-significant performance differences between experimental groups across tasks provide more concrete evidence of a lack of deficits related to cannabis use.

Study Limitations

The limitations of this study are mainly associated with its browser-based nature. Since participants are completing the battery of tasks on personal computers, the diversity of hardware utilized may create difficulties in creating a standardized environment for participants. This includes varying monitor sizes, different mouse sensitivities, and environmental distractors.

However, relevant information regarding hardware and software was gathered on both Qualtrics and Pavlovia, ensuring proper screening of outlier devices. Although proper participation in tasks was incentivized through the awarding of course credit, this did not guarantee that participants were highly motivated. Furthermore, the lack of researcher supervision during the experiment may have increased the chances of low participant effort. This was addressed through thorough screening of responses and participant task data through R and manual review to address low-effort responses. Additionally, participants were not asked to refrain from or to consume cannabis throughout the study resulting in differing times since their last cannabis use. As a result, although most participants did not indicate they were completing the task immediately following the consumption of cannabis, it is difficult to infer the validity of these claims due to the lack of researcher presence.

Another study limitation is the lack of information gathered regarding THC and CBD ratios. As previously noted, CBD may act as an antagonist to some of the adverse effects caused by THC (Niesink et al., 2013) and may mask performance deficits compared to cannabis strains with low amounts of CBD content. CBD has also been found to increase brain activity in regions that are associated with movement planning and other cognitive tasks (Bhattacharyya et al., 2010). Hence, further information regarding the cannabis composition may demonstrate how the ratio of THC and CBD may affect the degree of effect on visuomotor and cognitive function.

Implications

The implications of the current study's findings are mainly in regard to alleviating the concerns of deficits in completing activities of daily living. The lack of detriment we observed across the tasks suggests that there may not be a significant reduction in the performance of tasks such as driving which require visuomotor and cognitive functioning. This is promising due to the potential effect that the 2018 legalization of recreational use will have on population cannabis-use behaviours. However, as observed in several studies within the Discussion section, these findings are contrary to several studies regarding potential cannabis-use related deficits. Hence, it is important to address that the results of this thesis are only a small component of the larger cannabis literature and that more research is needed in order to have a more accurate understanding of its effects on visuomotor and cognitive measures.

Chapter Six: Conclusion

Overall, the results of this study suggest that there are no visuomotor and cognitive deficits related to cannabis use and use frequency. Only a few performance measures demonstrated significant differences between experimental groups across all the tasks, with none of the differences demonstrating improved performance with reduced cannabis use. The majority effect sizes related to cannabis use were small to very small, further supporting the lack of deficits related to cannabis use.

These findings are promising towards lowering the concern of cannabis-related impairments to visuomotor and cognitive abilities. Especially since the long-term population cannabis-use trajectories are uncertain due to the recent legalization, increasing our knowledge of the potential detriments to daily functioning associated with usage will continue to be of importance.

Future research needs to be completed on the effects of cannabis on visuomotor and cognitive functioning in a more standardized environment. This would allow for the reduction of potential individual performance differences attributed to external distractions and low effort. Furthermore, research is currently being conducted on the battery of experiments utilized in this study regarding participants under the immediate effects of cannabis. This data will help ascertain if cannabis-related performance deficits attributed to acute symptoms exists and how they compare to the lack of deficits observed in this thesis.

Bibliography

Aharonovich, E., Brooks, A. C., Nunes, E. v., & Hasin, D. S. (2008). Cognitive deficits in marijuana users: Effects on motivational enhancement therapy plus cognitive behavioral therapy treatment outcome. *Drug and Alcohol Dependence*, *95*(3), 279–283. https://doi.org/10.1016/J.DRUGALCDEP.2008.01.009

Atakan, Z. (2012). Cannabis, a complex plant: different compounds and different effects on individuals. *Therapeutic Advances in Psychopharmacology*, *2*(6), 241–254. https://doi.org/10.1177/2045125312457586

Bhattacharyya, S., Morrison, P. D., Fusar-Poli, P., Martin-Santos, R., Borgwardt, S., Winton-Brown, T., Nosarti, C., O'Carroll, C. M., Seal, M., Allen, P., Mehta, M. A., Stone, J. M., Tunstall, N., Giampietro, V., Kapur, S., Murray, R. M., Zuardi, A. W., Crippa, J. A., Atakan, Z., & McGuire, P. K. (2010). Opposite Effects of Δ-9-Tetrahydrocannabinol and Cannabidiol on Human Brain Function and Psychopathology. *Neuropsychopharmacology*, *35*(3), 764. https://doi.org/10.1038/NPP.2009.184

Bolla, K. I., Brown, K., Eldreth, D., Tate, K., & Cadet, J. L. (2002). Dose-related neurocognitive effects of marijuana use. *Neurology*, *59*(9), 1337–1343. https://doi.org/10.1212/01.WNL.0000031422.66442.49

Bolla, K. I., Eldreth, D. A., Matochik, J. A., & Cadet, J. L. (2005). Neural substrates of faulty decision-making in abstinent marijuana users. *NeuroImage*, *26*(2), 480–492. https://doi.org/10.1016/J.NEUROIMAGE.2005.02.012

Bourque, J., & Potvin, S. (2021). Cannabis and Cognitive Functioning: From Acute to Residual Effects, From Randomized Controlled Trials to Prospective Designs. *Frontiers in Psychiatry*, *12*, 919. https://doi.org/10.3389/FPSYT.2021.596601/BIBTEX

Bull, P. N., Tippett, L. J., & Addis, D. R. (2015). Decision making in healthy participants on the Iowa Gambling Task: New insights from an operant approach. *Frontiers in Psychology*, 6(APR). https://doi.org/10.3389/fpsyg.2015.00391

Castellanos-Ryan, N., Pingault, J. B., Parent, S., Vitaro, F., Tremblay, R. E., & Séguin, J. R. (2017). Adolescent cannabis use, change in neurocognitive function, and high-school graduation: A longitudinal study from early adolescence to young adulthood. *Development and Psychopathology*, *29*(4), 1253–1266. https://doi.org/10.1017/S0954579416001280

Cohen, K., & Weinstein, A. (2018). The Effects of Cannabinoids on Executive Functions: Evidence from Cannabis and Synthetic Cannabinoids—A Systematic Review. *Brain Sciences*, *8*(3). https://doi.org/10.3390/BRAINSCI8030040

Crean, R. D., Crane, N. A., & Mason, B. J. (2011). An Evidence Based Review of Acute and Long-Term Effects of Cannabis Use on Executive Cognitive Functions. *Journal of Addiction Medicine*, *5*(1), 1. https://doi.org/10.1097/ADM.0B013E31820C23FA

Cunha, P. J., Nicastri, S., de Andrade, A. G., & Bolla, K. I. (2010). The frontal assessment battery (FAB) reveals neurocognitive dysfunction in substance-dependent individuals in distinct executive domains: Abstract reasoning, motor programming, and cognitive flexibility. *Addictive Behaviors*, *35*(10), 875–881. https://doi.org/10.1016/J.ADDBEH.2010.05.005

Dafters, R. I. (2006). Chronic ecstasy (MDMA) use is associated with deficits in task-switching but not inhibition or memory updating executive functions. *Drug and Alcohol Dependence*, *83*(2), 181–184. https://doi.org/10.1016/J.DRUGALCDEP.2005.11.006

Dahlgren, M. K., Sagar, K. A., Smith, R. T., Lambros, A. M., Kuppe, M. K., & Gruber, S. A. (2020). Recreational cannabis use impairs driving performance in the absence of acute intoxication. *Drug and Alcohol Dependence, 208*. https://doi.org/10.1016/J.DRUGALCDEP.2019.107771

Dores, A. R., Barbosa, F., Carvalho, I. P., Almeida, I., Guerreiro, S., da Rocha, B. M., de Sousa, L., & Castro-Caldas, A. (2017). Study of behavioural and neural bases of visuo-spatial working memory with an fMRI paradigm based on an n-back task. *Journal of Neuropsychology*, 11(1), 122–134. https://doi.org/10.1111/jnp.12076

Echlin, H. v., Gorbet, D. J., & Sergio, L. E. (2020). Assessment of a Cognitive-Motor Training Program in Adults at Risk for Developing Dementia. *Canadian Geriatrics Journal*, 23(2), 190. https://doi.org/10.5770/CGJ.23.394

Egerton, A., Brett, R. R., & Pratt, J. A. (2005). Acute delta9-tetrahydrocannabinol-induced deficits in reversal learning: neural correlates of affective inflexibility. *Neuropsychopharmacology, 30*(10), 1895–1905. https://doi.org/10.1038/SJ.NPP.1300715

Figueiredo, P. R., Tolomeo, S., Steele, J. D., & Baldacchino, A. (2020). Neurocognitive consequences of chronic cannabis use: a systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews, 108,* 358–369. https://doi.org/10.1016/J.NEUBIOREV.2019.10.014

Gomez, P., Ratcliff, R., & Perea, M. (2007). A Model of the Go/No-Go Task. *Journal of Experimental Psychology*, 136(3), 389. https://doi.org/10.1037/0096-3445.136.3.389

Gonda, S., Rabani, A. S., Horesh, N., & Shmuelof, L. (2019). Fast and specific: Insights into the acquisition and generalization of motor acuity. *Journal of Neurophysiology*, 122(6), 2354–2363. https://doi.org/10.1152/jn.00558.2018

Grillner, S. (2013). Fundamentals of Motor Systems. *Fundamental Neuroscience: Fourth Edition*, 599–611. https://doi.org/10.1016/B978-0-12-385870-2.00027-5

Iversen, L. (2003). Cannabis and the brain. *Brain*, *126*(6), 1252–1270. https://doi.org/10.1093/BRAIN/AWG143

Lisdahl, K. M., Wright, N. E., Medina-Kirchner, C., Maple, K. E., & Shollenbarger, S. (2014). Considering Cannabis: The Effects of Regular Cannabis Use on Neurocognition in Adolescents and Young Adults. *Current Addiction Reports*, *1*(2), 144. https://doi.org/10.1007/S40429-014-0019-6

Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: The role of backward inhibition. *Journal of Experimental Psychology: General*, *129*(1), 4–26. https://doi.org/10.1037/0096-3445.129.1.4

McGrath, R. L., & Kantak, S. S. (2016). Reduced asymmetry in motor skill learning in left-handed compared to right-handed individuals. *Human Movement Science,* 45, 130–141. https://doi.org/10.1016/J.HUMOV.2015.11.012

Mirdamadi, J. L., & Block, H. J. (2020). Somatosensory changes associated with motor skill learning. *Journal of Neurophysiology*, 123(3), 1052–1062. https://doi.org/10.1152/JN.00497.2019/ASSET/IMAGES/LARGE/Z9K0032053920007.JPEG

Niesink, R. J. M., & van Laar, M. W. (2013). Does Cannabidiol Protect Against Adverse Psychological Effects of THC? *Frontiers in Psychiatry*, 4, 130. https://doi.org/10.3389/FPSYT.2013.00130/BIBTEX

Pope, H. G., Gruber, A. J., Hudson, J. I., Huestis, M. A., & Yurgelun-Todd, D. (2002). Cognitive Measures in Long-Term Cannabis Users. *Journal of Clinical Pharmacology*, *42*, 4–47. https://doi.org/10.1177/0091270002238793

Prashad, S., & Filbey, F. M. (2017). Cognitive motor deficits in cannabis users. *Current Opinion in Behavioral Sciences*, 13, 1. https://doi.org/10.1016/J.COBEHA.2016.07.001

Ramaekers, J. G., Kauert, G., Theunissen, E. L., Toennes, S. W., & Moeller, M. R. (2009). Neurocognitive performance during acute THC intoxication in heavy and occasional cannabis users. *Journal of Psychopharmacology (Oxford, England)*, *23*(3), 266–277. https://doi.org/10.1177/0269881108092393

Rogers, R. D., & Monsell, S. (1995). Costs of a Predictable Switch Between Simple Cognitive Tasks. *Journal of Experimental Psychology: General*, *124*(2), 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Rooke, S., Copeland, J., Norberg, M., Hine, D., & McCambridge, J. (2013). Effectiveness of a Self-Guided Web-Based Cannabis Treatment Program: Randomized Controlled Trial. *Journal of Medical Internet Research*, *15*(2), e2256. https://doi.org/10.2196/JMIR.2256

Rotermann, M. (2019). Analysis of trends in the prevalence of cannabis use and related metrics in Canada. *Health Reports*, *30*(6), 3–13. https://doi.org/10.25318/82-003-x201900600001-eng

Schmitz, F., & Voss, A. (2014). Components of task switching: A closer look at task switching and cue switching. *Acta Psychologica*, 151, 184–196. https://doi.org/10.1016/J.ACTPSY.2014.06.009

Schneider, D. W., & Logan, G. D. (2009). Task Switching. *Encyclopedia of Neuroscience*, 869–874. https://doi.org/10.1016/B978-008045046-9.00426-5

Shmuelof, L., Yang, J., Caffo, B., Mazzoni, P., & Krakauer, J. W. (2014). The neural correlates of learned motor acuity. *Journal of Neurophysiology*, 112(4), 971–980. https://doi.org/10.1152/JN.00897.2013

Silins, E., Horwood, L. J., Patton, G. C., Fergusson, D. M., Olsson, C. A., Hutchinson, D. M., Spry, E., Toumbourou, J. W., Degenhardt, L., Swift, W., Coffey, C., Tait, R. J., Letcher, P., Copeland, J., Mattick, R. P., Allsop, S., Hall, W., Hayatbakhsh, R., Little, K., … Slade, T. (2014). Young adult sequelae of adolescent cannabis use: an integrative analysis. *The Lancet. Psychiatry*, *1*(4), 286–293. https://doi.org/10.1016/S2215-0366(14)70307-4

Stoet, G. (2010). PsyToolkit: A software package for programming psychological experiments using Linux. *Behavior Research Methods*, 42(4), 1096–1104. https://doi.org/10.3758/BRM.42.4.1096

Svoboda, K., & Li, N. (2018). Neural mechanisms of movement planning: motor cortex and beyond. *Current Opinion in Neurobiology*, 49, 33–41. https://doi.org/10.1016/J.CONB.2017.10.023

Ramaekers, J. G., Kauert, G., van Ruitenbeek, P., Theunissen, E. L., Schneider, E., & Moeller, M. R. (2006). High-Potency Marijuana Impairs Executive Function and Inhibitory Motor Control. *Neuropsychopharmacology*, 31(10), 2296–2303. https://doi.org/10.1038/sj.npp.1301068

Tippett, W. J., & Sergio, L. E. (2006). Visuomotor integration is impaired in early stage Alzheimer's disease. *Brain Research*, 1102(1), 92–102. https://doi.org/10.1016/J.BRAINRES.2006.04.049

Todd, G., & White, J. M. (2017). The Long-Lasting Effects of Cannabis Use on Movement and Brain Regions that Control Movement. *Handbook of Cannabis and Related Pathologies: Biology, Pharmacology, Diagnosis, and Treatment*, 372–378. https://doi.org/10.1016/B978-0-12-800756-3.00044-2

Tombaugh, T. N. (2004). Trail Making Test A and B: Normative data stratified by age and education. *Archives of Clinical Neuropsychology*, 19(2), 203–214. https://doi.org/10.1016/S0887-6177(03)00039-8

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, 12(1), 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Turna, J., Belisario, K., Balodis, I., van Ameringen, M., Busse, J., & MacKillop, J. (2021). Cannabis use and misuse in the year following recreational cannabis legalization in Canada: A longitudinal observational cohort study of community adults in Ontario. *Drug and Alcohol Dependence*, *225*, 108781. https://doi.org/10.1016/J.DRUGALCDEP.2021.108781

Volkow, N. D., Baler, R. D., Compton, W. M., & Weiss, S. R. B. (2014). Adverse Health Effects of Marijuana Use. *The New England Journal of Medicine*, *370*(23), 2219. https://doi.org/10.1056/NEJMRA1402309

Weinstein, A., Brickner, O., Lerman, H., Greemland, M., Bloch, M., Lester, H., Chisin, R., Mechoulam, R., Bar-Hamburger, R., Freedman, N., & Even-Sapir, E. (2007). Brain imaging study of the acute effects of Δ9-tetrahydrocannabinol (THC) on attention and motor coordination in regular users of marijuana. *Psychopharmacology*, *196*(1), 119–131. https://doi.org/10.1007/S00213-007-0940-7

Wright, M. J., Vandewater, S. A., Parsons, L. H., & Taffe, M. A. (2013). Δ9tetrahydrocannabinol impairs reversal learning but not extra-dimensional shifts in rhesus macaques. *Neuroscience, 235*, 51. https://doi.org/10.1016/J.NEUROSCIENCE.2013.01.018

Appendices

Appendix A: Copy of the Fall 2021 demographic questionnaire

What is your age? Please enter a valid number (without spaces and/or special characters)
What sex were you assigned at birth?
To which gender identity do you most identify? - Selected Choice
To which gender identity do you most identify? - Not listed - Text
Which of the following best describes your ancestry?(select all that apply) - Selected Choice
Which of the following best describes your ancestry?(select all that apply) - Other - Text
What best describes your highest level of education?
What is your year of study? Please enter a valid number (without spaces and/or special characters)- enter 0 if you are not currently in school.
What is your height? (in cm) Please enter a valid number (without spaces and/or special characters)
Are you currently suffering from a neurological condition? - Selected Choice
Are you currently suffering from a neurological condition? - Yes. Please specify if comfortable - Text
What was the method of your birth?
Were you born preterm?
Do any of your parents or grandparents have dementia?
Which of your following family members have dementia? Select all that apply.
What is your handedness?
Which of the following devices are you using to complete this experiment?
Which of the following devices are you using to control the cursor during this experiment? - Selected Choice
Which of the following devices are you using to control the cursor during this experiment? - Other (please specify) - Text
Which hand are you using to control the cursor/mouse/trackpad?
Please rate your computer use adeptness/experience. (1 representing minimal and 5 representing excellent)
Do you need to wear any corrective devices (e.g. glasses, contact lenses) to see the screen?
Are you wearing your corrective devices right now OR able to see the screen well enough to participate?
On a scale of 1-7, how fit/physically active do you consider yourself? (1-not physically active at all and 7-extremely fit)
On a scale of 1-7, how stressed have you been feeling this week? (1-not stressed at all 7-extremely stressed)
Do you practice meditation?
How often do you practice meditation?
What type of meditation do you practice - Selected Choice
What type of meditation do you practice - Other - Text
Do you use opiates, or other recreational drugs (besides marijuana or alcohol), recreationally?
Do you use prescribed opiates for medical purposes?
Please rate your current level of pain. - 0 = No pain at all 100 = The most intense pain ever imaginable
English is:

On a scale of 1-3, please rate the fluency of your second language where 1 represents somewhat fluent and 3 represents extremely fluent. If you speak more than two languages, please rate your second most proficient language.
Do you play video games?
How often do you play video games?
Have you ever used marijuana (e.g. weed, joint, hash, oil etc)?
How often do you use Marijuana (on average within the past 3 months)?
Primary methods of intake (select all that apply): - Selected Choice
Primary methods of intake (select all that apply): - Other - Text
Why do you usually use marijuana (select all that apply)? - Selected Choice
Why do you usually use marijuana (select all that apply)? - Other - Text
If possible, describe the dose (THC mg) or number of hits.
How often do you combine marijuana with alcohol? (1 represents never and 5 represents every time)
When was the last time you used marijuana?
Do you foresee yourself using marijuana anytime soon? (select the best response) - Selected Choice
Do you foresee yourself using marijuana anytime soon? (select the best response) - Other - Text
How old were you when you first used marijuana or cannabis? Please enter a valid number (without spaces and/or special characters)
Do you have your driver's license? - Selected Choice
Do you have your driver's license? - Other - Text
Would you be interested in participating in a paid study in the future while using marijuana? - Selected Choice
Would you be interested in participating in a paid study in the future while using marijuana? - Yes (please enter your email address. Feel free to use a non-York email address to remain anonymous) - Text
During the past month, what time have you usually gone to bed at night? Note: 12AM is midnight an... - Approximate bedtime - Please select
During the past month, what time have you usually gone to bed at night? Note: 12AM is midnight an... - AM or PM - Please select
During the past month, how long (in minutes) has it usually taken you to fall asleep each night?
During the past month, what time have you usually gotten up in the morning? Note: 12AM is midnight... - Approximate wakeup time - Please select
During the past month, what time have you usually gotten up in the morning? Note: 12AM is midnight... - AM or PM - Please select
During the past month, how many hours of actual sleep did you get at night? This may be different than the number of hours you spend in bed.
During the past month, how often have you had trouble sleeping because... - a. you cannot get to sleep within 30 minutes
During the past month, how often have you had trouble sleeping because... - b. you wake up in the middle of the night or early morning
During the past month, how often have you had trouble sleeping because... - c. you have to get up to use the bathroom
During the past month, how often have you had trouble sleeping because... - d. you cannot breathe comfortably
During the past month, how often have you had trouble sleeping because... - e. you cough or snore loudly
During the past month, how often have you had trouble sleeping because... - f. you feel too cold
During the past month, how often have you had trouble sleeping because... - g. you feel too hot
During the past month, how often have you had trouble sleeping because... - h. you have bad dreams

During the past month, how often have you had trouble sleeping because... - i. you have pain
During the past month, how often have you had trouble sleeping because... - j. Other reason(s), please describe:
During the past month, how often have you had trouble sleeping because... - j. Other reason(s), please describe: - Text
During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep? - Please select
During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity? - Please select
During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done? - Please select
During the past month, how would you rate your sleep quality overall? - Please select
How many hours of sleep did you get last night?
Thinking about yourself and how you normally feel, to what extent do you generally feel upset?
Thinking about yourself and how you normally feel, to what extent do you generally feel hostile?
Thinking about yourself and how you normally feel, to what extent do you generally feel alert?
Thinking about yourself and how you normally feel, to what extent do you generally feel ashamed?
Thinking about yourself and how you normally feel, to what extent do you generally feel inspired?
Thinking about yourself and how you normally feel, to what extent do you generally feel nervous?
Thinking about yourself and how you normally feel, to what extent do you generally feel determined?
Thinking about yourself and how you normally feel, to what extent do you generally feel attentive?
Thinking about yourself and how you normally feel, to what extent do you generally feel afraid?
Thinking about yourself and how you normally feel, to what extent do you generally feel active?
Have you had, or suspect you have had symptoms of COVID-19?
When did your symptoms emerge? If you don't remember the exact date, please enter the year and the... - Month - Please select
When did your symptoms emerge? If you don't remember the exact date, please enter the year and the... - Day - Please select
When did your symptoms emerge? If you don't remember the exact date, please enter the year and the... - Year - Please select
Did you get tested for COVID-19? All diagnosis tests accepted (e.g. molecular/PCR tests, antigen tests, etc.)
When did you get tested? (if you have had multiple tests, consider your most recent negative test... - Month - Please select
When did you get tested? (if you have had multiple tests, consider your most recent negative test... - Day - Please select
When did you get tested? (if you have had multiple tests, consider your most recent negative test... - Year - Please select
As a result of the symptoms you have experienced, did you get tested for COVID-19? All diagnosis tests accepted (e.g. molecular/PCR tests, antigen tests, etc.) - Selected Choice
As a result of the symptoms you have experienced, did you get tested for COVID-19? All diagnosis tests accepted (e.g. molecular/PCR tests, antigen tests, etc.) - No, I did not get tested Optional: What prevented you from getting a test to confirm your diagnosis? - Text
When did you get tested? (consider the first test you did as a result of your COVID-19 symptoms)I... - Month - Please select
When did you get tested? (consider the first test you did as a result of your COVID-19 symptoms)I... - Day - Please select
When did you get tested? (consider the first test you did as a result of your COVID-19 symptoms)I... - Year - Please select

Did you get any subsequent COVID-19 tests since testing positive? All diagnosis tests accepted (e.g. molecular/PCR tests, antigen tests, etc.)
Your subsequent COVID-19 test was:
When did you get this subsequent COVID-19 test? If you don't remember the exact date, please ente... - Month - Please select
When did you get this subsequent COVID-19 test? If you don't remember the exact date, please ente... - Day - Please select
When did you get this subsequent COVID-19 test? If you don't remember the exact date, please ente... - Year - Please select
Out of your two or more subsequent COVID-19 tests, did you get: (select all that apply)
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Month - Please select the date of your most recent positive test
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Month - Please select the date of your first negative test
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Day - Please select the date of your most recent positive test
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Day - Please select the date of your first negative test
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Year - Please select the date of your most recent positive test
When did you get your subsequent COVID-19 tests? If you don't remember the exact date, please ent... - Year - Please select the date of your first negative test
Do you feel that you still suffer from COVID-19 symptoms? Symptoms include but are not limited to: cough, breathing difficulties, fever, chills, headache, loss of smell/taste, pain, fatigue, muscle weakness, gastrointestinal symptoms, chest pain, « brain fog » (cognitive dysfunction)
How long did your COVID-19 symptoms last? Please indicate how many days, weeks or months - Selected Choice
How long did your COVID-19 symptoms last? Please indicate how many days, weeks or months - Days - Text
How long did your COVID-19 symptoms last? Please indicate how many days, weeks or months - Weeks - Text
How long did your COVID-19 symptoms last? Please indicate how many days, weeks or months - Months - Text
Relative to your COVID-19 onset, please indicate all the times you experienced symptoms. Some people can experience COVID-19 symptoms which persist and fluctuate for several weeks or months after the start of their symptoms (also known as long COVID). If it is your case, select all that apply. The first day of week 1 refers to the onset of your COVID-19 symptoms Even if you have only experienced symptoms for part of a week or month, please select it.
Relative to the onset of your COVID-19 symptoms, please indicate when your symptoms were the worst. Some people can experience COVID-19 symptoms which persist and fluctuate for several weeks or months after the start of their symptoms (also known as long COVID). If it is your case, select all that apply. Day 1 refers to the onset of your COVID-19 symptoms
Do you know which variant affected you?
When your symptoms were at their worst, what happened?
How long did your hospitalization last? Please indicate how many days or weeks - Selected Choice

How long did your hospitalization last? Please indicate how many days or weeks - Days - Text
How long did your hospitalization last? Please indicate how many days or weeks - Weeks - Text
On a scale from 0 to 3, please evaluate your overall daily life function at least 1 month prior to your COVID-19 infection. - To perform usual duties/activities
When your symptoms were at their worst, how much were you affected in your everyday life by COVID-19? Please indicate which one of the following statements applies to you most. Statement 0 is associated with no limitations. Statement 4 is associated with the most severe limitations.
How long did the above limitations last? Please indicate how many days, weeks or months - Selected Choice
How long did the above limitations last? Please indicate how many days, weeks or months - Days - Text
How long did the above limitations last? Please indicate how many days, weeks or months - Weeks - Text
How long did the above limitations last? Please indicate how many days, weeks or months - Months - Text
At the moment, how much are you affected in your everyday life by COVID-19? Please indicate which one of the following statements applies to you most. Statement 0 is associated with no limitations. Statement 4 is associated with the most severe limitations.
Optional: Please use this space to describe anything about your COVID experience that you think might be relevant and have not been captured in the previous questions. Please do not include any identifying information (such as name or location)
Have you received a COVID-19 vaccine?
How many doses of COVID-19 vaccines did you get?
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a vaccine - Dose 1
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a vaccine - Dose 2
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a vaccine - Dose 3
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a year - Dose 1
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a year - Dose 2
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a year - Dose 3
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a month - Dose 1
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a month - Dose 2
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a month - Dose 3
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a day - Dose 1
For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a day - Dose 2

For each dose you have received, please indicate which COVID-19 vaccine you got and the date. - Select a day - Dose 3
Please enter in the text box the name of the COVID-19 vaccine you got. - Dose 1
Please enter in the text box the name of the COVID-19 vaccine you got. - Dose 2
Please enter in the text box the name of the COVID-19 vaccine you got. - Dose 3
Have you been diagnosed with any of the following conditions pre-COVID? (select all that apply) - Selected Choice
Have you been diagnosed with any of the following conditions pre-COVID? (select all that apply) - Parkinson's disease or any neurological condition (specify if comfortable) - Text
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Lung conditions (e.g. asthma, emphysema or bronchitis)
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Heart disease
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Chronic kidney disease
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Liver disease (e.g. hepatitis)
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Diabetes
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - High blood pressure
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Irregular heartbeat (atrial fibrillation)
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Problems with your spleen (e.g. sickle cell disease, or if you have had your spleen removed)
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - A weakened immune system as the result of a condition such as HIV or AIDS, or medicines such as steroid tablets or chemotherapy
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Parkinson's disease or any neurological condition (specify if comfortable)
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - Parkinson's disease or any neurological condition (specify if comfortable) - Text
You indicated you have been diagnosed with the following conditions, did any of them change during the course of your COVID-19 symptoms? - None of the above
Have you ever experienced a concussion before?
How many concussions have you experienced in the past 5 years? Please enter a valid number (without spaces and/or special characters)
When was the last concussion you experienced?
How severe was the last concussion you experienced?
Have you ever been diagnosed with ADHD?
Are you currently taking any medications for ADHD?
For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?

For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 2. How often do you have difficulty getting things in order when you have to do a task that requires organization?
For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 3. How often do you have problems remembering appointments or obligations?
For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 4. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?
For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 5. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?
For the questions below, check the box that best describes how you have felt and conducted yourself over the past 6 months. - 6. How often do you feel overly active and compelled to do things, like you were driven by a motor?
Have you been diagnosed with Autism Spectrum Disorder?
How severe is your Autism Spectrum Disorder diagnosis?
Do you play a musical instrument?
Which musical instrument(s) do you play? Select all that apply. - Selected Choice
Which musical instrument(s) do you play? Select all that apply. - Other - Text
How would you rate your ability to play your musical instrument(s)? (1 represents the lowest level and 7 represents a professional level)
How often have you practiced your main musical instrument in the past 3 months?