



NAVAL MEDICAL RESEARCH UNIT DAYTON

Assessing Benefits of Combining Strategic Naps with Modafinil to Improve Performance During Sleep Loss

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SUMMARY

Background: Performance effects due to insufficient sleep have been documented for decades. In military operations, countermeasures are put in place to offset these effects. Both pharmacological and non-pharmacological methods are available, with strict guidelines over when and how pharmacological countermeasures may be administered. Modafinil is the current approved “go-pill” for all branches of services, and is the only one approved for Navy operations. The current study was designed to determine if the combination of the allowable prescribed dose of 200mg modafinil and a 2-hr nap would be better than a nap alone. Two hypotheses were tested in this study: 1) modafinil would decrease sleep inertia effects immediately upon awakening from a nap; and 2) the combination of modafinil with a nap would benefit performance and subjective alertness better than a nap alone. The study additionally explored the effect of modafinil on the nap’s sleep architecture.

Methods: Participants were randomly assigned to one of two groups: modafinil (200mg) plus napping or placebo plus napping, with 12 participants per group. Prior to testing, participants completed a set of questionnaires and initial training on the cognitive tasks. Afterward, baseline testing occurred at 2000, followed by the first test session at 2300. At 0230, the treatment dose (modafinil or placebo) was administered with the 2-hr nap opportunity beginning at 0300. Wake-up was at 0500, with testing beginning immediately upon rising. Testing continued every 3 hours until dismissal at 2200, with a 1-hr break between sessions. Testing sessions included a battery of cognitive tests, physiological measures, and subjective evaluations of mood and side effects. Data analyses included group comparisons at session 3 to determine modafinil’s effects on sleep inertia, and group comparisons between baseline and test sessions 2 through 7 to determine the effects of the combination of modafinil and a nap versus the nap alone.

Results: Results indicated that the combination of modafinil with a nap was not beneficial compared to a nap alone. For the first hypothesis regarding the ability of modafinil to decrease the effects of sleep inertia, only the Peripheral Information Processing task and the oculometric assessments showed differences between the two groups. For the Peripheral Information Processing task, number of correct responses, number of incorrect responses, and reaction time were better in the modafinil group than in the placebo group. For the oculometric measures, people in the modafinil group showed greater saccadic velocity than those in the placebo group. For the second hypothesis in which the combination of modafinil with a nap was compared to a nap alone, only a few tests showed the desired interaction effect between group and session. The combination of modafinil with a nap showed faster reaction time and a greater number of correct responses as compared to a nap alone, particularly in the morning hours. Finally, the analyses investigating the effects of modafinil on sleep architecture during the nap showed an increase in Stage 2 sleep compared to the effects of placebo, with those participants in the modafinil group spending more time in Stage 2 sleep than in Stage 3 or Rapid Eye Movement sleep.

Conclusions: In conclusion, this study revealed that the use of 200mg modafinil is not adequate to combat sleep inertia which occurs immediately upon awakening from sleep. Additionally, combining modafinil with a nap does not produce an advantage over a nap alone. Finally, the use of 200mg modafinil slightly alters sleep architecture when taken before sleep, but not to the point where sleep is not restorative, at least during a 2-hour nap. Future research could explore other operationally-relevant dosing of modafinil and various nap lengths to determine if there is an optimal combination of these two countermeasures. Additionally, exploration of individual differences in response to both napping and modafinil may review who responds best to each of these countermeasures.

1.0 INTRODUCTION

Since the early years of the U.S. – Vietnam Conflict, some members of the U.S. military have been allowed to use stimulants during sustained operations to help stave off the detrimental effects of fatigue (Jones, 1985). Among the newer of these fatigue countermeasures is modafinil, an alertness aid selectively available to deployed servicemen and women. Research has shown its efficacy in improving performance during periods of total sleep loss (Baranski, Cian, Esquivie, Pigeau & Raphel, 1998; Baranski, Pigeau, Dinich, & Jacobs, 2004; Czeisler et al., 2005; Wesensten, Killgore, & Balkin, 2005). An attractive characteristic of modafinil is its low side-effect profile, free of many of the side effects associated with amphetamines (e.g., dextroamphetamine), such as sleep disruption, cardiovascular effects, and risk for addiction (Baranski et al., 1998). Moreover, modafinil can be taken shortly before going to bed without increasing sleep latency or significantly altering sleep architecture (Saletu et al., 1989).

The proper use of pharmacologic countermeasures when fatigued due to sleep loss can help to reduce both subjective and objective impairments, yet stimulants and alertness aids do nothing to address the actual source of fatigue – lack of sleep. Consequently, no treatment can help someone recover from periods of extended wakefulness other than sleep (Batéjat & Lagarde, 1999; Caldwell et al., 2009; Dinges, Whitehouse, Orne, & Orne, 1988; Hardaway & Gregory, 2005). This critical realization has led to increased research examining behavioral and environmental factors intended to improve sleep quality (Gore, Webb, & Hermes, 2010), as well as a growing emphasis on the benefits of strategic naps for military personnel during sustained operations and long-haul flights (Caldwell et al., 2009; Rosekind et al., 1995). Strategic naps, taken either prophylactically (i.e., before sleep loss accumulates and impairs performance) or operationally (i.e., after performance has already begun to deteriorate due to sleep loss) may be beneficial in helping to maintain or return performance to adequate levels (Naitoh & Angus, 1987; Rosekind et al., 1995). A review of the available literature on napping revealed that naps of any length may be beneficial, helping to reverse the impairments associated with sleep loss for up to 10 hours after waking (Driskell & Mullen, 2005).

Although the benefits of implementing strategic naps during periods of prolonged wakefulness have been well documented, the period of grogginess and impaired performance frequently experienced upon awakening is the most serious concern (Ferrar, De Gennaro, & Bertini, 2000; Naitoh & Angus, 1987). Commonly called sleep inertia, as well as “sleep drunkenness” (Dinges, 1990), this is the transitory state experienced upon awakening which typically involves both mood disruptions as well as physical and cognitive deficits. During this time, performance is actually more impaired than it was prior to going to sleep (Ferrara & De Gennaro, 2000; Wilkinson & Stretton, 1970), even if the individual was deprived of adequate sleep (Angus, Pigeau & Heslegrave, 1992). The duration of sleep inertia depends on many factors; however, most sleep inertia dissipates 1-35 minutes after awakening (Akerstedt, Torsvall, & Gillberg, 1989; Rosekind et al., 1995).

Existing research has indicated that the combination of caffeine with a brief nap is more beneficial than either treatment alone (Reyner & Horne, 1997) and that this combination can help to maintain performance on some measures for more than 80 hours (Van Dongen et al., 2001). Likewise, a study conducted by Batéjat and Lagarde (1999) examined the potential benefits of

combining 200mg modafinil with a 6-hour nap after 27 hours of continuous wakefulness toward maintaining performance during a subsequent period of total sleep loss. Participant performance on measures such as mathematical processing and choice reaction time revealed that, although the nap was beneficial at returning performance to rested baseline levels, participants who also took modafinil demonstrated markedly superior performance during the second period of sleep loss in comparison to participants who took the placebo. However, this study had several drawbacks: participants were only tested 2 to 3 times per day with no consistency in the timing of the testing sessions, the countermeasures were not implemented until after 27 hours of continuous wakefulness, and 6 hours is a longer sleep period than would likely be available to personnel involved in continuous operations. Further, participants were not tested until 2 hours after awakening from the nap, so this report revealed nothing about how modafinil might alleviate some of the performance degradations associated with sleep inertia.

Thus, the primary aim of the present study was to examine the benefits of combining a 2-hour prophylactic nap with 200mg modafinil toward reducing the severity and duration of sleep inertia experienced upon awakening. The second aim of this study was to determine whether the combination of a strategic nap with modafinil would maintain performance during the subsequent period of continuous wakefulness longer than a nap alone. In this laboratory-based study, participants remained awake for approximately 20 hours, and then were given either a placebo or modafinil (200mg). After taking their assigned treatment, participants were given a 2-hour nap opportunity, and then remained awake for the following 17 hours. During the two periods of continuous wakefulness, participants completed a series of neurobehavioral assessments. Thus, this experiment is a 2x7 mixed factorial design with one between-subjects variable (modafinil vs placebo treatment), and one within-subjects variable (7 test sessions). The study protocol was approved by the Naval Medical Research Unit Dayton Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects. The sponsor for the study was the Department of the Army, through the Military Operational Medicine Joint Program Committee 5 (MOMJPC5).

Hypotheses tested:

- 1) Participants who receive 200mg modafinil before a nap will perform better on objective assessments completed immediately after awakening in comparison to participants who receive the placebo treatment.
- 2) Participants who receive the 200mg modafinil in conjunction with the nap will perform better on both subjective and objective assessments than for participants who receive the placebo with the nap.

Other objective

- 1) Determine whether sleep architecture will differ following consumption of 200mg modafinil administered an hour prior to a 2-hour nap compared to placebo.

2.0 METHOD AND PROCEDURES

This laboratory-based study was a mixed-model design in which 2 groups of participants were assessed for sleep inertia and cognitive and mood changes following a 2-hour nap placed in the circadian nadir (0300). One hour prior to the nap, participants received either 200mg modafinil or placebo. Immediately upon awakening and for the following 17 hours, participants were assessed on a variety of cognitive and mood measures.

2.1 Prestudy questionnaires and assessments

2.1.1 Questionnaires. The following is a list of assessments taken prior to baseline day. Personality and circadian type questionnaires were administered prior to data collection in order to determine whether any of the participants were extreme morning or evening types, and to quantify certain personality factors (e.g., neuroticism, extraversion) which may impact one's response to sleep deprivation.

2.1.1.1 The Horne and Östberg Morningness/Eveningness Questionnaire (MEQ) (Horne & Östberg, 1976) was used to subjectively evaluate each participant's circadian type and was administered when participants arrived at the laboratory for the beginning of the study. This 19-item questionnaire was presented on a computer screen and scored automatically by the program.

2.1.1.2 The Revised NEO Personality Inventory (NEO-PI-RTM) is a widely used instrument for the assessment of personality functioning (Costa & McCrae, 1992). The inventory consists of 240 items answered on a 5-point scale, ranging from "strongly disagree" to "strongly agree." The five domains measured are: Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness. Each domain is further subdivided into six facets that measure specific features of the primary personality factor. The participants answered this questionnaire on the printed copy. A research staff member scored the completed questionnaire from the template provided by PAR (Psychological Assessment Resources, Inc.).

2.1.1.3 The Need for Cognition (NFC) scale is a personality scale which was designed to evaluate an individual's tendency to engage in and enjoy thinking and cognitive challenges (Cacioppo & Petty, 1982). The scale consists of 18 statements presented on a computer screen and automatically scored by the program; participants are directed to indicate the degree to which each statement is characteristic or uncharacteristic of themselves.

2.1.2 Activity/sleep monitor. Sleep/wake data were collected to ensure participants attained adequate sleep each of the 3 days prior to their training day. The Motionlogger Micro Sleep Watch® (wrist activity monitor) from Ambulatory Monitory, Inc., is a water-resistant, wrist-worn device that measures frequency and intensity of wearer movement using a precision motion sensitive piezoelectric assembly. A 1-minute data capture epoch length was used to collect movement data. The movement results were plotted using accompanying software to track subjects' sleep patterns. Participants were given the wrist activity monitor 3 days prior to the in-house portion of the study and instructed to wear the watch for the next 3 days. The data were downloaded and reviewed for compliance with the sleep requirement on the first day of the in-

house portion of the study. Study volunteers who did not sleep at least 7 hours per night were either rescheduled until the sleep requirements were met or dismissed from the study.

2.2 Performance tests and questionnaires

The following is a list of cognitive tasks, questionnaires, and physiological assessments included in the study to evaluate the effects of modafinil and napping on performance, mood, and physical state.

2.2.1 Cognitive and physiological measures. A series of cognitive evaluations were collected during the training, baseline (pre-nap), and continuous wakefulness (post-nap) periods. Tests measured a variety of cognitive functioning, including participants' ability to maintain attention, reaction time, memory, and psychomotor tracking. Most of the tests were presented from the NTI Armory Test System (ATS)TM battery of tests (NTI, Inc., Fairborn, OH) and will be indicated as such.

2.2.1.1 Psychomotor Vigilance Test (PVT). Reaction time was assessed using the 10-minute PVT, a simple reaction time test known to be sensitive to sleep loss (Dinges et al., 1997). The PVT requires sustained attention and discrete motor responses. The 8" x 4.5" x 2.4" portable, battery-operated device visually displays numbers counted up by milliseconds in a window. The stimulus is presented for up to 1 minute (60,000 msec), allowing the participant to respond. The participant is asked to press a microswitch as quickly as possible once the numbers are displayed and the device records reaction time. The interstimulus interval varies randomly from 2 to 12 seconds. The data were downloaded from the device, stored on a computer, and reduced using custom software for future analysis. Figure 1 shows the PVT device.



Figure 1. The Psychomotor Vigilance Test (PVT)

2.2.1.2 NovaScan (NTI ATSTM). The NTI ATSTM implementation of NovaScan uses two of the individual tests described elsewhere in this document (Manikin and Continuous Memory). By presenting multiple tasks, a degree of difficulty is introduced which does not occur when each task is presented independently. In this “directed attention” task, NovaScan directs the person to the test that must be attended to at any given time by having only one test appear on the screen at a time. In effect, the person has to keep one test's requirements in memory, while actively performing another test. In this way, the participant's strategy is highly constrained, and it is easier to determine where a cognitive decrement or improvement has occurred. For this divided attention task, the Manikin task appears on the screen until the participant responds or for 5

seconds. At irregular intervals, this task is replaced by the Continuous Memory task, and the participant responds to this stimulus. When that task is again replaced with the Manikin task, the participant must remember the demands of the Continuous Memory task while again performing the Manikin task. This alternation continues for the remainder of the test. In addition to the demands involved with remembering each task, during the Manikin task, the participant must monitor a dial in which the pointer is moving at a constant rate, but in an inconsistent manner (the Dial Task). The participant must detect when the dial has gone into a "danger" zone by establishing a scan rate for the dial that optimizes the opportunity to detect a danger indication, while allowing time to optimally process the Manikin task. The screen for the Manikin and the Dial tasks are shown in Figure 2.

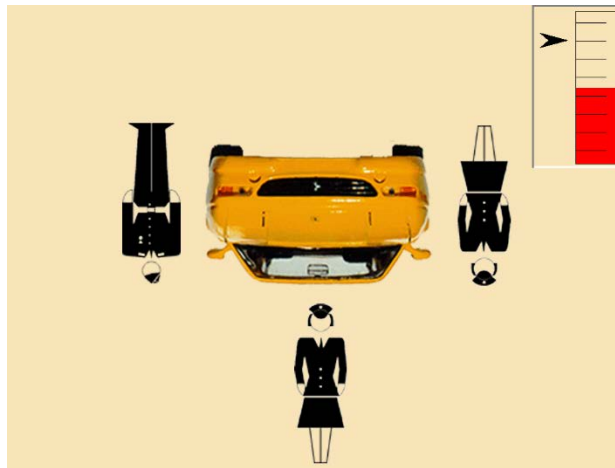


Figure 2. The Manikin and Dial task part of the NovaScan

2.2.1.3 Rapid Decision Making (NTI ATSTM). This test measures the participants' ability to examine visual stimuli in the context of the task's stated rules. Participants were shown several levels represented by overlapping ring sections with each level equating to a different threat level (red = critical, yellow = danger, green = alert). At various intervals, different "vehicles" were indicated somewhere on the display and the possible danger posed by that vehicle was evident by the symbol representing it (i.e., "?" = minimal danger, "O" = medium danger, and "X" = high danger). Participants were instructed to assess the threat posed by a given vehicle based on its location as well as the danger rating using the vehicle's symbol, and indicate which vehicle is the greatest threat. Participants were instructed to weigh the vehicle's location more heavily than the classification. For example, a medium threat symbol "O" placed in the critical area (red) should be perceived as a greater threat than the symbol "X" placed in the alert area (green). Examples are shown in Figure 3 below.

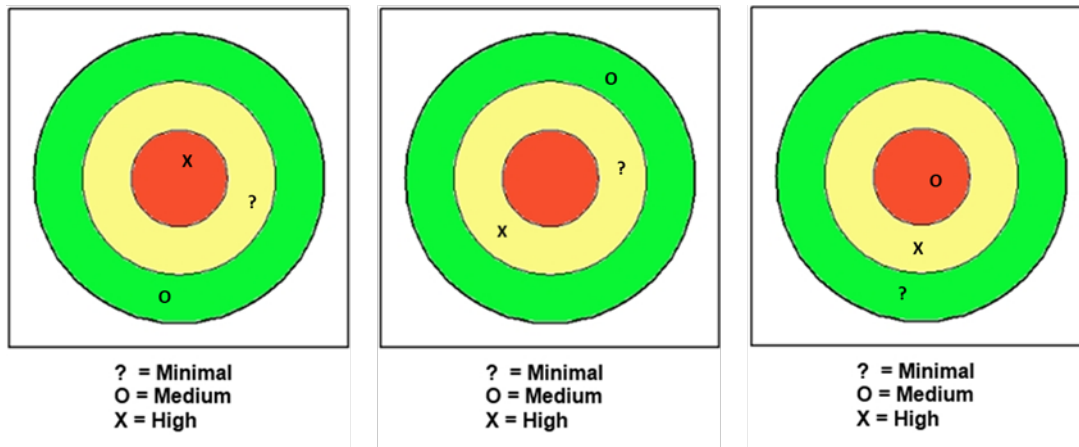


Figure 3. The Rapid Decision Making task

2.2.1.4 Math Processing (NTI ATSTM). This is a traditional test probing the participant's ability to carry out basic mathematical calculations. The participant was presented with an equation consisting of three numbers and operators, and then was required to carry out addition and/or subtraction functions on the equation (e.g., $5 + 7 - 9$). The required response was to indicate whether or not the result of the three operations is greater or less than 5. Participants were directed to click the left mouse button if the solution to the problem was less than 5 or the right mouse button if the solution was greater than 5. Participants were directed to work as quickly and accurately as possible.

2.2.1.5 Delayed Match to Sample (NTI ATSTM). This task is designed to assess the participant's short-term spatial memory and pattern recognition skills by quickly and accurately choosing a test stimulus which is identical to a standard stimulus presented previously. Participants were initially presented with a 4 x 4 checkerboard matrix design. After viewing the sample matrix stimulus for a time adequate for committing the stimulus to memory (maximum view time was 60 seconds), the participant pressed a mouse key to clear the screen and initiate the interference stimulus. The interference stimuli consisted of 4 alphabet characters presented for 4 seconds when a vowel was present and 25 seconds when a vowel was not present and required the participants to determine if the letter string contained a vowel. The participant pressed the left mouse button if a vowel was present, and the right mouse button if no vowel was present. Afterward, the test trial was presented which consisted of two matrices side by side on the screen. One of the matrices was identical with the initial sample matrix while the other was different. The participant responded with the mouse button which corresponded to the test matrix which was identical to the initial sample matrix with a maximum viewing time of 30 seconds. The sequence of stimuli are shown in Figure 4.

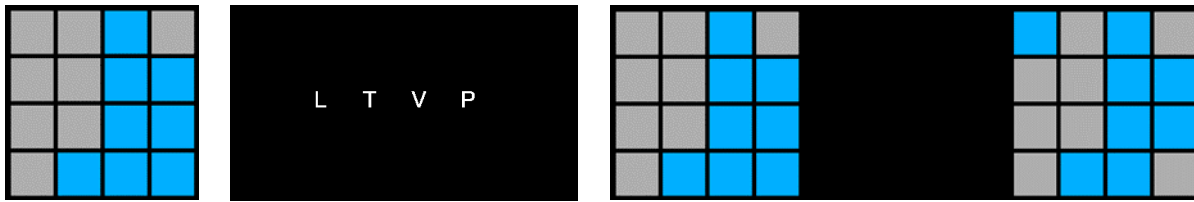


Figure 4. Delayed Match to Sample task. First image: Initial matrix; Second image: Interference stimulus; Third image: Test trial

2.2.1.6 *Peripheral Information Processing (NTI ATSTM)*. This task was designed to assess participants' ability to focus on a particular point and yet still attend to information being presented in the periphery. For this task, participants saw a black screen with an "X" at the center as well as a vertical gauge on both the right and left sides. The gauge had three different color segments (red, green, and yellow) as well as an arrow indicator. Participants focused on the X at the center of the screen while simultaneously monitoring the gauges on either side without looking directly at the gauges. They were instructed to press the center mouse button if the arrow on either gauge moved. A sample screen is shown in Figure 5 below.

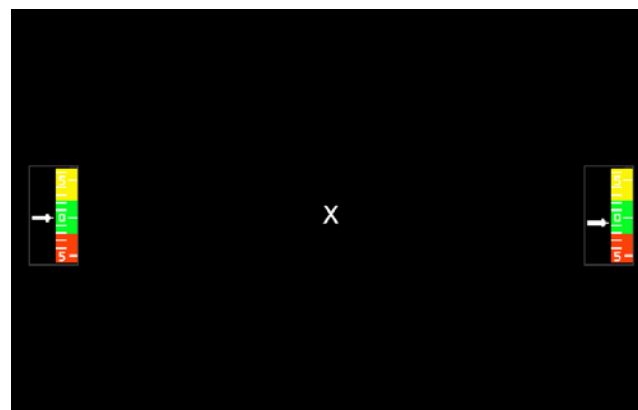


Figure 5. Stimulus presented for the Peripheral Information Processing task

2.2.1.7 *Dichotic Listening (NTI ATSTM)*. This task was designed to test participants' ability to focus on relevant auditory information being received in one ear while concurrently ignoring distracting information received in the other ear. Only single-syllable digits were used as the stimuli (1 through 6, 8 through 10). Participants wore binaural headphones. At the start of each presentation, participants heard a cuing tone in the left ear (low pitch tone) or the right ear (high pitch tone) which served as a prompt to only attend to the stimulus in that ear (i.e., if the tone was presented to the participant's left ear, he or she should ignore the next stimulus presented in the right ear). The tone was quickly followed by a stimulus (number, 1-6, 8-10) spoken into each ear. A different number was presented to each ear. The participant was to attend to the ear where the tone was presented and report the number presented to that ear by responding on the keypad using the 0-9 keys (press 0 for the number 10).

2.2.1.8 *Warship Commander Task (WSC)*. This task is a multi-tasking attention and verbal memory measure. Participants monitored aircraft (i.e., tracks) on a geographical display to identify friend or foe (IFF) and then responded to the hostile aircraft according to the explicit rules of engagement. When planes first appeared on the screen, they were white, indicating

unknown status. Participants identified which planes were friendly or hostile by selecting one of the aircraft and then clicking the IFF button at the bottom of the screen. The selected plane's color then changed to blue (friendly), red (hostile), or yellow (status unknown until further identified). To determine the threat level of the yellow tracks, participants relied on the communication panel at the bottom of the screen to provide a classification for each individual plane. Each aircraft was assigned a four-digit number and participants clicked on the corresponding button with the same four-digit number. The determination of either hostile or friendly was then presented in the black box at the bottom right corner of the display.

Participants were told not to engage any planes, either red or yellow, until they passed below the red line of engagement on the display. Participants could destroy red aircraft once they crossed this line by clicking on the particular track and then hitting the FIRE button at the bottom of the display. Planes which were colored yellow and labeled as being hostile must first be warned that they are in restricted air space. Participants clicked on the target aircraft and then hit the WARN button. If a plane remained within the restricted area for 3 seconds after the warning had been sent, the participant destroyed it in the same manner that red planes are destroyed. Blue planes were also introduced on the display; these were "friendly" planes and no action was required for them.

This task also had an auditory component. While monitoring the visual, geographic display, participants needed to monitor the ship's verbal communications for ship status information given by fellow crew members (e.g. "Our current fresh water level is 695"). At random intervals, the ship's Captain asked a question about the ship's status such as "What is the ship's current fresh water level?" Participants then had to select the correct response from the list of four options on the left-hand side of the screen.

Task load was manipulated by changing the quantity and types of planes appearing throughout the primary task, and by varying the presence or absence of the secondary verbal-memory task. The task began with 6 tracks (or planes) on the screen. As the task continued, the tracks changed as well as the types of tracks appearing on the screen. There were 9 waves of planes presented, starting with 6 tracks, then 18 tracks, and then 12 tracks. The 9 waves were presented 3 times for a total of 27 waves. An example of one of the waves is presented in Figure 6 below.

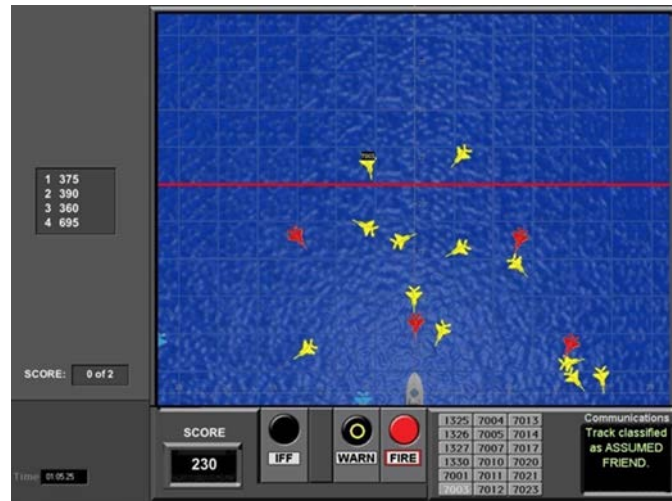


Figure 6. Warship Commander task

2.2.1.9 Visual Vigilance (NTI ATS™). This task, also referred to as a go/no-go task, measures simple attention and vigilance. Participants were presented rapidly with either the letters “O”, “D”, or a backward “D” in random order in the center of the screen on top of background circles. The letters were on the screen for 40 msec and presented at a rate of approximately 60 per minute. The participants monitored the letters to detect when the letter “O” was presented. If an “O” was detected, the participant responded by pressing the left button on the mouse. No response was required for either of the other two letters. The screen with the stimulus presented is shown in Figure 7 below.

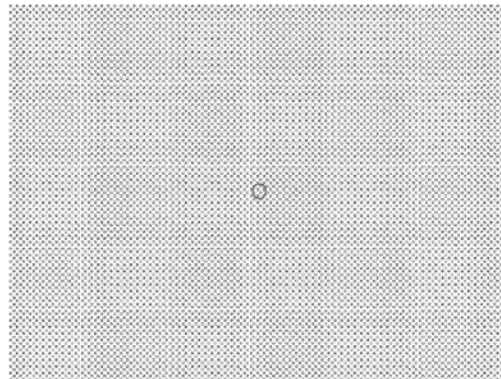


Figure 7. Visual Vigilance task screen with the letter “O” (darkened in this example).

2.2.1.10 Continuous Memory (NTI ATS™). This task is a measure of participants’ working memory capacity for visually-presented stimuli and is often referred to as an “n-back” task. For this task, participants were instructed to utilize a flexible, working memory for a series of digits that were presented so they could compare the current stimuli with what they saw previously. The program simultaneously displayed two numbers, one directly above the other, with the number on top (numerator) being the memory probe item, and the bottom number (denominator) being the target number. Participants were instructed to remember the target number while comparing the probe number to a number shown on the previous screen. If the numbers matched, the participant selected the left mouse button. If they did not match, the participant selected the right mouse button. In the first panel of the example in Figure 8 below, the memory probe item is

“7” and the target number is “2.” In the second panel, the probe number is “2;” therefore, the target number and the probe number are the same and considered a match, and the correct response is the left mouse button.



Figure 8. A sample of the Continuous Memory task

2.2.1.11 Manikin Task (NTI ATSTM). This test is a single test which was presented in the NovaScan task described earlier. It is designed to index the ability to mentally rotate objects and determine the orientation of a given stimulus. In this version, the “manikin,” or object, is an automobile. To the sides of the object are a male and a female figure, lined up horizontally. Below the object and figures is a single figure (male or female) (see Figure 9). The objective for this task was to determine on which side of the object (i.e., right or left) was the figure that matched the figure at the bottom of the screen. The participant indicated an answer by pressing one of two keys with the corresponding right or left index finger. For example, if the figure at the bottom of the screen matched the figure on the left, the participant pressed the left mouse button. The figures could appear either upright or upside down, and facing either toward or away from the participant. The 16 combinations of orientation, stimuli and side were pseudo-randomly ordered so that each combination is presented only once each in 16-trial blocks.



Figure 9. Manikin task example

2.2.1.12 Motion Inference (NTI ATSTM). This task tests participants’ ability to monitor and evaluate different sources of information simultaneously. Participants were initially shown a light moving across the screen in an arc with a target stopping point indicated. The moving light suddenly disappeared and participants were instructed to estimate when the light would have reached the target stop point based on the speed at which the light appeared to be moving

initially. Participants indicated their response using the mouse. The task also included a distractor task between the initial presentation and the timing response. Below the arc, participants were shown a series of four letters and asked to indicate whether or not any of the letters shown was a vowel. Thus, for each trial participants first were shown the moving light which then disappeared; second, they were presented with the series of letters and asked to determine whether any of the letters shown were vowels; and third, indicate when the light reached the target stopping point. Therefore, two separate responses were required: a “vowel or no vowel” response and a “stop” response to the light. Once the “stop” response to the light was made, the light reappeared in the location where the participant stopped it. The participant always received this feedback, but not feedback regarding the vowel response. An image of the screen with the four letters displayed is shown in Figure 10.

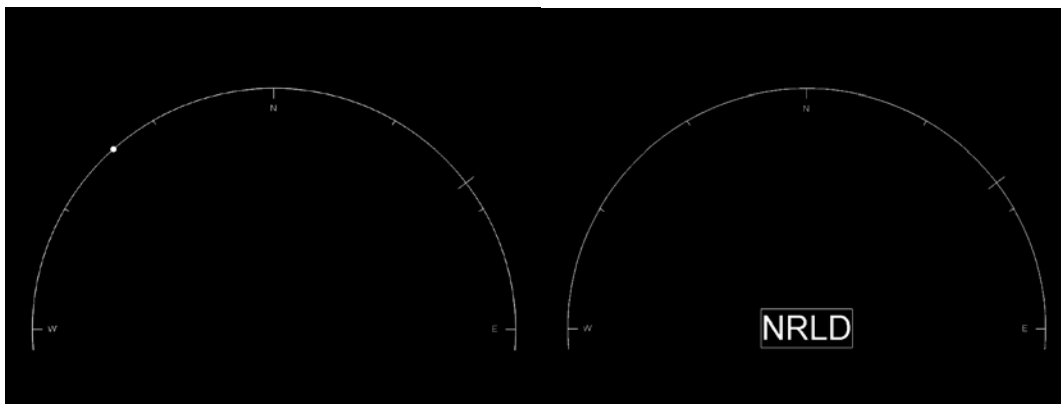


Figure 10. Motion Inference task. On the left is the light on the arc; on the right is the distractor task

2.2.1.13 Three-Choice Reaction Time (NTI ATSTM). The choice reaction time task measures discriminative judgment about two or more stimuli, and forces the participant to select the proper response from a number of potential responses. This task probes simple discrimination capacity and response selection abilities. In the present use of the task, two levels of complexity were manipulated. For the simple task trials, participants were presented with three stimulus boxes, and were required to press the appropriate response key, depending on which box the stimulus (a white dot) appeared. For example, if the stimulus appeared in the left box, the participant was asked to press the left response key (see Figure 11, left panel). For the complex task trials, the appearance of an “X” on the screen signaled a different set of responses to the same lights (see Figure X, right panel). Whenever an “X” appeared, the response was in the reverse direction from the simple condition. For example, if the stimulus appeared in the left box and the “X” was present, the right response key should be pressed. For the three choice condition, the “X” could appear only if the stimulus appeared in the left or right boxes, but not when the stimulus appeared in the middle box.

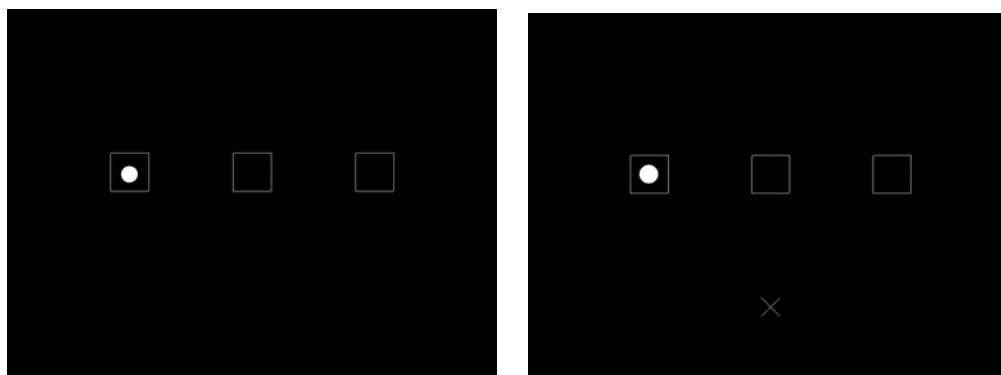


Figure 11. Three-Choice Reaction task. The left screen is for low complexity; the right screen is the high complexity screen

2.2.1.14 Flight simulator performance. Flight simulator performance was measured using the X-Plane® 9 flight simulator (Laminar Research, Columbia, SC). Participants were given a simple flight profile, with instructions to fly “straight and level” at an altitude of 2000 feet, airspeed of 140 knots, and a heading of 180 degrees (south), for 20 minutes. The first 5 minutes of the “flight” allowed the participant to obtain steady flight, with the final 15 minutes scored for accuracy. Figure 12 illustrates a view seen by the participants for this test.



Figure 12. Screen display for the flight simulator

2.2.1.15 Oculometric assessments. The PMI Fitness Impairment Tester (FIT) 2000 (PMI, Inc.) uses eye-tracking and pupillometry to identify impaired physiological states due to fatigue and other factors such as alcohol or drug use. The system employs an algorithm that compares an individual’s present state on four pupillometric variables (saccadic velocity, pupil diameter, pupil constriction amplitude, and pupil constriction latency) to their baseline state data. This task was completed during each session. Each trial required approximately 30 seconds to complete. Figure 13 illustrates the posture of the participant when viewing the stimuli from the FIT.



Figure 13. The PMI FIT device

2.2.1.16 Digit span (auditory) (NTI ATSTM). The primary focus of this task was to assess participants' short-term memory ability to correctly recall the order in which a series of digits was audibly presented. Using headphones, participants heard a digitally-recorded sequence using numbers 1 – 9. Using the number pad, participants were then instructed to type in the digits they heard either forwards (e.g., in the same order the digits were presented) or backwards (e.g., in the reverse order that the digits were presented). In the first trial, participants heard two digits; the size of the sequence then continued to increase by one digit after each correctly completed trial for a maximum sequence of nine digits.

2.2.2 Mood and side effects assessments. Mood was measured with two questionnaires, the Profile of Mood States (POMS) and the Visual Analogue Scale (VAS), and participants indicated any side effects they may have experienced on the Side Effects (SE) questionnaire. These assessments were administered at the end of each of the testing sessions.

2.2.2.1 The POMS (McNair, Lorr, & Droppleman, 1981) is a questionnaire consisting of 65 items which measure affect on 6 scales: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. A Total Mood Disturbance score is calculated based on all the items in the questionnaire. The questionnaire was administered and scored by computer.

2.2.2.2 The VAS is a self-report measure of adjectives reflecting mood states of 'alert/able to concentrate', 'anxious', 'energetic', 'feel confident', 'irritable', 'jittery/nervous', 'sleepy', and 'talkative' (Penetar et al., 1993). Each adjective is presented with a 100mm line centered above each word. At the extremes of each line, 'not at all' and 'extremely' were printed respectively, with 'not at all' located at the far left of the line. Using the computer mouse, participants indicated where on the line they felt their mood was best represented. Scores consisted of the distance of the participant's mark from the left end of the line (in mm), with higher scores indicating an increased presence of the stated mood. This questionnaire was presented on a computer screen and scored by computer program.

2.2.2.3 Side-effects were assessed via a questionnaire. Participants were shown a list of possible symptoms which included those associated with stimulant use (e.g., headache, tremor, anxiety, etc.) and asked to indicate whether and to what degree they were currently experiencing that side effect. Responses were made on a 5-point scale, ranging from "not at all" to "extremely." This questionnaire was presented and scored by computer.

2.2.3 Biological samples. Breath and saliva samples were collected in an effort to identify potential biomarkers to fatigue.

2.2.3.1 Breath samples. Two slightly different methods of collecting breath were used because the samples were analyzed by different labs. Two samples were taken at a time, one for each method. For the first method, the breath samples were collected into 5 L Tedlar bags, a standard used by the Environmental Protection Agency (EPA) for chemical capture. These samples were collected by instructing participants to exhale through a disposable syringe connected to the Tedlar bag. A total of 4 to 5 exhalations into the bag resulted in a volume of approximately 2 L. This method of breath collection was compatible with existing THz breath sensors as well as with the equipment contracted by Wright State Research Institute/Advratech. Extensive gas chromatography–mass spectrometry (GC-MS) analysis at the highest level of sensitivity (up to 200 tentative compounds or peaks) were achievable through attainment of these samples. These sample data were collected for researchers affiliated with the Wright State Research Institute and will be analyzed and reported in a separate report.

For the second sampling method, exhaled breath was collected using a 1 L polypropylene bag affixed with Teflon breathing tubes. Participants were instructed to first make a normal exhalation into the room, and then inflate the bag using the remaining alveolar air from the lungs, termed as “post-tidal breath”. This process was repeated until the 1 L bag was filled. This sample was collected for researchers affiliated with the 711th Human Performance Wing; they will analyze and report these data in a separate report.

2.2.3.2 Saliva samples. A second effort to identify potential fatigue biomarkers was through saliva analysis. Participants were given a saliva sample collection tube (Salimetrics; Carlsbad, CA) and asked to allow saliva to pool in their mouth, and then pushed the pooled saliva into the collection tube until it was filled, for a total of 2 mL. Samples were stored at -20° C (-4° F) until the liquid chromatography-tandem mass spectrometry (LC-MS/MS) analysis was conducted. These data were collected for researchers affiliated with the 711th Human Performance Wing; a separate report will be submitted for these data.

2.2.4 Polysomnography. Evaluations of sleep architecture during each nap period were made using an electroencephalograph system. The electroencephalographic (EEG) data from electrodes placed at the International 10-20 System sites F3, F4, C3, C4, O1, and O2, referenced to contralateral mastoids (M1 or M2) were recorded. Eye movements (electrooculogram - EOG) were assessed with electrodes affixed slightly above the outer canthus of one eye and slightly below the outer canthus of the other eye and referenced to M1. Muscle activity (electromyogram - EMG) was recorded from submental electrodes (below the jaw) affixed with adhesive collars. The time constant for the EEG channels was 0.3 seconds, and the high filter was 35 Hz. For EOG, the time constant was 5.0 seconds, and the high filter was 10 Hz. For EMG, the time constant was 0.003 seconds, and the high filter was 120 Hz. The 60 Hz notch filter was used. Sampling rate was set at 200 Hz.

2.3 Participants

A sample of 25 individuals enrolled in the protocol, with 24 successfully completing the entire data collection period. One participant dropped out after the experimental dose due to nausea. Participants were male (N=18) and female (N=6), between the ages of 21 and 33 (M=25.33, SD=4.97). All were active duty military. Exclusion criteria included pregnancy; daily consumption of more than 250mg of caffeine; a history of significant psychiatric, neurological, or sleep-related problems; tobacco use within the last 6 months; insufficient sleep for the 3 days prior to the study days; and medication use. Participants were compensated for their time and effort. The breakdown of payment was as follows: successful completion of 3 nights at home with activity monitor was \$45 (\$15/night); completion of in-laboratory portion of the study was \$400 (\$10/hour for 40 hours); bonus for completion was \$30. The total amount was determined according to Federal policy that payment to research subjects must be undertaken with the intent to minimize the possibility of coercion or undue influence (32 CFR.219.116). Participants were compensated on a prorated basis if they discontinued participation (either by choice or investigator discontinuation).

2.4 Description of study

Participation in this study took approximately 3 days at home where sleep was assessed by wrist activity monitors and 2 days in the laboratory. Participants wore a wrist activity monitor to track their sleep/wake schedules and were also asked to estimate their nightly sleep time on a sleep log, which they returned on Day 1. The required time in bed was no less than 8 hours/night with at least 7.5 hours of total sleep time the 3 nights prior to the in-house laboratory portion of the study. Those not meeting this requirement were offered another time to complete the in-house portion of the study or were dismissed and not enrolled in the in-laboratory portion of the study. Prior to beginning the in-house portion of the study, participants completed the Horne Östberg Morningness/Eveningness Questionnaire, the Need for Cognition Scale, and the NEO-PI-R™. They also received initial training on the more complex cognitive tasks (e.g., Warship Commander Task and Rapid Decision Making task). Participants were randomly assigned to one of the two condition groups, either the placebo or the 200mg modafinil group.

For the in-house portion of the study, participants remained at the Naval Medical Research Unit Dayton (NAMRU-D) research facility throughout the study. They were provided three meals per day plus snacks ad libitum. No caffeine was allowed. Otherwise, no dietary restrictions were imposed. Entertainment to fill non-test times included a choice of movies, games, or quiet time reading. At no time other than during personal hygiene was the participant left alone; a staff member was always with the participant. Participants were tested in pairs whenever possible; however, single participant runs were also scheduled. The data collection schedule for this 2-day phase of the study is depicted in Table 1 with the session schedule depicted in Table 2.

Table 1. Daily testing schedule

Time	Day 1	Day 2
0000		
0200 0230		Treatment Dose
0300		Nap
0400		
0500		Test 2
0600		
0700		
0800	Arrive at lab	Test 3
0900	Electrode placement	
1000		
1100	Training Session 1	Test 4
1200		
1300		
1400	Training Session 2	Test 5
1500		
1600		
1700	Training Session 3	Test 6
1800		
1900		
2000	Baseline	Test 7
2100		
2200		Debrief/Dismiss
2300	Test 1	
2400		

Table 2. Session tests schedule

Time in minutes from beginning of session	Test
00	Psychomotor Vigilance Task (PVT)
10	<u>NTI ATS Battery</u> NovaScan Rapid Decision Making Math Processing Match to Sample Peripheral Information Processing Dichotic Listening
35	Warship Commander Task
48	<u>NTI ATS Battery</u> Visual Vigilance Continuous Memory Manikin Motion Inference Three-Choice Reaction Time Task
62	X-Plane Flight Simulation Task
85	Physiologic/Subjective Measures Oculomotor Measures Visual Analogue Scale (VAS) Profile of Mood States Questionnaire (POMS) Side-effects Questionnaire
95	<u>NTI ATS Battery</u> Auditory Digit Span
108	Biological Samples Breath Sample Saliva Sample
	BREAK

On the first day of the laboratory portion of the study, participants awoke at 0700 and arrived at the NAMRU-D laboratory no later than 0830. At this time, participants' wrist activity data were downloaded and checked for compliance with the time-in-bed requirements. Those not meeting this requirement were not enrolled in the in-laboratory portion of the study until this requirement was met. If the participant received enough sleep, he or she was admitted into the in-laboratory phase of the study. At this time, the 12 EEG electrodes and the 2 mastoid electrodes were applied to the participant for the purpose of recording polysomnographic data during the nap. The electrodes remained in place until the study was complete or the participant withdrew from the study.

The training sessions began at 1100 on Day 1 and were repeated every 3 hours until the 3 sessions were completed. These sessions were identical in content to the testing sessions; however the tests were abbreviated to allow more time for participant instruction and familiarization. After the third training session, participants completed the baseline testing session (BL). This and all of the following test sessions included only the full versions of each of the tasks. The session took approximately 2 hours to complete. The baseline session was followed by the first test session which occurred prior to the dose and nap. Participants had at least 60 minutes to relax between testing sessions.

At 0230 on Day 2, participants received their assigned treatment dose, either the capsule filled with psyllium fiber (the placebo) or a capsule with 200mg of modafinil. Both the participants and the research staff were blind to which treatment was given. The remaining electrodes (EOG and EMG) were placed prior to the beginning of the nap.

The 2-hour nap began at 0300. Approximately 10 minutes prior to lights out, the participants were escorted to their private bedrooms, the electrodes were connected to the amplifiers and signal quality was checked and corrected as needed. At 0300, lights were turned out, the door was closed, and the participants were instructed to try to sleep. Upon awaking at 0500, participants immediately were escorted to the test computer and began the second test session (T2). Because sleep inertia is greatest during the first 30 minutes after awakening, it was important that this test session begin as soon as possible once the participant awoke. Participants completed five more test sessions, identical in content and duration, during the remainder of the study (T3-T7). Upon completing the seventh test session, electrodes were removed, the participants were debriefed, dismissed from the study, and driven home by a pre-identified individual.

3.0 RESULTS AND DISCUSSION

The SPSS statistical software package Version 25 (International Business Machines Corporation, Armonk NY) was used to analyze the data from each of the tasks and questionnaires. Data were screened for outliers and were excluded from the analyses if a score was 3 or more standard deviations from the mean. Analyses were conducted on each of the cognitive tasks to directly test the stated hypotheses, while the secondary objective was addressed using the polysomnography (PSG) data obtained during the nap.

- 1) H1: Participants who take 200mg modafinil before a nap will perform better on objective assessments completed immediately after awakening in comparison to participants who receive the placebo treatment before a nap.
- 2) H2: Both the subjective and objective assessments will be better for participants who receive the 200mg modafinil treatment in conjunction with the nap than for participants who receive the placebo treatment before the nap.
- 3) O: Other objective: Determine whether sleep architecture will differ following consumption of 200mg modafinil an hour prior to a 2-hour nap compared to placebo before the nap.

A total of 25 individuals enrolled in the study. One participant (woman) dropped out of the study due to nausea following her modafinil dose. Therefore, 24 individuals completed the study, 12 individuals per group. The group enrollment with demographic characteristics is shown in Table 3. None of the *t*-tests for any of the characteristics were significant between the groups.

Table 3. Demographics of each group (means with standard deviations in parentheses)

Group	N	# Men	Age	Horne- Östberg MEQ Score	NEO-PI-R Neuroticism Score	NEO-PI-R Extraversion Score	Epworth Sleepiness Score
Placebo	12	8	25.42 (5.16)	51.25 (10.35)	66.42 (17.85)	124.50 (15.93)	4.33 (2.23)
Modafinil	12	10	25.50 (4.27)	50.42 (6.27)	70.33 (19.93)	114.58 (26.13)	4.92 (2.64)

3.1 Performance tests and questionnaires for Hypothesis 1

The analyses conducted in this section addresses the first hypothesis: H1) Participants who take 200mg modafinil before a nap will perform better on objective assessments completed immediately after awakening in comparison to participants who receive the placebo treatment before a nap. A priori *t*-tests were conducted between groups at the 0500 (T2) testing session immediately after awakening. Since sleep inertia lasts generally no more than 30 minutes, only the tests presented within 30 minutes of awakening are of interest. However, all tests were analyzed, even if presented more than 30 minutes post-awakening. For each measure, unless otherwise noted, analyses of the cognitive tests were conducted on the following variables: number correct (Ncorr), correct reaction time (CorrRT), number incorrect (NIncorr), incorrect reaction time (IncorrRT), and number of time outs (NTO). The questionnaires and physiological assessments are also presented.

3.1.1 Cognitive and physiological measures. A series of cognitive evaluations were measured during the training, baseline (pre-nap), and continuous wakefulness period (post-nap). Tests measured a variety of cognitive functioning, including participants' ability to maintain attention, reaction time, memory, and tracking. Most of the tests were presented from the NTI ATSTM =battery of tests and will be indicated as such. Unless noted, N=12 for each condition.

3.1.1.1 Psychomotor Vigilance Test (PVT). The metrics analyzed for this task were the sum of the number of lapses (RTs > 500msec) added to the number of false starts (Lapses+FS), and reciprocal reaction time (RRT). One participant from the placebo group was excluded as an outlier for number of lapses. Levene's test indicated that the assumption of equal variances was not violated for Lapses+FS or RRT ($F = 0.594, p = .450$; $F = 0.560, p = .462$, respectively). The *t*-tests did not reveal any significant differences between the conditions at 0500 for RRT ($t(23) = -0.497, p = .624$) or Lapses+FS ($t(21) = 0.267, p = .792$). Means and standard errors (SE) are shown in Table 4.

Table 4. PVT Means (SE)

	Group	
	Placebo	Modafinil
Lapses+FS	#5.545 (1.925)	4.833 (1.843)
RRT	3.358 (0.166)	3.447 (0.166)

#N=11

3.1.1.2 Warship Commander Task (WSC).

Data for WSC were broken down by “waves” (W) or trial number and number of “tracks” (T). Tracks refers to the numbers of airplanes to be monitored during a wave. Each metric is summarized separately by waves and tracks. There were 3 waves and 7 tracks, so variables are abbreviated by metric (e.g., correct answer is “CA”), wave (e.g., first wave is “W1”), and track (e.g., 6 tracks or planes are T6). Therefore, the first wave with 6 tracks for the correct answers metric is abbreviated “CAW1T6.”

WSC Correct Answers (CA)

Levene’s test indicated that the assumption of equal variances was violated for CAW3T12 ($F = 5.500, p = .028$). Therefore, equal variances were not assumed for this metric. The t-tests did not show significant differences between the conditions at 0500 for CAW1T6 ($t(22) = -0.348, p = .731$), CAW1T18 ($t(22) = 0.260, p = .797$), CAW1T12 ($t(22) = 0.789, p = .438$), CAW2T6 ($t(22) = 1.254, p = .223$), CAW2T18 ($t(22) = 1.173, p = .253$), CAW2T12 ($t(22) = 0.616, p = .544$), CAW3T6 ($t(22) = -0.281, p = .781$), CAW3T18 ($t(22) = 0.752, p = .460$), and CAW3T12 ($t(18.066) = 0.856, p = .403$). Means and standard errors are shown in Table 5.

Table 5. WSC Correct Answers Means (SE)

	Group	
	Placebo	Modafinil
CAW1T6	1.583 (0.169)	1.667 (0.169)
CAW1T18	1.417 (0.227)	1.333 (0.227)
CAW1T12	1.500 (0.224)	1.250 (0.224)
CAW2T6	1.667 (0.188)	1.333 (0.188)
CAW2T18	1.500 (0.201)	1.167 (0.201)
CAW2T12	1.667 (0.191)	1.500 (0.191)
CAW3T6	1.333 (0.209)	1.417 (0.209)
CAW3T18	1.167 (0.235)	0.917 (0.235)
CAW3T12	1.500 (0.206)	1.250 (0.206)

WSC Errors (Err)

One participant from the placebo group was excluded as an outlier for ErrW3T18 and ErrW3T12. Levene’s test indicated that the assumption of equal variances was violated for ErrW2T18 ($F = 6.143, p = .021$). Therefore, equal variances were not assumed for this metric. The t-tests did not show significant differences between the conditions at 0500 for ErrW1T6 ($t(22) = 0.0, p = 1.0$), ErrW1T18 ($t(22) = -0.302, p = .766$), ErrW1T12 ($t(22) = 0.069, p = .946$), ErrW2T6 ($t(22) = -1.215, p = .237$), ErrW2T18 ($t(16.684) = -1.557, p = .138$), ErrW2T12 ($t(22) = -.317, p = .754$), ErrW3T6 ($t(22) = 0.398, p = .695$), ErrW3T18 ($t(22) = 0.734, p = .471$), and ErrW3T12 ($t(22) = -1.025, p = .317$). Means and standard errors are shown in Table 6.

Table 6. WSC Errors Means (SE)

	Group	
	Placebo	Modafinil
ErrW1T6	0.417 (0.212)	0.417 (0.212)
ErrW1T18	3.500 (1.368)	4.083 (1.368)
ErrW1T12	3.750 (0.855)	3.667 (0.855)
ErrW2T6	1.000 (0.679)	2.167 (0.679)
ErrW2T18	2.083 (0.757)	3.750 (0.757)
ErrW2T12	2.000 (0.558)	2.250 (0.558)
ErrW3T6	0.917 (0.296)	0.750 (0.296)
ErrW3T18	#3.727 (1.091)	2.333 (1.044)
ErrW3T12	#1.636 (0.798)	2.667 (0.764)

#N=11

WSC Total Max Score (TotMax)

Two subjects from the modafinil group were excluded as outliers for all total max variables. Levene's test indicated that the assumption of equal variances was violated for TotMaxW1T6 and TotMaxW3T18 ($F = 5.459, p = .030$; $F = 4.490, p = .047$, respectively). Therefore, equal variances were not assumed for these metrics. The t -tests did not show significant differences between the conditions at 0500 for TotMaxW1T6 ($t(9.522) = 1.442, p = .181$), TotMaxW1T18 ($t(20) = -0.053, p = .958$), TotMaxW1T12 ($t(20) = -1.879, p = .075$), TotMaxW2T6 ($t(20) = 1.000, p = .339$), TotMaxW2T18 ($t(20) = 1.044, p = .309$), TotMaxW2T12 ($t(20) = -1.128, p = .273$), TotMaxW3T6 ($t(20) = 1.000, p = .339$), TotMaxW3T18 ($t(15.606) = -0.784, p = .445$), and TotMaxW3T12 ($t(20) = -0.970, p = .344$). Means and standard errors are displayed in Table 7.

Table 7. WSC Total Max Score Means (SE)

	Group	
	Placebo	Modafinil
TotMaxW1T6	294.167 (3.063)	#287.000 (3.355)
TotMaxW1T18	581.250 (34.677)	#584.000 (37.987)
TotMaxW1T12	535.833 (18.714)	#588.000 (20.500)
TotMaxW2T6	355.000 (0.000)	#355.000 (0.000)
TotMaxW2T18	748.333 (29.915)	#702.000 (32.770)
TotMaxW2T12	583.750 (32.434)	#638.000 (35.529)
TotMaxW3T6	355.000 (0.000)	#355.000 (0.000)
TotMaxW3T18	833.333 (46.476)	#884.000 (50.912)
TotMaxW3T12	622.083 (24.969)	#658.000 (27.353)

#N=10

3.1.1.3 Flight simulator performance. Metrics analyzed for the flight simulator task were altitude, speed, and heading. All measures were converted to root mean square errors (RMSE). The formula for calculating RMSE is basically the same as for calculating a standard deviation except the RMSE is the amount of deviation from an ideal value. For example, RMSE for altitude is 2000 feet minus the altitude flown. Altitude target was 2,000 feet, airspeed target was 240 knots, and heading target was south (180 degrees).

The *t*-tests did not show any significant differences between conditions at 0500 for altitude ($t(22) = 1.568, p = .131$), airspeed ($t(22) = -0.159, p = .875$), or heading ($t(22) = 0.944, p = .355$). The means and standard errors are shown in Table 8.

Table 8. Flight Simulator Performance Means (SE)

	Group	
	Placebo	Modafinil
Altitude	240.696 (60.352)	106.869 (60.352)
Airspeed	7.143 (1.314)	7.438 (1.314)
Heading	11.409 (3.609)	6.590 (3.609)

3.1.1.4 Oculometric assessments. The oculometric metrics from the PMI-FIT included amplitude (mm), pupil diameter (mm), saccadic velocity (mm/s), and constriction latency (msec).

The *t*-tests did not reveal any significant differences between the conditions at 0500 for amplitude ($t(22) = 0.759, p = .456$), pupil diameter ($t(22) = -1.682, p = .107$), and constriction latency ($t(22) = -1.081, p = .292$). The *t*-test for saccadic velocity did reveal significant differences between the conditions at T2 ($t(22) = -2.167, p = .041$). Means and standard errors are shown in Table 9.

Table 9. Oculomotor Assessments PMI FIT Means (SE)

	Group	
	Placebo	Modafinil
Amplitude (mm)	1.454 (0.088)	1.359 (0.088)
Diameter (mm)	6.230 (0.247)	6.817 (0.247)
Velocity (mm/s)	*73.533 (2.851)	82.271 (2.851)
Latency (msec)	299.215 (7.555)	310.763 (7.555)

* $p < .05$

3.1.1.5 NovaScan (NTI ATS™). The NTI ATS™ NovaScan test used three individual tasks: Manikin, Continuous Memory, and Dial tasks. Metrics analyzed for these tasks were number of correct responses (NCorr), reaction time for correct responses (CorrRT), number of incorrect responses (NIncorr), reaction time for incorrect responses (IncorrRT), and number of time outs (NTO).

Manikin Task

One participant from the placebo group was excluded as an outlier for NCorr. Levene's test indicated that the assumption of equal variances was violated for Ncorr and NIncorr ($F = 4.373, p = .049$; $F = 4.528, p = .045$, respectively). Therefore, equal variances were not assumed for these metrics. The *t*-tests between conditions did not reveal any significant differences between the two groups at 0500 for Ncorr ($t(16.387) = 1.583, p = .133$) CorrRT ($t(22) = -1.853, p = .077$), NIncorr ($t(16.251) = -1.318, p = .206$), IncorrRT ($t(22) = -1.120, p = .275$), and NTO ($t(22) = -.789, p = .438$). Means and standard errors are shown in Table 10.

Table 10. Nova Scan Manikin Means (SE)

	Group	
	Placebo	Modafinil
NCorr	#40.545 (0.881)	38.667 (0.844)
CorrRT	2.290 (0.109)	2.576 (0.109)
NIncorr	1.417 (0.760)	2.833 (0.760)
IncorrRT	1.286 (0.350)	1.841 (0.350)
NTO	0.250 (0.224)	0.500 (0.224)

#N=11

Continuous Memory Task

Levene's test indicated that the assumption of equal variances was violated for Ncorr, NIncorr, IncorrRT, and NTO ($F = 6.361, p = .019$; $F = 6.361, p = .019$; $F = 4.336, p = .049$; $F = 12.243, p = .002$, respectively). Therefore, equal variances were not assumed for these metrics. The t -tests showed no significant differences between the conditions at 0500 for the Ncorr ($t(16.975) = -1.093, p = .290$), CorrRT ($t(22) = -.204, p = .840$), NIncorr ($t(16.975) = 1.093, p = .290$), IncorrRT ($t(18.468) = 0.835, p = .414$), and NTO ($t(11.033) = 1.704, p = .116$). Means and standard errors are shown in Table 11.

Table 11. Nova Scan Continuous Memory Means (SE)

	Group	
	Placebo	Modafinil
NCorr	33.833 (1.887)	36.750 (1.887)
CorrRT	1.880 (0.110)	1.912 (0.110)
NIncorr	7.167 (1.887)	4.250 (1.887)
IncorrRT	2.405 (0.421)	1.908 (0.421)
NTO	3.750 (1.522)	0.083 (1.522)

Dial Task

The third task included in the NovaScan was the Dial task. The t -tests did not reveal any significant differences between the conditions at 0500 for Ncorr ($t(22) = 0.753, p = .460$), CorrRT ($t(22) = -1.008, p = .325$), NIncorr ($t(22) = -.672, p = .509$), IncorrRT ($t(22) = 1.430, p = .167$), and NTO ($t(22) = -0.265, p = .793$). Means and standard errors are shown in Table 12.

Table 12. Nova Scan Dial Means (SE)

	Group	
	Placebo	Modafinil
NCorr	39.417 (1.566)	37.750 (1.566)
CorrRT	1.019 (0.106)	1.170 (0.106)
NIncorr	1.083 (0.614)	1.667 (0.614)
IncorrRT	0.559 (0.146)	0.263 (0.146)
NTO	3.250 (1.332)	3.750 (1.332)

3.1.1.6 Rapid Decision Making (NTI ATSTM). Levene's test indicated that the assumption of equal variances was violated for Ncorr ($F = 4.435, p = .047$). Therefore, equal variances were not assumed for this metric. The t -tests did not show any significant differences between the

conditions at 0500 for Ncorr ($t(17.184) = -1.869, p = .079$), CorrRT ($t(22) = -0.633, p = .533$), NIncorr ($t(22) = 1.773, p = .090$), and IncorrRT ($t(22) = 0.688, p = .498$). Means with standard errors are shown in Table 13.

Table 13. Rapid Decision Making Means (SE)

	Group	
	Placebo	Modafinil
NCorr	62.750 (0.284)	63.500 (0.284)
CorrRT	1.095 (0.057)	1.146 (0.057)
NIncorr	1.167 (0.266)	0.500 (0.266)
IncorrRT	0.697 (0.178)	0.524 (0.178)

3.1.1.7 *Math Processing (NTI ATSTM)*. One participant from the modafinil group was excluded as an outlier for Ncorr. One participant from the placebo group was excluded as an outlier for NIncorr. The t -tests did not show any significant differences between the conditions at 0500 for Ncorr ($t(21) = 0.080, p = .937$), CorrRT ($t(22) = -0.995, p = .331$), NIncorr ($t(22) = -0.498, p = .624$), and IncorrRT ($t(22) = -0.206, p = .839$). Means and standard errors are shown in Table 14.

Table 14. Math Processing Means (SE)

	Group	
	Placebo	Modafinil
NCorr	46.250 (0.591)	[#] 46.182 (0.617)
CorrRT	1.686 (0.156)	1.906 (0.156)
NIncorr	1.000 (0.379)	[#] 1.273 (0.396)
IncorrRT	0.875 (0.365)	0.981 (0.365)

[#]N=11

3.1.1.8 *Delayed Match to Sample (NTI ATSTM)*. One participant from the placebo group was excluded as an outlier for CorrRT. The t -tests did not indicate any significant differences between the two conditions at 0500 for Ncorr ($t(22) = 0.411, p = .685$), CorrRT ($t(21) = 0.032, p = .975$), NIncorr ($t(22) = -0.411, p = .685$), IncorrRT ($t(22) = -0.237, p = .815$), memorization time for correct responses (CorrMem) ($t(22) = -0.708, p = .486$), and memorization time for incorrect responses (IncorrMem) ($t(22) = -1.554, p = .135$). Means and standard errors are shown in Table 15.

Table 15. Delayed Match to Sample Means (SE)

	Group	
	Placebo	Modafinil
NCorr	30.250 (0.718)	29.833 (0.718)
CorrRT	[#] 1.999 (0.135)	1.993 (0.130)
NIncorr	1.750 (0.718)	2.167 (0.718)
IncorrRT	1.815 (0.528)	1.992 (0.528)
CorrMem	3.287 (0.462)	3.750 (0.462)
IncorrMem	1.229 (0.497)	2.322 (0.497)

[#]N=11

3.1.1.9 *Peripheral Information Processing (NTI ATSTM)*. Metrics from this test included number of hits (NHit) and average reaction time (AvgRT) as well as NCorr and NIncorr. One participant from the placebo group was excluded as an outlier for NHit. Levene's test indicated that the assumption of equal variances was violated for NHit, Ncorr, and NIncorr ($F = 12.189, p = .002$; $F = 10.230, p = .004$; $F = 4.302, p = .05$, respectively). Therefore, equal variances were not assumed for these metrics. The t-tests revealed significant differences between the conditions at 0500 for AvgRT ($t(22) = 2.121, p = .045$), Ncorr ($t(14.434) = -2.473, p = .026$), and NIncorr ($t(15.212) = 2.559, p = .022$). The t-test for NHit ($t(12.256) = -1.422, p = .180$) did not reveal significant differences between the conditions at 0500. Means and standard errors are shown in Table 16.

Table 16. Peripheral Information Processing Means (SE)

	Group	
	Placebo	Modafinil
AvgRT	5.544 (0.024)	5.472 (0.024)
NHit	#31.545 (0.182)	31.917 (0.174)
NCorr	25.750 (1.168)	29.833 (1.168)
NIncorr	5.000 (0.967)	1.500 (0.967)

#N=11

3.1.1.10 *Dichotic Listening (NTI ATSTM)*. Metrics for this test included latency correct switch (LatCorr) and latency incorrect switch (LatIncorr) as well as CorrRT and NIncorr. One participant from the modafinil group was excluded as an outlier for NCorr and NIncorr. Levene's test indicated that the assumption of equal variances was violated for Ncorr, NIncorr, and LatIncorr ($F = 11.07, p = .003$; $F = 5.731, p = .026$; $F = 7.158, p = .014$, respectively). Therefore, equal variances were not assumed for these metrics. The t-tests did not reveal significant differences between the conditions at 0500 for Ncorr ($t(13.69) = -1.718, p = .108$), CorrRT ($t(22) = 1.745, p = .095$), NIncorr ($t(17.974) = 1.192, p = .249$), IncorrRT ($t(22) = 0.893, p = .381$), LatCorr ($t(22) = 0.857, p = .401$), and LatIncorr ($t(22) = 17.135, p = .219$). Means and standard errors are shown in Table 17.

Table 17. Dichotic Listening Means (SE)

	Group	
	Placebo	Modafinil
NCorr	40.917 (1.590)	#44.727 (1.661)
CorrRT	3.042 (0.072)	2.864 (0.072)
NIncorr	4.417 (0.948)	#2.818 (0.990)
IncorrRT	3.101 (0.337)	2.675 (0.337)
LatCorr	68.584 (4.206)	63.485 (4.206)
LatIncorr	10.510 (2.160)	6.610 (2.160)

#N=11

3.1.1.11 *Visual Vigilance (NTI ATSTM)*. One participant from the placebo group was excluded as an outlier for NCorr, CorrRT, NIncorr, and NTO. The t-tests did not show significant differences between the conditions at 0500 for NCorr ($t(21) = 0.608, p = .550$), CorrRT ($t(21) = 0.953, p =$

.352), NIncorr ($t(21) = 0.159, p = .875$), IncorrRT ($t(22) = 1.738, p = .096$), and NTO ($t(21) = -.810, p = .427$). Means and standard errors are shown in Table 18.

Table 18. Visual Vigilance Means (SE)

	Group	
	Placebo	Modafinil
NCorr	#193.000 (2.276)	194.917 (2.179)
CorrRT	#0.576 (0.017)	0.554 (0.016)
NIncorr	#4.182 (1.581)	3.833 (1.514)
IncorrRT	0.264 (0.072)	0.441 (0.072)
NTO	#161.364 (1.088)	162.583 (1.042)

#N=11

3.1.1.12 Continuous Memory (NTI ATSTTM). One participant from the modafinil group was excluded as an outlier for IncorrRT. Levene's test indicated that the assumption of equal variances was violated for Ncorr, NIncorr, and NTO ($F = 6.312, p = .020$; $F = 6.312, p = .020$; $F = 11.702, p = .002$, respectively). Therefore, equal variances were not assumed for these metrics. The t-tests did not show significant differences between the conditions at 0500 for Ncorr ($t(13.227) = 1.038, p = .318$), CorrRT ($t(22) = -0.097, p = .342$), NIncorr ($t(13.227) = 1.038, p = .318$), IncorrRT ($t(21) = 1.418, p = .171$), and NTO ($t(11.097) = 1.444, p = .176$). Means and standard errors are shown in Table 19.

Table 19. Continuous Memory Means (SE)

	Group	
	Placebo	Modafinil
NCorr	54.917 (2.498)	58.583 (2.498)
CorrRT	1.373 (0.134)	1.556 (0.134)
NIncorr	8.083 (2.498)	4.417 (2.498)
IncorrRT	2.429 (0.423)	#1.562 (0.442)
NTO	5.417 (2.448)	0.417 (2.448)

#N=11

3.1.1.13 Manikin Task (NTI ATSTTM). One participant from the placebo group was excluded as an outlier for NTO. The t-tests did not reveal significant differences between the conditions at 0500 for Ncorr ($t(22) = -0.178, p = .860$), CorrRT ($t(22) = -0.491, p = .628$), NIncorr ($t(22) = -0.331, p = .743$), IncorrRT ($t(22) = -2.058, p = .052$), and NTO ($t(21) = 1.047, p = .307$). Means and standard errors are shown in Table 20.

Table 20. Manikin Means (SE)

	Group	
	Placebo	Modafinil
NCorr	60.083 (1.654)	60.500 (1.654)
CorrRT	1.763 (0.091)	1.826 (0.091)
NIncorr	2.750 (1.245)	3.333 (1.245)
IncorrRT	1.085 (0.276)	1.887 (0.276)
NTO	#0.909 (0.512)	0.167 (0.490)

#N=11

3.1.1.14 *Motion Inference (NTI ATSTM)*. Levene's test indicated that the assumption of equal variances was violated for Ncorr and CorrRT ($F = 9.418$, $p = .006$; $F = 13.278$, $p = .001$, respectively). Therefore, equal variances were not assumed for these metrics. The t-tests did not show significant differences between the conditions at 0500 for Ncorr ($t(16.361) = -1.332$, $p = .201$), CorrRT ($t(11.848) = 1.321$, $p = .211$), NIncorr ($t(22) = 0.953$, $p = .351$), IncorrRT ($t(22) = 0.708$, $p = .487$), number of responses before the light (NLow) ($t(22) = 0.929$, $p = .363$), speed of response before the light (LowRT) ($t(22) = -1.152$, $p = .262$), number of responses after the light (NHigh) ($t(22) = -1.017$, $p = .320$), and speed of response after the light (HighRT) ($t(22) = 1.33$, $p = .197$). Means and standard errors are shown in Table 21.

Table 21. Motion Inference Means (SE)

	Group	
	Placebo	Modafinil
NCorr	30.500 (0.442)	31.333 (0.442)
CorrRT	0.946 (0.041)	0.870 (0.041)
NIncorr	1.167 (0.371)	0.667 (0.371)
IncorrRT	0.566 (0.179)	0.386 (0.179)
NLow	19.500 (1.586)	17.417 (1.586)
LowRT	-0.374 (0.033)	-0.320 (0.033)
NHigh	12.333 (1.564)	14.583 (1.564)
HighRT	0.337 (0.044)	0.255 (0.044)

3.1.1.15 *Three-Choice Reaction Time (NTI ATSTM)*. One participant from the placebo group was excluded as an outlier for CorrRT. The t-tests did not indicate significant differences between the conditions at 0500 for Ncorr ($t(22) = 0.240$, $p = .813$), CorrRT ($t(21) = 0.965$, $p = .346$), NIncorr ($t(22) = 0.240$, $p = .813$), and IncorrRT ($t(22) = 0.037$, $p = .971$). Means and standard errors are shown in Table 22.

Table 22. Three-Choice Reaction Time Means (SE)

	Group	
	Placebo	Modafinil
NCorr	62.000 (0.491)	62.167 (0.491)
CorrRT	#0.656 (0.039)	0.604 (0.037)
NIncorr	2.000 (0.491)	1.833 (0.491)
IncorrRT	0.468 (0.068)	0.464 (0.068)

#N=11

3.1.1.17 Digit span (auditory) (NTI ATSTM). One participant from the modafinil group was excluded as an outlier for NIncorr. One participant from the placebo group and one participant from the modafinil group were excluded as outliers for NTO. Levene's test indicated that the assumption of equal variances was violated for NTO ($F = 4.938, p = .038$). Therefore, equal variances were not assumed for this metric. The t -tests did not reveal any significant differences between the conditions at 0500 for Ncorr ($t(22) = 1.307, p = .205$), CorrRT ($t(22) = 0.275, p = .786$), NIncorr ($t(21) = 1.071, p = .296$), IncorrRT ($t(22) = 0.531, p = .600$), and NTO ($t(10) = -1.00, p = .341$). Means and standard errors are shown in Table 23.

Table 23. Digit Span Means (SE)

	Group	
	Placebo	Modafinil
NCorr	89.167 (11.544)	110.500 (11.544)
CorrRT	0.575 (0.038)	0.560 (0.038)
NIncorr	3.500 (0.205)	#3.818 (0.215)
IncorrRT	1.212 (0.164)	1.089 (0.164)
NTO	#0.000 (0.064)	*0.091 (0.064)

#N=11

3.1.2 Mood and side effects assessments. Mood was measured with two questionnaires, the Profile of Mood States (POMS) and the Visual Analogue Scale (VAS), and participants indicated any side effects they may have experienced on the Side Effects Questionnaire (SEQ).

3.1.2.1 Profile of Mood States (POMS) questionnaire. All six factors from the POMS, as well as the Total Mood Disturbance (TMD) score, were analyzed. The results from these analyses are presented below.

Two participants were removed as outliers from the modafinil group for all metrics, therefore the total N for the placebo group was 12 and was 10 for the modafinil group. The t -tests did not reveal any significant differences between the conditions at 0500 for Tension ($t(20) = -1.309, p = .205$), Depression ($t(20) = -0.531, p = .601$), Anger ($t(19) = -0.965, p = .949$), Vigor ($t(20) = -0.783, p = .443$), Fatigue ($t(20) = 0.684, p = .502$), Confusion ($t(19) = -0.263, p = .795$) and Total ($t(20) = 0.014, p = .989$). Means and standard errors are shown in Table 25.

Table 24. POMS Means (SE)

	Group	
	Placebo	Modafinil
Tension	3.08 (0.484)	#4.10 (0.623)
Depressed	1.25 (0.524)	#1.70 (0.684)
Anger	1.08 (0.288)	#1.11 (0.309)
Vigor	6.25 (1.518)	#7.80 (1.172)
Fatigue	7.83 (1.107)	#6.70 (1.239)
Confusion	3.67 (0.555)	#3.89 (0.633)
TMD score	10.67 (2.914)	#10.60 (4.047)

#N=10

3.1.2.2 *Visual Analogue Scale (VAS)*. All eight adjectives from the VAS were analyzed: ‘alert/able to concentrate’, ‘anxious’, ‘energetic’, ‘feel confident’, ‘irritable’, ‘jittery/nervous’, ‘sleepy’, and ‘talkative.’ Higher scores indicate an increased presence of the stated mood.

Two participants were removed as outliers from the modafinil group for all metrics. Therefore, the total N for the placebo group was 12 and 10 for the modafinil group. Levene’s test indicated that the assumption of equal variances was violated for Alertness ($F = 7.439, p = .013$). Therefore, equal variances were not assumed for this metric. The t -tests did not reveal any significant differences between the conditions at 0500 for Alertness ($t(15.268) = -1.436, p = .171$), Anxiety ($t(20) = 0.640, p = .529$), Energy ($t(20) = -0.719, p = .480$), Confidence ($t(20) = -0.827, p = .418$), Irritable ($t(20) = 0.493, p = .627$), Jittery ($t(20) = 0.558, p = .583$), Sleepy ($t(20) = 1.147, p = .265$), and Talkative ($t(20) = 0.260, p = .797$). Means and standard errors are shown in Table 26.

Table 25. VAS Means (SE)

	Group	
	Placebo	Modafinil
Alert	43.25 (7.883)	#55.70 (3.606)
Anxiety	18.33 (8.053)	#11.60 (6.244)
Energetic	28.67 (5.608)	#34.30 (5.313)
Confident	47.33 (6.695)	#55.20 (6.636)
Irritable	25.50 (8.977)	#19.60 (7.440)
Jittery	15.17 (6.754)	#10.20 (5.393)
Sleepy	66.25 (7.547)	#54.60 (6.436)
Talkative	28.92 (7.389)	#26.00 (8.485)

#N=10

3.2 Performance tests and questionnaires for Hypothesis 2.

The analyses conducted in this section addresses the second hypothesis: H2) Both the subjective and objective assessments will be better for participants who receive the 200mg modafinil treatment in conjunction with the nap than for participants who receive the placebo treatment before the nap. The second session (T1) immediately before the treatment dose and nap was not included in the data analysis. Inspection of the data indicated declines in performance which may have been due to the time of the test (2300). For the majority of the participants, this time was around habitual bedtime or after which may have led to the decline in performance. Therefore,

rather than include these data, only the baseline session was included as pre-nap data, giving only seven sessions in the analysis.

Mixed-model analyses of variance (ANOVA) modeling treatment group across time were conducted. Each analysis yielded three F tests: a main effect of group (condition), a main effect of time (session effect), and a group by time interaction. In order for a task to support H2, the group by time interaction must be significant. For each measure, analyses were conducted on the following variables: number correct (Ncorr), correct reaction time (CorrRT), number incorrect (NIncorr), incorrect reaction time (IncorrRT), and number of time outs (NTO). All results are presented by task below. Levine's Test for Equality of Variances was used to test the assumption of equal variance. Mauchly's Test of Sphericity was used to test the assumption of sphericity. In most cases, this assumption was violated; therefore, the Huynh-Feldt adjusted degrees of freedom were used to calculate the F statistic unless otherwise stated. The results of both the Levine's Test for Equality of Variances and Mauchly's Test of Sphericity are reported only when the assumptions are violated. Significant interactions were followed with analyses of simple effects and Fisher's Least Significant Difference (LSD) tests. Significant main effects for session were further analyzed with LSD tests.

3.2.1 Cognitive and physiological measures. All analyses for the cognitive and physiological measures included the BL session and sessions T2 through T7. A summary of significant results are presented in Table 26, sorted by task.

Table 26. Summary statistics for all significant results for Hypothesis 2

Task	Metric	Effect	F (df)	p	η_p^2
PVT	RRT	Condition X Session Interaction	$F(5.163, 113.577) = 2.521$	.032	.103
		Session Main Effect	$F(5.163, 113.577) = 16.09$	< .001	.422
WSC – TotMax	W2T18	Condition X Session Interaction	$F(6,120) = 3.019$	.009	.131
		Session Main Effect	$F(6,120) = 2.835$	.013	.124
Flight Simulator Performance	Airspeed	Session Main Effect	$F(3.672,80.778) = 3.017$	.026	.121
Oculometric Assessments	Amplitude	Session Main Effect	$F(4.718,103.799) = 4.498$	.001	.170
	Pupil Diameter	Session Main Effect	$F(6,132) = 6.403$	< .001	.225
Nova Scan – Manikin	CorrRT	Session Main Effect	$F(5.085,111.861) = 7.328$	< .001	.250
Nova Scan – Continuous Memory	NCorr	Condition X Session Interaction	$F(4.666,102.656) = 2.897$	.020	.116
	CorrRT	Session Main Effect	$F(4.519,99.414) = 7.361$	< .001	.251
	NIncorr	Condition X Session Interaction	$F(4.666,102.656) = 2.897$	.020	.116
	IncorrRT	Session Main Effect	$F(6,132) = 2.638$	.019	.107
		Condition Main Effect	$F(1,22) = 4.466$	.046	.169
Nova Scan – Dial	CorrRT	Session Main Effect	$F(3.509,77.201) = 5.995$	.001	.214
	NTO	Session Main Effect	$F(3.854,84.784) = 3.008$	.024	.120

Rapid Decision Making	CorrRT	Condition X Session Interaction	$F(4.418,97.201) = 2.719$	.029	.110
		Session Main Effect	$F(4.418,97.201) = 12.735$	< .001	.367
Math Processing	CorrRT	Session Main Effect	$F(6,132) = 6.980$	< .001	.241
Delayed Match to Sample	NCorr	Condition X Session Interaction	$F(6,132) = 2.184$	.048	.090
	CorrRT	Condition X Session Interaction	$F(6,126) = 2.803$	.014	.118
		Session Main Effect	$F(6,126) = 4.007$	.001	.160
	NIncorr	Condition X Session Interaction	$F(6,132) = 2.184$	.048	.090
	CorrMem	Session Main Effect	$F(4.425,97.360) = 3.51$	.008	.138
	IncorrMem	Session Main Effect	$F(6,132) = 3.377$	.004	.133
Peripheral Information Processing	RT	Condition X Session Interaction	$F(4.945,108.784) = 4.420$	.001	.167
		Session Main Effect	$F(4.945,108.784) = 9.477$	< .001	.301
		Condition Main Effect	$F(1,22) = 4.561$	.044	.172
	NCorr	Condition X Session Interaction	$F(4.963,109.186) = 4.038$	.002	.155
		Session Main Effect	$F(4.963,109.186) = 5.631$	< .001	.204
		Condition Main Effect	$F(1,22) = 8.388$	.008	.276
	NIncorr	Condition X Session Interaction	$F(4.432,97.514) = 3.143$	.015	.125
		Session Main Effect	$F(4.432,97.514) = 6.518$	< .001	.229
		Condition Main Effect	$F(1,22) = 10.116$	.004	.315
Dichotic Listening	CorrRT	Session Main Effect	$F(1.460,32.129) = 4.163$	.036	.159
	NIncorr	Session Main Effect	$F(5.096,107.015) = 3.532$	.005	.144
	LatIncorr	Session Main Effect	$F(4.436,97.600) = 3.485$	.008	.137
Visual Vigilance	CorrRT	Session Main Effect	$F(6,126) = 5.287$	< .001	.201
	NTO	Session Main Effect	$F(6,126) = 2.762$	.015	.116
Continuous Memory	CorrRT	Session Main Effect	$F(3.678,80.911) = 3.354$	.016	.132
	IncorrRT	Session Main Effect	$F(6,132) = 2.344$	.035	.100
Manikin	CorrRT	Session Main Effect	$F(4.921,108.267) = 4.183$	.002	.160
Motion Interference	CorrRT	Session Main Effect	$F(6,132) = 3.198$	.006	.127
	NIncorr	Session Main Effect	$F(4.660,102.511)$	.047	.098
	NLow	Condition X Session Interaction	$F(6,132) = 2.781$	.014	.112
		Session Main Effect	$F(6,132) = 4.410$	< .001	.167
	NHigh	Condition X Session Interaction	$F(6,132) = 2.922$	.010	.117
		Session Main Effect	$F(6,132) = 4.438$	< .001	.168
	HighRT	Session Main Effect	$F(4.913,108.084) = 2.593$	.030	.105
		Condition Main Effect	$F(1,22) = 5.134$	.034	.189

Three-Choice Reaction Time	CorrRT	Condition X Session Interaction	$F(3.945, 82.838) = 2.651$	.040	.112
		Session Main Effect	$F(3.945, 82.838) = 3.313$	.015	.136
Digit Span	NCorr	Condition X Session Interaction	$F(6, 132) = 2.253$	.042	.093

3.2.1.1 Psychomotor Vigilance Test (PVT).

Several metrics were collected from the PVT analysis program. However, the only metrics analyzed for this task were Lapses+FS and RRT.

Lapses+FS: One participant from the placebo group was excluded as an outlier for Lapses+FS. The assumption of sphericity was violated ($\chi^2(20) = 55.196$, $p < .001$; $\varepsilon = .668$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.005, 84.106) = 1.539$, $p = 0.198$, $\eta_p^2 = .068$). There was a significant main effect for session ($F(4.005, 84.106) = 4.026$, $p = .005$, $\eta_p^2 = .161$). Pairwise comparisons revealed significant differences between BL and T2 ($p = .002$), BL and T5 ($p = .003$), BL and T6 ($p = .001$), BL and T7 ($p = .017$), T2 and T3 ($p = .050$), T2 and T4 ($p = .013$), and T2 and T5 ($p = .023$). The session main effect is depicted in Figure 14. There was not a significant main effect of condition ($F(1, 21) = 0.349$, $p = .561$, $\eta_p^2 = .016$).

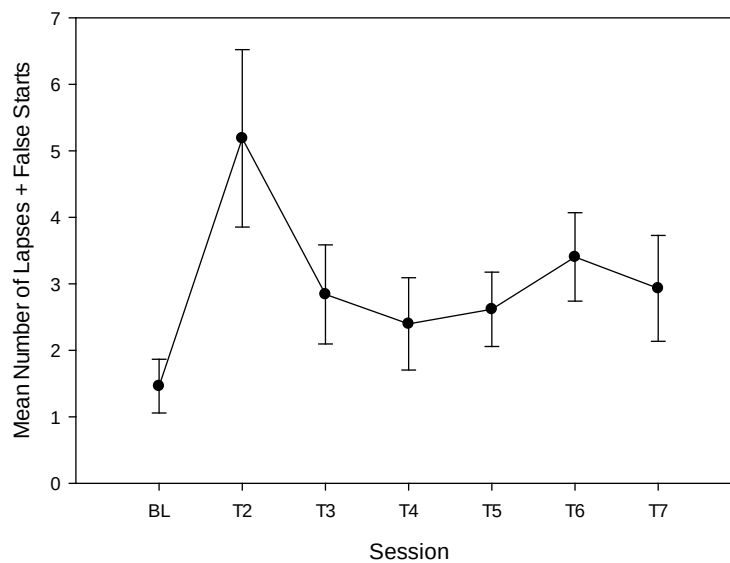


Figure 14. PVT Lapses+FS Session Main Effect

RRT: The assumption of sphericity was violated for RRT ($\chi^2(20) = 38.643$, $p = .008$; $\varepsilon = .860$). The mixed model ANOVA showed a significant interaction between condition and session ($F(5.163, 113.577) = 2.521$, $p = .032$, $\eta_p^2 = .103$). The simple effects analysis did not indicate significant differences between the groups at BL ($p = .840$), T2 ($p = .707$), T3 ($p = .192$), T4 ($p = .276$), T5 ($p = .606$), T6 ($p = .718$), or T7 ($p = .712$). The simple effects analysis among sessions within each group showed various effects. Within the placebo group, there was a significant main effect for session ($F(6, 66) = 8.831$, $p < .001$). Pairwise comparisons revealed significant differences between BL and T2 ($p < .001$), BL and T3 ($p < .001$), BL and T4 ($p < .001$), BL and

T5 ($p < .001$), BL and T6 ($p < .001$), BL and T7 ($p < .001$), T2 and T3 ($p = .048$), T2 and T4 ($p = .019$), T2 and T5 ($p = .005$), T2 and T6 ($p = .002$), and T2 and T7 ($p = .002$). Within the modafinil group, there was a significant main effect for session ($F(6, 66) = 9.971, p < .001$). Pairwise comparisons showed significant differences between BL and T2 ($p < .001$), BL and T5 ($p = .007$), BL and T6 ($p = .011$), BL and T7 ($p = .032$), T2 and T3 ($p < .001$), T2 and T4 ($p < .001$), T2 and T5 ($p = .003$), T2 and T6 ($p = .002$), T2 and T7 ($p = .002$), and T3 and T5 ($p = .047$). The interaction is illustrated in Figure 15.

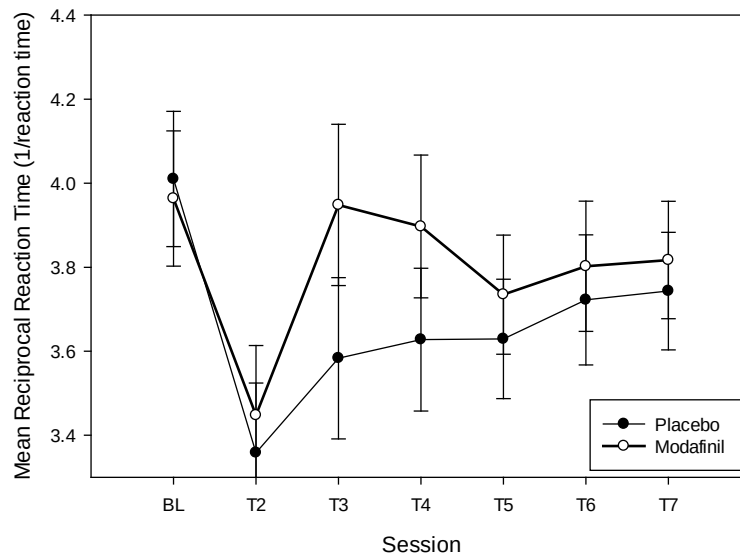


Figure 15. PVT RRT Condition X Session Interaction

There was a significant main effect for session ($F(5.163, 113.577) = 16.09, p < .001, \eta_p^2 = .422$), shown in Figure 16. Pairwise comparisons showed significant differences between BL and T2 ($p < .001$), BL and T3 ($p = .002$), BL and T4 ($p = .002$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), BL and T7 ($p < .001$), T2 and T3 ($p < .001$), T2 and T4 ($p < .001$), T2 and T5 ($p < .001$), T2 and T6 ($p < .001$), T2 and T7 ($p < .001$), and T5 and T7 ($p = .024$).

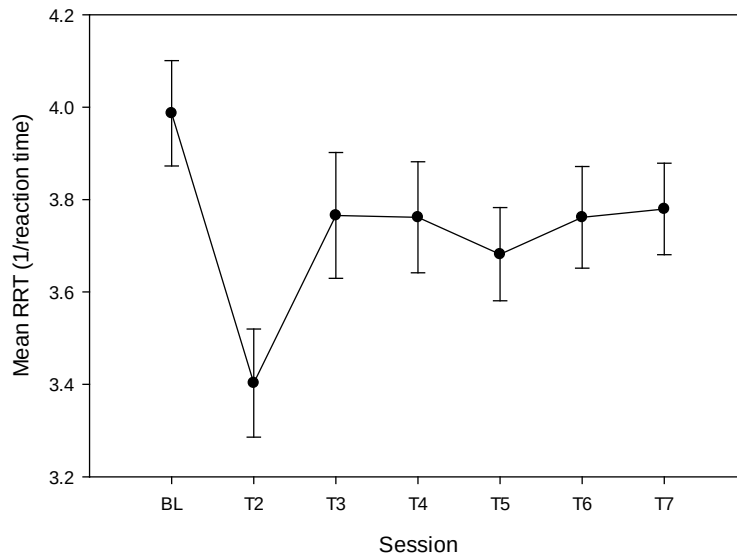


Figure 16. PVT RRT Session Main Effect

There was no significant main effect for condition ($F(1, 21) = .391, p = .538, \eta_p^2 = .017$). The mean and standard error for the placebo group were 3.668 and .151 respectively, and for the modafinil group were 3.802 and .151, respectively.

3.2.1.2 Warship Commander Task (WSC).

WSC CA

CAW1T6: The assumption of sphericity was violated for CAW1T6 ($\chi^2(20) = 55.917, p < .001; \epsilon = .720$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.317, 94.981) = .588, p = .685, \eta_p^2 = .026$). There was not a significant main effect for session ($F(4.317, 94.981) = 1.529, p = .196, \eta_p^2 = .065$) or condition ($F(1, 22) = .503, p = .486, \eta_p^2 = .022$).

CAW1T18: The assumption of sphericity was violated for CAW1T18 ($\chi^2(20) = 32.172, p = .044; \epsilon = .872$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.230, 115.063) = .075, p = .997, \eta_p^2 = .003$). There was not a significant main effect for session ($F(5.230, 115.063) = .741, p = .600, \eta_p^2 = .033$) or condition ($F(1, 22) = 0, p = 1, \eta_p^2 = 0$).

CAW1T12: The mixed model ANOVA for CAW1T12 did not show a significant interaction between condition and session ($F(6, 132) = 1.477, p = .191, \eta_p^2 = .063$). There was not a significant main effect for session ($F(6, 132) = .896, p = .500, \eta_p^2 = .039$) or condition ($F(1, 22) = 1.905, p = .181, \eta_p^2 = .080$).

CAW2T6: The assumption of sphericity was violated for CAW2T6 ($\chi^2(20) = 35.215, p = .020; \epsilon = .986$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.918, 130.199) = 1.044, p = .400, \eta_p^2 = .045$). There was not a significant main effect

for session ($F(5.918, 130.199) = 2.009, p = .070, \eta_p^2 = .084$) or condition ($F(1, 22) = .049, p = .826, \eta_p^2 = .002$).

CAW2T18: The mixed model ANOVA for CAW2T18 did not show a significant interaction between condition and session ($F(6, 132) = 1.094, p = .370, \eta_p^2 = .047$). There was not a significant main effect for session ($F(6, 132) = 1.115, p = .357, \eta_p^2 = .048$) or condition ($F(1, 22) = .257, p = .617, \eta_p^2 = .012$).

CAW2T12: The mixed model ANOVA for CAW2T12 did not show a significant interaction between condition and session ($F(6, 132) = .455, p = .841, \eta_p^2 = .020$). There was not a significant main effect for session ($F(6, 132) = .411, p = .870, \eta_p^2 = .018$) or condition ($F(1, 22) = 0, p = 1, \eta_p^2 = 0$).

CAW3T6: The mixed model ANOVA for CAW3T6 did not show a significant interaction between condition and session ($F(6, 132) = 1.283, p = .269, \eta_p^2 = .055$). There was not a significant main effect for session ($F(6, 132) = .653, p = .687, \eta_p^2 = .029$) or condition ($F(1, 22) = .343, p = .564, \eta_p^2 = .015$).

CAW3T18: The mixed model ANOVA for CAW3T18 did not show a significant interaction between condition and session ($F(6, 132) = .639, p = .698, \eta_p^2 = .028$). There was not a significant main effect for session ($F(6, 132) = 1.604, p = .151, \eta_p^2 = .068$) or condition ($F(1, 22) = .007, p = .934, \eta_p^2 = 0$).

CAW3T12: The mixed model ANOVA for CAW3T12 did not show a significant interaction between condition and session ($F(6, 132) = .744, p = .615, \eta_p^2 = .033$). There was not a significant main effect for session ($F(6, 132) = .751, p = .609, \eta_p^2 = .033$) or condition ($F(1, 22) = .937, p = .343, \eta_p^2 = .041$).

WSC Errors

ErrW1T6: The assumption of sphericity was violated for ErrW1T6 ($\chi^2(20) = 54.270, p < .001; \epsilon = .649$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.892, 85.626) = 1.025, p = .398, \eta_p^2 = .045$). There was not a significant main effect for session ($F(3.892, 85.626) = 1.295, p = .279, \eta_p^2 = .056$) or condition ($F(1, 22) = 1.664, p = .210, \eta_p^2 = .070$).

ErrW1T18: The mixed model ANOVA for ErrW1T18 did not show a significant interaction between condition and session ($F(6, 132) = 1.40, p = .219, \eta_p^2 = .060$). There was not a significant main effect for session ($F(6, 132) = 1.977, p = .073, \eta_p^2 = .082$) or condition ($F(1, 22) = .046, p = .831, \eta_p^2 = .002$).

ErrW1T12: The assumption of sphericity was violated for ErrW1T12 ($\chi^2(20) = 41.357, p = .004; \epsilon = .763$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.580, 100.770) = .393, p = .838, \eta_p^2 = .018$). There was not a significant main effect for session ($F(4.580, 100.770) = .812, p = .534, \eta_p^2 = .036$) or condition ($F(1, 22) = .117, p = .736, \eta_p^2 = .005$).

ErrW2T6: The assumption of sphericity was violated for ErrW2T6 ($\chi^2(20) = 49.811, p < .001; \varepsilon = .768$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.609, 101.391) = .176, p = .964, \eta_p^2 = .008$). There was not a significant main effect for session ($F(4.609, 101.391) = 1.546, p = .187, \eta_p^2 = .066$) or condition ($F(1, 22) = 2.779, p = .110, \eta_p^2 = .112$).

ErrW2T18: The assumption of sphericity was violated for ErrW2T18 ($\chi^2(20) = 38.924, p = .007; \varepsilon = .793$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.757, 104.646) = .673, p = .637, \eta_p^2 = .030$). There was not a significant main effect for session ($F(4.757, 104.646) = 1.589, p = .173, \eta_p^2 = .067$) or condition ($F(1, 22) = 2.820, p = .107, \eta_p^2 = .114$).

ErrW2T12: The assumption of sphericity was violated for ErrW2T12 ($\chi^2(20) = 43.452, p = .002; \varepsilon = .709$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.256, 93.642) = .538, p = .719, \eta_p^2 = .024$). There was not a significant main effect for session ($F(4.256, 93.642) = 2.020, p = .094, \eta_p^2 = .084$) or condition ($F(1, 22) = 2.816, p = .107, \eta_p^2 = .113$).

ErrW3T6: The assumption of sphericity was violated for ErrW3T6 ($\chi^2(20) = 43.330, p = .002; \varepsilon = .836$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.016, 110.347) = .791, p = .558, \eta_p^2 = .035$). There was not a significant main effect for session ($F(5.016, 110.347) = 1.684, p = .144, \eta_p^2 = .071$) or condition ($F(1, 22) = .812, p = .377, \eta_p^2 = .036$).

ErrW3T18: One participant from the placebo group was excluded as an outlier for ErrW3T18. The assumption of sphericity was violated ($\chi^2(20) = 32.672, p = .039; \varepsilon = .886$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.314, 111.589) = 1.546, p = .178, \eta_p^2 = .069$). There was not a significant main effect for session ($F(5.314, 111.589) = 2.111, p = .065, \eta_p^2 = .091$) or condition ($F(1, 21) = 1.895, p = .183, \eta_p^2 = .083$).

ErrW3T12: One participant from the placebo group was excluded as an outlier for ErrW3T12. The assumption of sphericity was violated ($\chi^2(20) = 46.158, p = .001; \varepsilon = .633$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.800, 79.803) = .908, p = .460, \eta_p^2 = .041$). There was not a significant main effect for session ($F(3.800, 79.803) = 1.051, p = .384, \eta_p^2 = .048$) or condition ($F(1, 21) = .976, p = .334, \eta_p^2 = .044$).

WSC TotMax

TotMaxW1T6: Two participants from the modafinil group were excluded as outliers for TotMaxW1T6. The assumption of sphericity was violated ($\chi^2(20) = 118.178, p < .001; \varepsilon = .462$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(2.773, 55.455) = .945, p = .419, \eta_p^2 = .045$). There was not a significant main effect for

session ($F(2.773, 55.455) = 1.629, p = .196, \eta_p^2 = .075$) or condition ($F(1, 20) = 1.189, p = .289, \eta_p^2 = .056$).

TotMaxW1T12: Two participants from the modafinil group were excluded as outliers for TotMaxW1T18. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = 1.346, p = .242, \eta_p^2 = .063$). There was not a significant main effect for session ($F(6, 120) = .983, p = .440, \eta_p^2 = .047$) or condition ($F(1, 20) = 0, p = .999, \eta_p^2 = 0$).

TotMaxW1T12: Two participants from the modafinil group were excluded as outliers for TotMaxW1T12. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = .738, p = .620, \eta_p^2 = .036$). There was not a significant main effect for session ($F(6, 120) = 1.793, p = .106, \eta_p^2 = .082$) or condition ($F(1, 20) = .996, p = .330, \eta_p^2 = .047$).

TotMaxW2T6: Two participants from the modafinil group were excluded as outliers for TotMaxW2T6. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = 1.159, p = .333, \eta_p^2 = .055$). There was not a significant main effect for session ($F(6, 120) = .828, p = .550, \eta_p^2 = .040$) or condition ($F(1, 20) = .002, p = .968, \eta_p^2 = 0$).

TotMaxW2T18: Two participants from the modafinil group were excluded as outliers for TotMaxW2T18. The mixed model ANOVA showed a significant interaction between condition and session ($F(6, 120) = 3.019, p = .009, \eta_p^2 = .131$). Simple effects analyses showed no significant differences between the groups at BL ($p = .631$), T2 ($p = .309$), T3 ($p = .058$), T4 ($p = .316$), T5 ($p = .097$), T6 ($p = .774$), or T7 ($p = .711$). Within the placebo group, there was not a significant main effect for session ($F(6, 66) = 1.428, p = .217$). Within the modafinil group, there was a significant main effect for session ($F(6, 54) = 4.702, p = .001$). Pairwise comparisons revealed significant differences between BL and T3 ($p = .019$), BL and T5 ($p = .008$), BL and T7 ($p = .004$), T2 and T3 ($p = .003$), T2 and T5 ($p = .005$), T2 and T7 ($p = .004$), and T5 and T6 ($p = .022$). Results are illustrated in Figure 17.

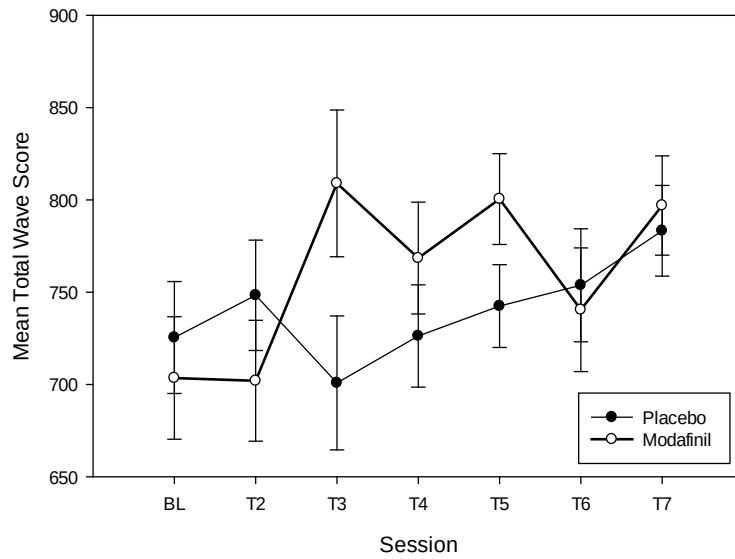


Figure 17. WSC TotMax W2T18 Condition X Session Interaction

There was a significant main effect for session ($F(6, 120) = 2.835, p = .013, \eta_p^2 = .124$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .018$), BL and T7 ($p = .001$), T2 and T5 ($p = .040$), T2 and T7 ($p = .004$), and T6 and T7 ($p = .039$). Results are shown in Figure 18. There was not a significant main effect of condition ($F(1, 20) = .379, p = .545, \eta_p^2 = .019$).

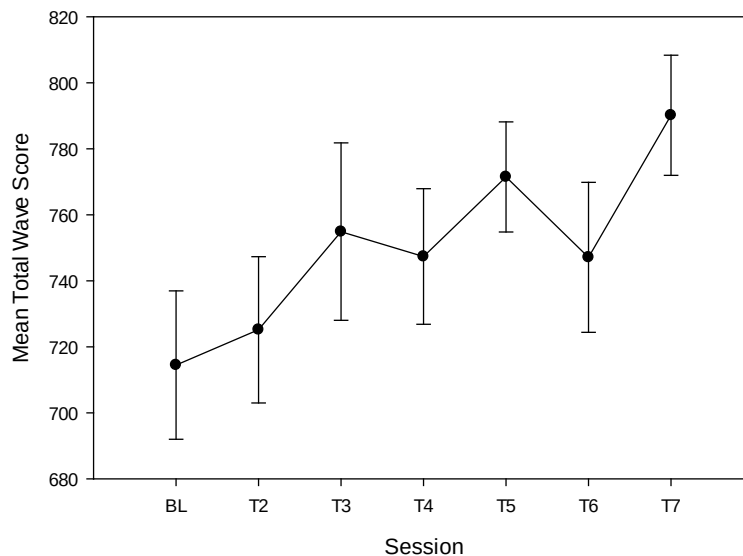


Figure 18. WSC TotMax W2T18 Session Main Effect

TotMaxW2T12: Two participants from the modafinil group were excluded as outliers for TotMaxW2T12. The assumption of sphericity was violated ($\chi^2(20) = 37.546, p = .011; \epsilon = .870$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.222, 104.438) = .754, p = .590, \eta_p^2 = .036$). There was not a significant main effect for

session ($F(5.222, 104.438) = 1.225, p = .302, \eta_p^2 = .058$) or condition ($F(1, 20) = .294, p = .594, \eta_p^2 = .014$).

TotMaxW3T6: Two participants from the modafinil group were excluded as outliers for TotMaxW3T6. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = 1.184, p = .319, \eta_p^2 = .056$). There was not a significant main effect for session ($F(6, 120) = .851, p = .533, \eta_p^2 = .041$) or condition ($F(1, 20) = .017, p = .899, \eta_p^2 = .001$).

TotMaxW3T18: Two participants from the modafinil group and one participant from the placebo group were excluded as outliers for TotMaxW3T18. The assumption of sphericity was violated ($\chi^2(20) = 40.925, p = .004; \epsilon = .659$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.956, 79.119) = 1.613, p = .180, \eta_p^2 = .075$). There was not a significant main effect for session ($F(3.956, 79.119) = 1.602, p = .183, \eta_p^2 = .074$) or condition ($F(1, 20) = .009, p = .924, \eta_p^2 = 0$).

TotMaxW3T12: Two participants from the modafinil group and one participant from the placebo group were excluded as outliers for TotMaxW3T12. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = 1.186, p = .318, \eta_p^2 = .056$). There was not a significant main effect for session ($F(6, 120) = 1.668, p = .135, \eta_p^2 = .077$) or condition ($F(1, 20) = .547, p = .468, \eta_p^2 = .027$).

3.2.1.3 Flight simulator performance. Metrics analyzed for the flight simulator task were altitude, airspeed, and heading. All measures were converted to RMSE. Altitude target was 2,000 feet, airspeed target was 240 knots, and heading target was south (180 degrees).

Altitude: The assumption of sphericity was violated for altitude ($\chi^2(20) = 151.187, p < .001; \epsilon = .276$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.659, 36.492) = 2.184, p = .135, \eta_p^2 = .090$). There was not a significant main effect for session ($F(1.659, 36.492) = .647, p = .502, \eta_p^2 = .029$) or condition ($F(1, 22) = 1.135, p = .298, \eta_p^2 = .049$).

Heading: The assumption of sphericity was violated for heading ($\chi^2(20) = 267.077, p < .001; \epsilon = .197$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.185, 26.061) = 1.300, p = .272, \eta_p^2 = .056$). There was not a significant main effect for session ($F(1.185, 26.061) = 1.041, p = .330, \eta_p^2 = .045$) or condition ($F(1, 22) = .756, p = .394, \eta_p^2 = .033$).

Airspeed: The assumption of sphericity was violated for airspeed ($\chi^2(20) = 72.992, p < .001; \epsilon = .612$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.672, 80.778) = .588, p = .658, \eta_p^2 = .026$). There was a significant main effect for session ($F(3.672, 80.778) = 3.017, p = .026, \eta_p^2 = .121$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .030$), BL and T5 ($p = .049$), BL and T6 ($p = .027$), BL and T7 ($p = .010$), T2 and T4 ($p = .020$), T2 and T6 ($p = .021$), and T2 and T7 ($p = .002$). Results are illustrated in Figure 19. There was not a significant main effect for condition ($F(1, 22) = .183, p = .673, \eta_p^2 = .008$).

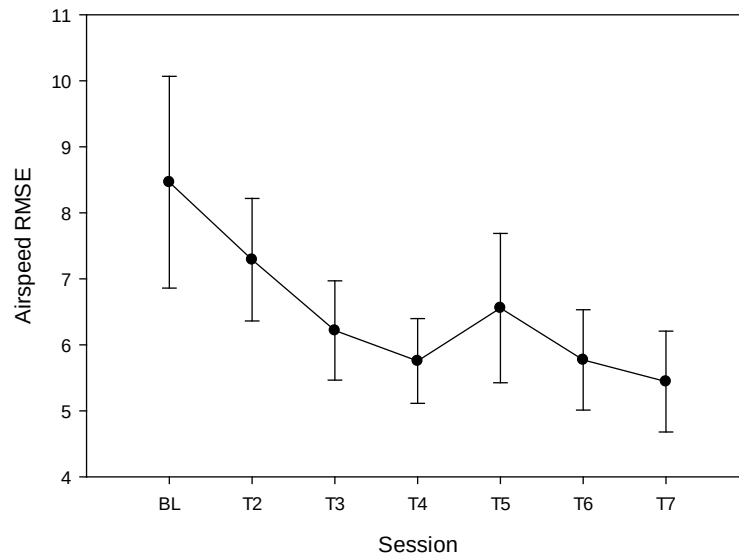


Figure 19. Flight Simulator Performance Airspeed Session Main Effect

3.2.1.4 Oculometric assessments.

Amplitude: The assumption of sphericity was violated for amplitude ($\chi^2(20) = 47.982, p < .001; \varepsilon = .786$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.718, 103.799) = .411, p = .830, \eta_p^2 = .018$). There was a significant main effect for session ($F(4.718, 103.799) = 4.498, p = .001, \eta_p^2 = .170$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .044$), BL and T6 ($p = .044$), BL and T7 ($p < .001$), T2 and T4 ($p = .019$), T2 and T5 ($p = .046$), T2 and T6 ($p = .025$), T2 and T7 ($p = .001$), T3 and T7 ($p = .019$), T5 and T7 ($p = .039$), and T6 and T7 ($p = .005$). Results are illustrated in Figure 20. There was not a significant main effect for condition ($F(1, 22) = .833, p = .371, \eta_p^2 = .036$).

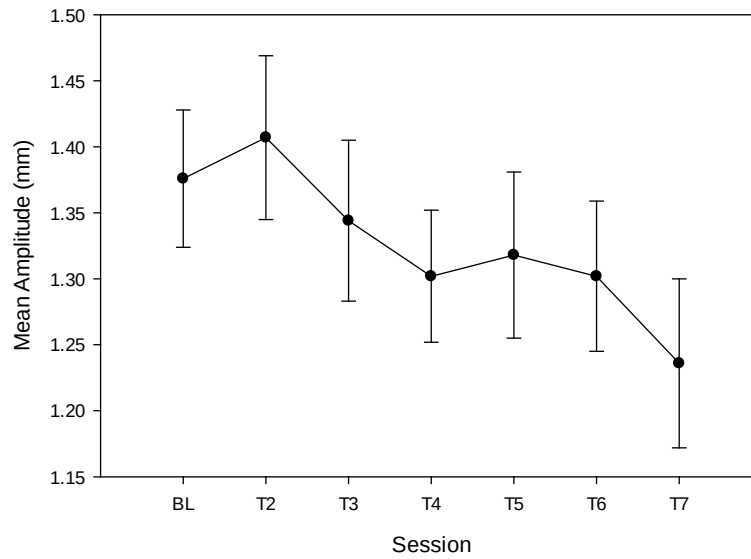


Figure 20. Oculometric Assessment Amplitude Session Main Effect

Pupil diameter: The mixed model ANOVA for pupil diameter did not show a significant interaction between condition and session ($F(6, 132) = .721, p = .633, \eta_p^2 = .032$). There was a significant main effect for session ($F(6, 132) = 6.403, p < .001, \eta_p^2 = .225$). Pairwise comparisons showed significant differences between BL and T5 ($p = .002$), BL and T6 ($p < .001$), BL and T7 ($p < .001$), T2 and T6 ($p = .020$), T2 and T7 ($p = .020$), T3 and T5 ($p = .046$), T3 and T6 ($p = .007$), T3 and T7 ($p = .001$), T4 and T6 ($p = .010$), T4 and T7 ($p = .003$), and T5 and T7 ($p = .009$). Results are shown in Figure 21. There was not a significant main effect for condition ($F(1, 22) = 1.845, p = .188, \eta_p^2 = .077$).

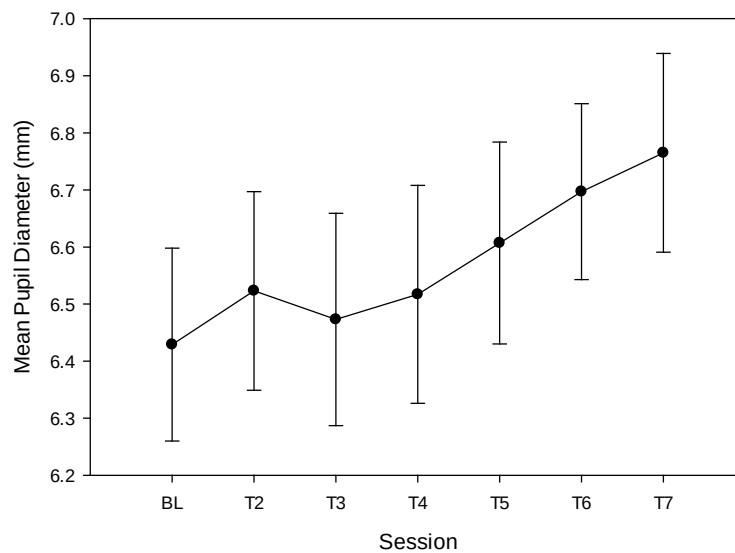


Figure 21. Oculometric Assessment Pupil Diameter Session Main Effect

Constriction latency: The assumption of sphericity was violated for constriction latency ($\chi^2(20) = 48.174, p < .001; \varepsilon = .618$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.711, 81.632) = .388, p = .803, \eta_p^2 = .017$). There was not a significant main effect for session ($F(3.711, 81.632) = 1.379, p = .250, \eta_p^2 = .059$) or condition ($F(1, 22) = 1.612, p = .217, \eta_p^2 = .068$).

Saccadic velocity: The assumption of sphericity was violated for saccadic velocity ($\chi^2(20) = 32.275, p = .043; \varepsilon = .800$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.799, 105.578) = 1.708, p = .142, \eta_p^2 = .072$). There was not a significant main effect for session ($F(4.799, 105.578) = 1.761, p = .130, \eta_p^2 = .074$) or condition ($F(1, 22) = 2.923, p = .101, \eta_p^2 = .117$).

3.2.1.5 NovaScan (NTI ATS™). The NTI ATS™ NovaScan test used three individual tasks: the Manikin, Continuous Memory, and Dial tasks. Metrics analyzed for these tasks were number of correct responses (NCorr), reaction time during correct responses, (CorrRT), number of incorrect responses (NIncorr), reaction time during incorrect responses (IncorrRT), and number of time outs (NTO).

Manikin Task

NCorr: One participant from the placebo group was considered an outlier and thus excluded from the analysis for Ncorr. The mixed model ANOVA did not reveal a significant interaction between condition and session ($F(6, 126) = .676, p = .669, \eta_p^2 = .031$). There was no significant main effect for session ($F(6, 126) = .540, p = .779, \eta_p^2 = .025$) or condition ($F(1, 21) = 1.373, p = .254, \eta_p^2 = .061$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 32.739, p = .038; \varepsilon = .847$). The mixed model ANOVA did not reveal a significant interaction between condition and session ($F(5.085, 111.861) = 1.133, p = .347, \eta_p^2 = .049$). There was a significant main effect for session ($F(5.085, 111.861) = 7.328, p < .001, \eta_p^2 = .250$). Pairwise comparisons showed significant differences between BL and T3 ($p = .001$), BL and T4 ($p = .005$), BL and T5 ($p = .005$), BL and T6 ($p = .001$), BL and T7 ($p = .001$), T2 and T3 ($p = .004$), T2 and T4 ($p = .007$), T2 and T5 ($p = .019$), T2 and T6 ($p = .001$), and T2 and T7 ($p = .003$), illustrated in Figure 22. There was not a significant main effect for condition ($F(1, 22) = 1.015, p = .325, \eta_p^2 = .044$). The means for placebo and modafinil groups were 2.263 and 2.402 respectively, and the standard errors for both groups were .097.

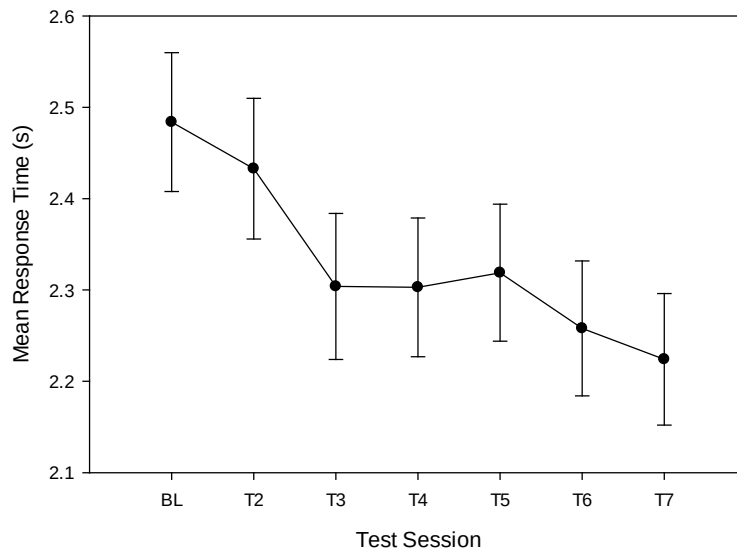


Figure 22. Nova Scan Manikin Task CorrRT Session Main Effect

NIncorr: The assumption of sphericity was violated for NIncorr ($\chi^2(20) = 32.842, p = .037; \epsilon = .731$). The mixed model ANOVA did not reveal a significant interaction between condition and session ($F(4.388, 96.540) = .735, p = .582, \eta_p^2 = .032$). There was not a significant main effect for session ($F(4.388, 96.540) = .281, p = .904, \eta_p^2 = .013$) or for condition ($F(1, 22) = 1.330, p = .261, \eta_p^2 = .057$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.439, p = .205, \eta_p^2 = .061$). There was not a significant main effect for session ($F(6, 132) = .635, p = .702, \eta_p^2 = .028$) or condition ($F(1, 22) = .940, p = .343, \eta_p^2 = .041$).

NTO: The assumption of sphericity was violated for NTO ($\chi^2(20) = 36.258, p = .015; \epsilon = .695$). The mixed model ANOVA for NTO did not show a significant interaction between condition and session ($F(4.17, 91.739) = 1.242, p = .299, \eta_p^2 = .053$). There was not a significant main effect for session ($F(4.17, 91.739) = .410, p = .809, \eta_p^2 = .018$) or condition ($F(1, 22) = .455, p = .507, \eta_p^2 = .020$).

Continuous Memory Task

NCorr: The assumption of sphericity was violated for Ncorr ($\chi^2(20) = 39.038, p = .007; \epsilon = .778$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.666, 102.656) = 2.897, p = .020, \eta_p^2 = .116$). Simple effects analysis did not show any significant differences between the groups at BL ($p = .945$), T2 ($p = .286$), T3 ($p = .055$), T4 ($p = .234$), T5 ($p = .972$), T6 ($p = .190$), or T7 ($p = .614$). Analyses were also conducted to determine if there were differences among the sessions within each group. For the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 46.200, p = .001; \epsilon = .604$). There were no differences among the sessions within the placebo group ($F(3.625, 39.880) = .728, p = .565$). Within the modafinil group, there was a significant main effect for session ($F(6, 66) = 2.660, p = .023$). Pairwise comparisons revealed significant differences between BL and T3 ($p = .002$), BL

and T4 ($p = .032$), T3 and T4 ($p = .014$), T3 and T5 ($p = .001$), T4 and T5 ($p = .039$), T5 and T6 ($p = .002$), and T5 and T7 ($p = .025$). Results for this interaction are shown in Figure 23.

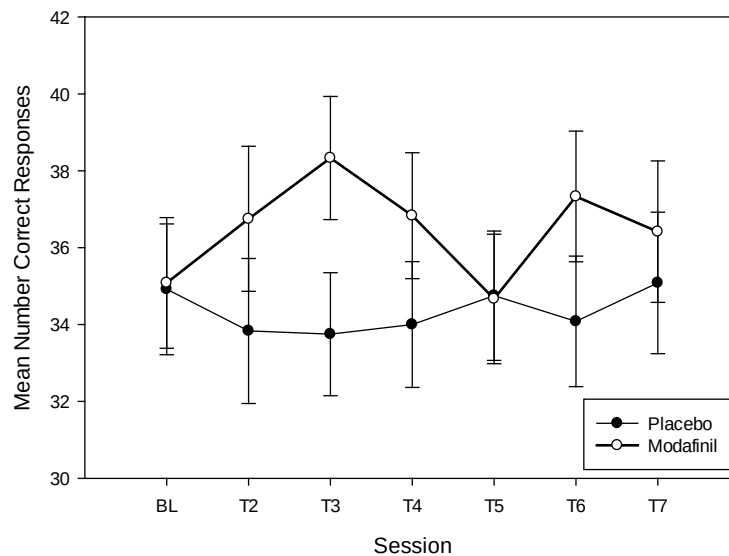


Figure 23. Nova Scan Continuous Memory Task NCorr Condition X Session Interaction

The main effect for session was not significant ($F(4.666, 102.656) = .833, p = .522, \eta_p^2 = .036$). The main effect for condition also was not significant ($F(1, 22) = .906, p = .352, \eta_p^2 = .040$).

CorrRT: The assumption of sphericity was violated ($\chi^2(20) = 38.618, p = .008; \epsilon = .753$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.519, 99.414) = .818, p = .529, \eta_p^2 = .036$). There was a significant main effect for session ($F(4.519, 99.414) = 7.361, p < .001, \eta_p^2 = .251$). Pairwise comparisons showed significant differences between BL and T2 ($p = .023$), BL and T3 ($p = .050$), BL and T7 ($p = .011$), T2 and T3 ($p < .001$), T2 and T4 ($p = .001$), T2 and T5 ($p = .006$), T2 and T6 ($p < .001$), T2 and T7 ($p < .001$), T4 and T7 ($p = .010$), T5 and T7 ($p = .007$), and T6 and T7 ($p = .044$). Results are shown in Figure 24.

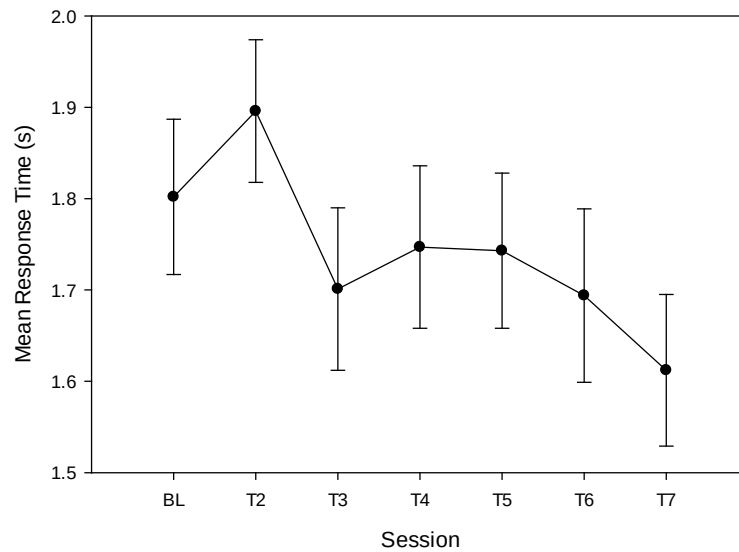


Figure 24. Nova Scan Continuous Memory Task CorrRT Session Main Effect

There was not a significant main effect of condition ($F(1, 22) = .002, p = .969, \eta_p^2 = 0$). The means for placebo and modafinil groups were 1.745 and 1.739, respectively, and the standard error for both groups was 0.114.

NIncorr: The assumption of sphericity was violated for NIncorr ($\chi^2(20) = 39.038, p = .007; \epsilon = .778$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.666, 102.656) = 2.897, p = .020, \eta_p^2 = .116$). Simple effects analysis did not show any significant differences between the groups at BL ($p = .945$), T2 ($p = .286$), T3 ($p = .055$), T4 ($p = .234$), T5 ($p = .972$), T6 ($p = .190$), or T7 ($p = .614$). Analyses to determine differences among the sessions within each group were conducted. For the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 46.200, p = .001; \epsilon = .604$). There was no significant main effect of session within the placebo group ($F(3.625, 39.880) = .728, p = .565$). Within the modafinil group, there was a significant main effect of session ($F(6, 66) = 2.660, p = .050$). Pairwise comparisons revealed significant differences between BL and T3 ($p = .002$), BL and T4 ($p = .032$), T3 and T4 ($p = .014$), T3 and T5 ($p = .001$), T4 and T5 ($p = .039$), T5 and T6 ($p = .002$), and T5 and T7 ($p = .025$). Results are illustrated in Figure 25.

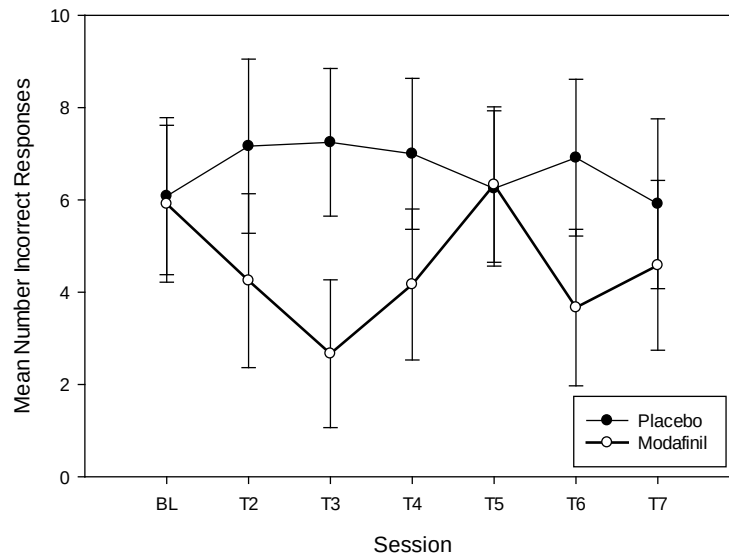


Figure 25. Nova Scan Continuous Memory Task NIncorr Condition X Session Interaction

There was not a significant main effect for session ($F(4.666, 102.833) = .0833, p = .522, \eta_p^2 = .036$) or condition ($F(1, 22) = .906, p = .352, \eta_p^2 = .040$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.348, p = .240, \eta_p^2 = .058$). There was a significant main effect for session ($F(6, 132) = 2.638, p = .019, \eta_p^2 = .107$). Pairwise comparisons with LSD adjustments revealed significant differences between BL and T3 ($p = .032$), BL and T7 ($p < .001$), T4 and T7 ($p = .029$), and T6 and T7 ($p = .003$). Results are shown in Figure 26.

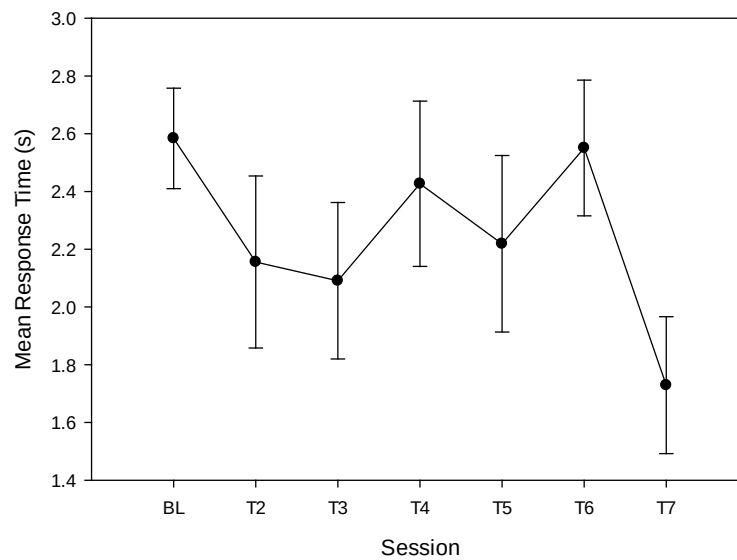


Figure 26. Nova Scan Continuous Memory Task IncorrRT Session Main Effect

There was a significant main effect for condition ($F(1, 22) = 4.466, p = .046, \eta_p^2 = .169$). The means for placebo and modafinil groups were 2.670 and 1.832, respectively, and the standard error for both groups was 0.280.

NTO: The assumption of sphericity was violated for NTO ($\chi^2(20) = 73.137, p < .001; \epsilon = .525$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.153, 69.359) = 2.248, p = .087, \eta_p^2 = .093$). There was not a significant main effect for session ($F(3.153, 69.359) = 1.337, p = .269, \eta_p^2 = .057$) or condition ($F(1, 22) = 2.623, p = .120, \eta_p^2 = .107$).

Dial Task

NCorr: The mixed model ANOVA for Ncorr did not show a significant interaction between condition and session ($F(6, 132) = .342, p = .913, \eta_p^2 = .015$). There was not a significant main effect for session ($F(6, 132) = 1.646, p = .139, \eta_p^2 = .070$) or condition ($F(1, 22) = .240, p = .629, \eta_p^2 = .011$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 62.378, p < .001; \epsilon = .585$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.509, 77.201) = 1.311, p = .275, \eta_p^2 = .056$). There was a significant main effect for session ($F(3.509, 77.201) = 5.995, p = .001, \eta_p^2 = .214$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .025$), BL and T5 ($p = .024$), BL and T6 ($p = .018$), BL and T7 ($p = .003$), T2 and T4 ($p = .013$), T2 and T5 ($p = .032$), T2 and T6 ($p = .011$), T2 and T7 ($p = .002$), T3 and T6 ($p = .042$), T3 and T7 ($p = .012$), T4 and T7 ($p = .036$), T5 and T7 ($p = .009$), and T6 and T7 ($p = .031$). This effect is shown in Figure 27.

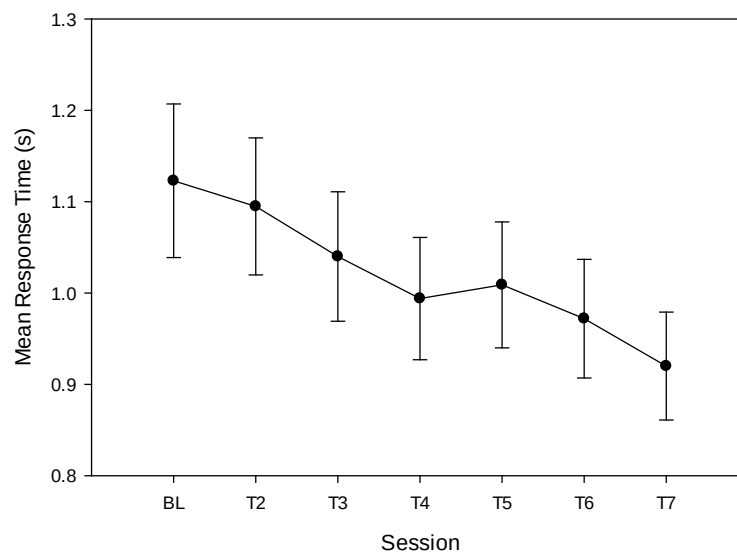


Figure 27. Nova Scan Dial Task CorrRT Session Main Effect

There was not a significant main effect for condition ($F(1, 22) = .051, p = .823, \eta_p^2 = .002$). The means for placebo and modafinil groups were 1.007 and 1.037, respectively, and the standard error for both groups was 0.092.

NIncorr: The assumption of sphericity was violated for NIncorr ($\chi^2(20) = 37.496, p = .011; \epsilon = .811$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.864, 107.011) = .673, p = .640, \eta_p^2 = .030$). There was not a significant main effect for session ($F(4.864, 107.011) = .325, p = .893, \eta_p^2 = .015$) or condition ($F(1, 22) = .442, p = .513, \eta_p^2 = .020$).

InCorrRT: The assumption of sphericity was violated for InCorrRT ($\chi^2(20) = 68.663, p < .001; \epsilon = .629$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.773, 83.006) = 1.271, p = .289, \eta_p^2 = .055$). There was not a significant main effect for session ($F(3.773, 83.006) = 1.011, p = .404, \eta_p^2 = .044$) or condition ($F(1, 22) = .015, p = .903, \eta_p^2 = .001$).

NTO: The assumption of sphericity was violated for NTO ($\chi^2(20) = 66.034, p < .001; \epsilon = .642$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.854, 84.784) = 1.145, p = .340, \eta_p^2 = .049$). There was a significant main effect for session ($F(3.854, 84.784) = 3.008, p = .024, \eta_p^2 = .120$). Pairwise comparisons showed significant differences between BL and T2 ($p = .012$), BL and T3 ($p = .040$), BL and T4 ($p = .027$), BL and T5 ($p = .010$), BL and T6 ($p = .010$), and BL and T7 ($p = .024$). Results are illustrated in Figure 28.

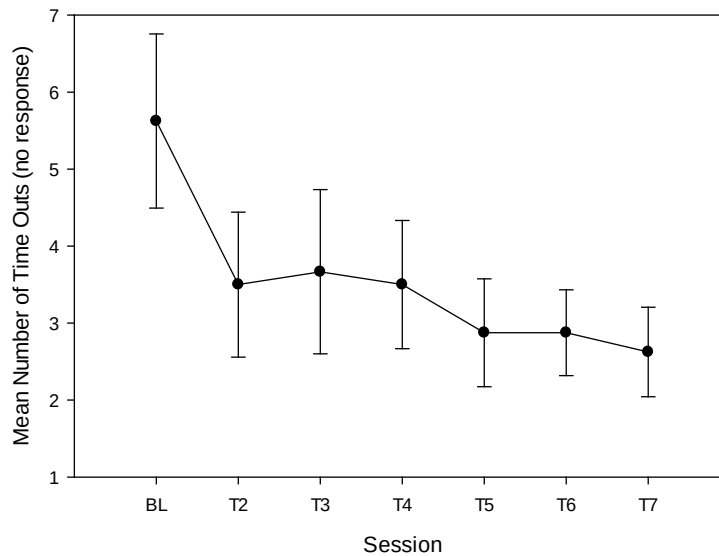


Figure 28. Nova Scan Dial Task NTO Session Main Effect

There was not a significant main effect for condition ($F(1, 22) = .005, p = .944, \eta_p^2 = 0$). The means for placebo and modafinil groups were 3.571 and 3.476 respectively, and the standard error for both groups was 0.943.

3.2.1.6 Rapid Decision Making (NTI ATSTTM).

Ncorr: The mixed model ANOVA for Ncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.039, p = .403, \eta_p^2 = .045$). There was not a significant main effect for session ($F(6, 132) = .961, p = .454, \eta_p^2 = .042$) or condition ($F(1, 22) = 1.021, p = .323, \eta_p^2 = .044$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 48.080, p < .001; \epsilon = .736$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.418, 97.201) = 2.719, p = .029, \eta_p^2 = .110$). Simple effects analyses showed no significant differences between the groups at BL ($p = .365$), T2 ($p = .533$), T3 ($p = .349$), T4 ($p = .800$), T5 ($p = .501$), T6 ($p = .635$), or T7 ($p = .570$). Within the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 43.034, p = .003; \epsilon = .537$). There was a significant main effect of session within the placebo group ($F(3.223, 35.453) = 5.053, p = .004$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .035$), BL and T6 ($p = .002$), BL and T7 ($p < .001$), T2 and T5 ($p = .012$), T2 and T6 ($p = .004$), T2 and T7 ($p = .001$), T3 and T6 ($p = .015$), T3 and T7 ($p = .002$), T4 and T6 ($p = .023$), T4 and T7 ($p = .002$), and T6 and T7 ($p = .004$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 35.639, p = .023; \epsilon = .697$). There was a significant main effect of session within the modafinil group ($F(4.184, 46.021) = 12.314, p < .001$). Pairwise comparisons revealed significant differences between BL and T3 ($p = .003$), BL and T4 ($p < .001$), BL and T5 ($p = .009$), BL and T6 ($p < .001$), BL and T7 ($p < .001$), T2 and T3 ($p < .001$), T2 and T4 ($p < .001$), T2 and T5 ($p = .005$), T2 and T6 ($p = .001$), T2 and T7 ($p < .001$), T5 and T7 ($p = .029$), and T6 and T7 ($p = .008$). Results are illustrated in Figure 29.

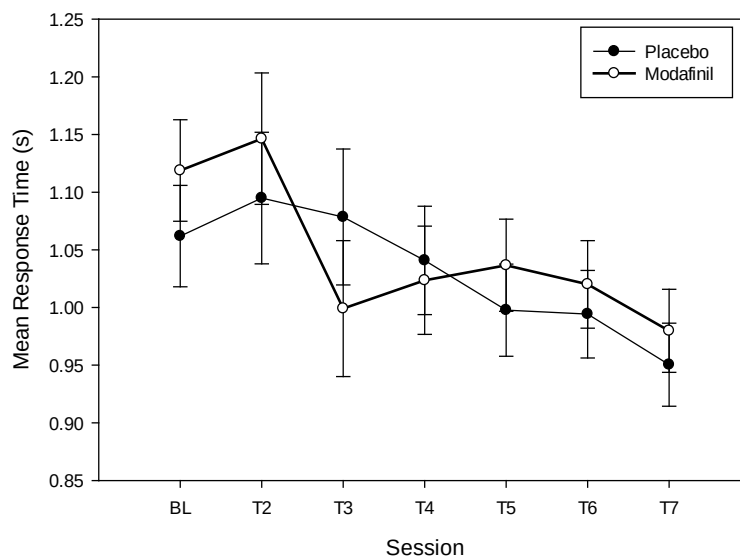


Figure 29. Rapid Decision Making CorrRT Condition X Session Interaction

There was a significant main effect for session ($F(4.418, 97.201) = 12.735, p < .001, \eta_p^2 = .367$). Pairwise comparisons showed significant differences between BL and T4 ($p < .001$), BL and T5 ($p = .001$), BL and T6 ($p < .001$), BL and T7 ($p < .001$), T2 and T3 ($p = .001$), T2 and T4 ($p < .001$), T2 and T5 ($p < .001$), T2 and T6 ($p < .001$), T2 and T7 ($p < .001$), T3 and T7 ($p = .011$),

T4 and T7 ($p = .001$), T5 and T7 ($p = .006$), and T6 and T7 ($p < .001$). Results are illustrated in Figure 30.

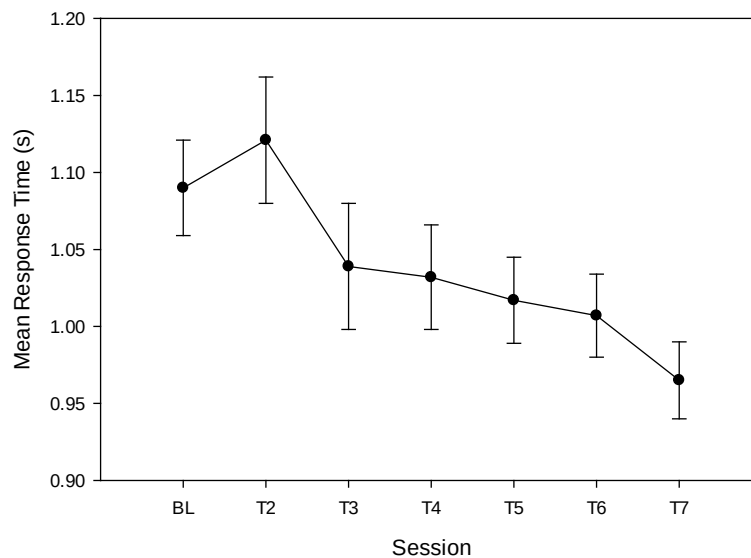


Figure 30. Rapid Decision Making CorrRT Session Main Effect

There was not a significant main effect of condition ($F(1, 22) = .063, p = .804, \eta_p^2 = .003$). The means for placebo and modafinil groups were 1.031 and 1.046 respectively, and the standard error for both groups was 0.043.

NIncorr: The mixed model ANOVA for NIncorr did not show a significant interaction between condition and session ($F(6, 132) = .976, p = .444, \eta_p^2 = .042$). There was not a significant main effect for session ($F(6, 132) = .989, p = .435, \eta_p^2 = .043$) or condition ($F(1, 22) = .927, p = .346, \eta_p^2 = .040$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .352, p = .908, \eta_p^2 = .016$). There was not a significant main effect for session ($F(6, 132) = .142, p = .990, \eta_p^2 = .006$) or condition ($F(1, 22) = 2.235, p = .149, \eta_p^2 = .092$).

3.2.1.8 Math Processing (NTI ATSTM).

NCorr: One participant from the modafinil group was excluded as an outlier for NCorr. The assumption of sphericity was violated ($\chi^2(20) = 51.359, p < .001; \epsilon = .598$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.588, 75.346) = .950, p = .433, \eta_p^2 = .043$). There was not a significant main effect for session ($F(3.588, 75.346) = 1.965, p = .116, \eta_p^2 = .086$) or condition ($F(1, 21) = .029, p = .865, \eta_p^2 = .001$).

CorrRT: The mixed model ANOVA for CorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.824, p = .099, \eta_p^2 = .077$). There was a significant main effect for session ($F(6, 132) = 6.980, p < .001, \eta_p^2 = .241$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .046$), BL and T6 ($p < .001$), BL and T7 ($p < .001$).

.001), T2 and T6 ($p = .004$), T2 and T7 ($p < .001$), T3 and T6 ($p = .005$), T3 and T7 ($p < .001$), T4 and T6 ($p = .017$), T4 and T7 ($p = .002$), T5 and T6 ($p = .045$), and T5 and T7 ($p = .001$). Results are illustrated in Figure 31. There was not a significant main effect of condition ($F(1, 22) = .098$, $p = .757$, $\eta_p^2 = .004$).

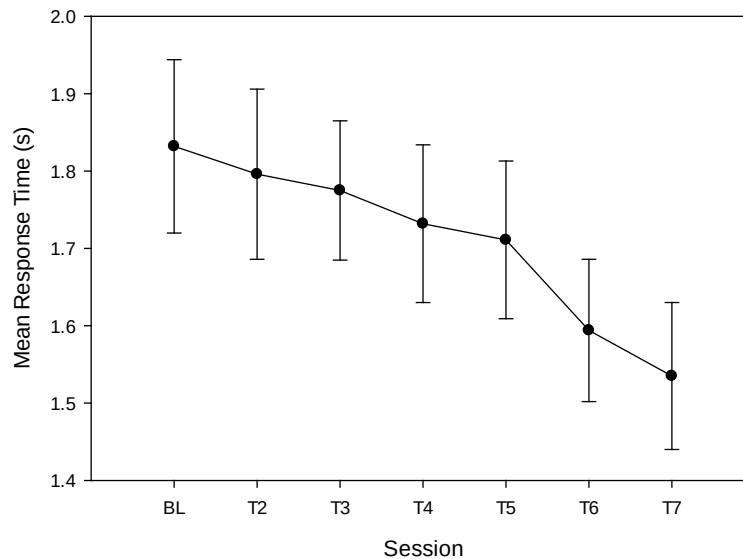


Figure 31. Math Processing CorrRT Session Main Effect

There was not a significant main effect for condition ($F(1, 22) = .098$, $p = .757$, $\eta_p^2 = .004$). The mean for placebo and modafinil groups were 1.681 and 1.740, respectively, and the standard error for both groups was 0.132.

NIncorr: One participant from the modafinil group was excluded as an outlier for NIncorr. Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated ($\chi^2(20) = 54.773$, $p < .001$; $\epsilon = .530$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.178, 66.728) = .680$, $p = .576$, $\eta_p^2 = .031$). There was not a significant main effect for session ($F(3.178, 66.728) = 1.981$, $p = .122$, $\eta_p^2 = .086$) or condition ($F(1, 21) = .370$, $p = .549$, $\eta_p^2 = .017$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .745$, $p = .614$, $\eta_p^2 = .033$). There was not a significant main effect for session ($F(6, 132) = 1.222$, $p = .299$, $\eta_p^2 = .053$) or condition ($F(1, 22) = 1.592$, $p = .220$, $\eta_p^2 = .067$).

3.2.1.9 Delayed Match to Sample (NTI ATSTM).

Ncorr: The mixed model ANOVA for Ncorr showed a significant interaction between condition and session ($F(6, 132) = 2.184$, $p = .048$, $\eta_p^2 = .090$). Simple effects analyses did not show any significant differences between the groups at BL ($p = .724$), T2 ($p = .685$), T3 ($p = .064$), T4 ($p = .640$), T5 ($p = .401$), T6 ($p = .774$), or T7 ($p = .342$). Within the placebo group, there were no significant differences of session ($F(6, 66) = 1.871$, $p = .099$). Within the modafinil group, there

were no significant differences of session ($F(6, 66) = .729, p = .628$). Results are illustrated in Figure 32.

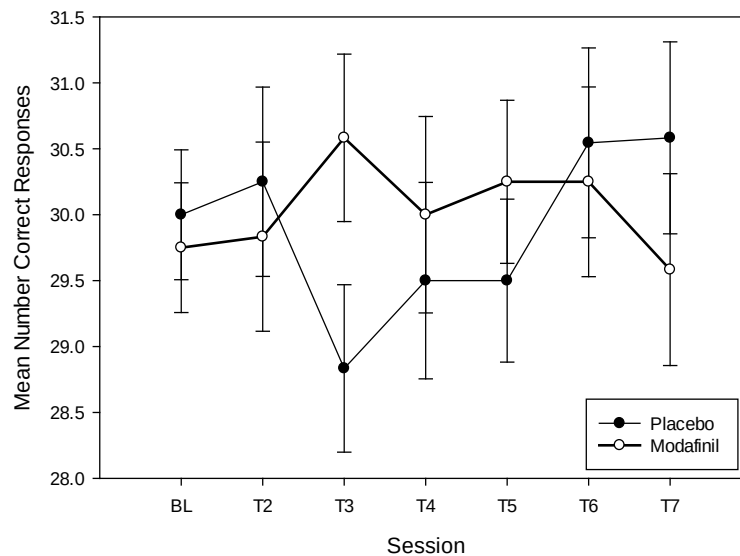


Figure 32. Delayed Match to Sample NCorr Condition X Session Interaction

There was not a significant main effect for session ($F(6, 132) = .581, p = .745, \eta_p^2 = .026$) or condition ($F(1, 22) = .039, p = .846, \eta_p^2 = .002$).

CorrRT: One participant from the placebo group was excluded as an outlier for CorrRT. The mixed model ANOVA showed a significant interaction between condition and session ($F(6, 126) = 2.803, p = .014, \eta_p^2 = .118$). Simple effects analyses did not show any significant differences between the groups at BL ($p = .880$), T2 ($p = .975$), T3 ($p = .114$), T4 ($p = .397$), T5 ($p = .220$), T6 ($p = .714$), or T7 ($p = .386$). Within the placebo group, there were significant differences between sessions ($F(6, 60) = 5.163, p < .001$). Pairwise comparisons showed significant differences between BL and T7 ($p = .021$), T2 and T7 ($p = .001$), T3 and T6 ($p = .046$), T3 and T7 ($p < .001$), T4 and T7 ($p = .002$), T5 and T6 ($p = .001$), T5 and T7 ($p < .001$), and T6 and T7 ($p = .010$). Within the modafinil group, there was no significant main effect for session ($F(6, 66) = 1.232, p = .301$). Results are illustrated in Figure 33.

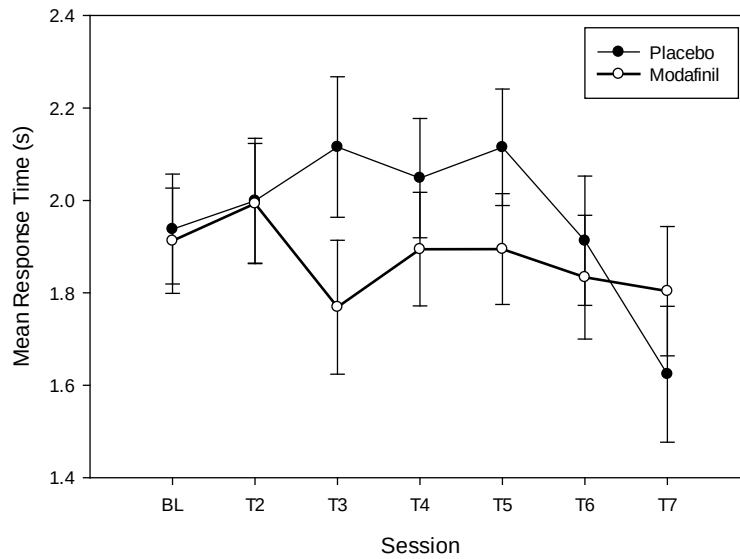


Figure 33. Delayed Match to Sample CorrRT Condition X Session Interaction

There was a significant main effect for session ($F(6, 126) = 4.007, p = .001, \eta_p^2 = .160$). Pairwise comparisons showed significant differences between BL and T7 ($p = .025$), T2 and T7 ($p < .001$), T3 and T7 ($p = .009$), T4 and T7 ($p = .005$), T5 and T6 ($p = .002$), T5 and T7 ($p < .001$), and T6 and T7 ($p = .034$). Results are shown in Figure 34.

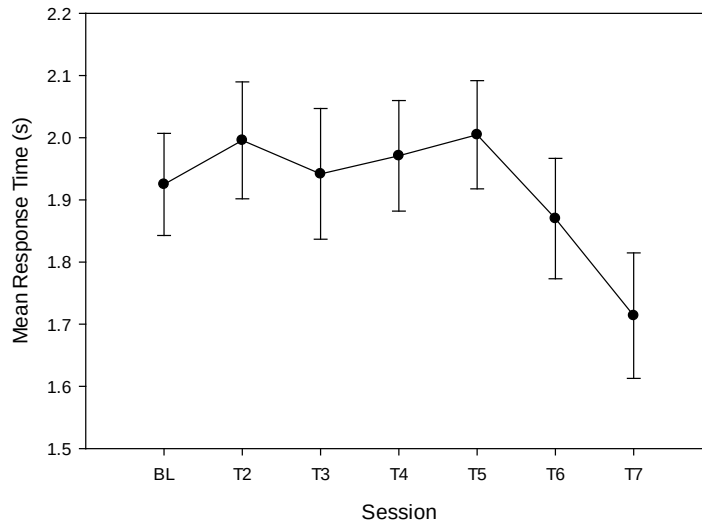


Figure 34. Delayed Match to Sample CorrRT Session Main Effect

There was not a significant main effect for condition ($F(1, 21) = .319, p = .578, \eta_p^2 = .015$). The means for placebo and modafinil groups were 1.964 and 1.872, respectively, and the standard errors for the placebo and modafinil groups were 0.118 and 0.113, respectively.

NIncorr: The mixed model ANOVA for NIncorr showed a significant interaction between condition and session ($F(6, 132) = 2.184, p = .048, \eta_p^2 = .090$). Simple effects analyses did not show any significant differences between the groups at BL ($p = .724$), T2 ($p = .685$), T3 ($p =$

.064), T4 ($p = .640$), T5 ($p = .401$), T6 ($p = .774$), or T7 ($p = .342$). Within the placebo group, there was not a significant main effect of session ($F(6, 66) = 1.871, p = .099$). Within the modafinil group, there was no significant main effect of session ($F(6, 66) = .729, p = .628$). Results are illustrated in Figure 35.

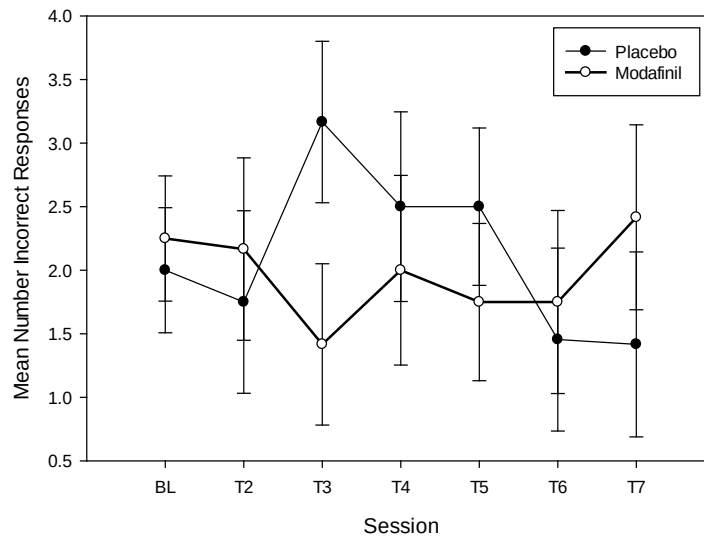


Figure 35. Delayed Match to Sample NIncorr Condition X Session Interaction

There was not a significant main effect for session ($F(6, 132) = .581, p = .745, \eta_p^2 = .026$) or condition ($F(1, 22) = .039, p = .846, \eta_p^2 = .002$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.174, p = .324, \eta_p^2 = .051$). There was not a significant main effect for session ($F(6, 132) = 1.961, p = .076, \eta_p^2 = .082$) or condition ($F(1, 22) = .006, p = .939, \eta_p^2 = 0$).

CorrMem: The assumption of sphericity was violated for CorrMem ($\chi^2(20) = 36.577, p = .014; \epsilon = .738$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.425, 97.360) = 1.098, p = .364, \eta_p^2 = .048$).

There was a significant main effect for session ($F(4.425, 97.360) = 3.51, p = .008, \eta_p^2 = .138$). Pairwise comparisons showed significant differences between BL and T7 ($p = .015$), T2 and T6 ($p = .029$), T2 and T7 ($p = .002$), T3 and T7 ($p = .014$), T4 and T7 ($p = .001$), T5 and T7 ($p = .001$), and T6 and T7 ($p = .040$). Results are illustrated in Figure 36.

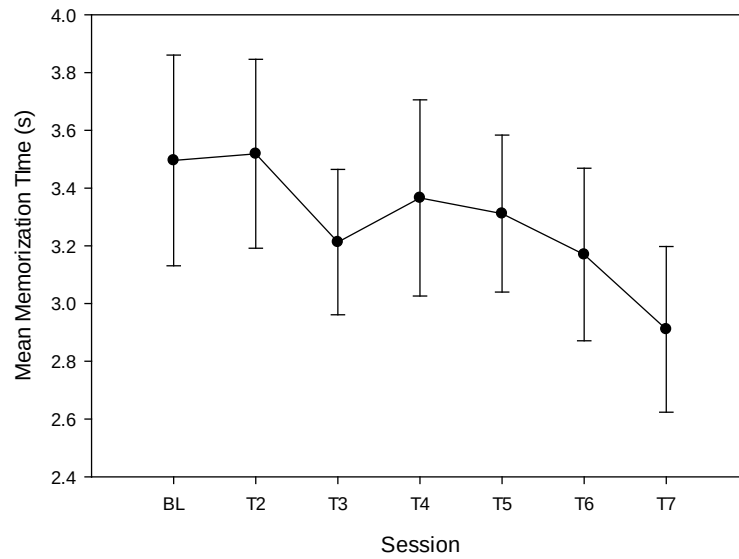


Figure 36. Delayed Match to Sample CorrMem Session Main Effect

There was not a significant main effect of condition ($F(1, 22) = .990, p = .331, \eta_p^2 = .043$). The means for placebo and modafinil groups were 2.995 and 3.573, respectively, and the standard error for both groups was 0.410.

IncorrMem: The mixed model ANOVA for IncorrMem did not show a significant interaction between condition and session ($F(6, 132) = 1.511, p = .179, \eta_p^2 = .064$).

There was a significant main effect for session ($F(6, 132) = 3.377, p = .004, \eta_p^2 = .133$). Pairwise comparisons revealed significant differences between BL and T2 ($p = .004$), BL and T4 ($p = .027$), BL and T6 ($p = .002$), BL and T7 ($p = .032$), and T3 and T6 ($p = .008$). Results are illustrated in Figure 37.

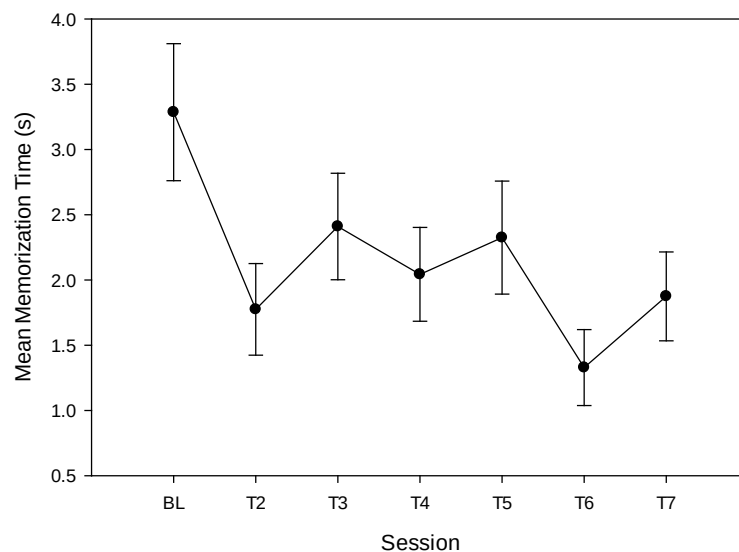


Figure 37. Delayed Match to Sample IncorrMem Session Main Effect

There was not a significant main effect of condition ($F(1, 22) = .900, p = .353, \eta_p^2 = .039$). The means for placebo and modafinil groups were 1.921 and 2.377, respectively, and the standard error for both groups was 0.340.

3.2.1.10 Peripheral Information Processing (NTI ATSTM).

RT: The assumption of sphericity was violated for RT ($\chi^2(20) = 42.755, p = .002; \epsilon = .824$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.945, 108.784) = 4.420, p = .001, \eta_p^2 = .167$). Simple effects analyses showed significant differences between the groups at T2 ($p = .045$) and T3 ($p = .004$). There were not significant differences between the groups at BL ($p = .320$), T4 ($p = .064$), T5 ($p = .252$), T6 ($p = .103$), or T7 ($p = .495$). Within the placebo group, there was a significant main effect for session ($F(6, 66) = 8.568, p < .001$). Pairwise comparisons showed significant differences between BL and T2 ($p < .001$), BL and T3 ($p < .001$), BL and T4 ($p < .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), BL and T7 ($p = .012$), T2 and T6 ($p = .045$), T2 and T7 ($p = .002$), T3 and T6 ($p = .017$), T3 and T7 ($p < .001$), T4 and T7 ($p = .004$), T5 and T6 ($p = .014$), T5 and T7 ($p = .003$), and T6 and T7 ($p = .038$). Within the modafinil group, the assumption of sphericity was violated for RT ($\chi^2(20) = 38.026, p = .012; \epsilon = .642$). There was a significant main effect for session within the modafinil group ($F(3.849, 42.341) = 3.317, p = .020$). Pairwise comparisons showed significant differences between BL and T5 ($p = .015$), T3 and T5 ($p = .023$), T5 and T6 ($p = .016$), and T5 and T7 ($p = .047$). Results are illustrated in Figure 38.

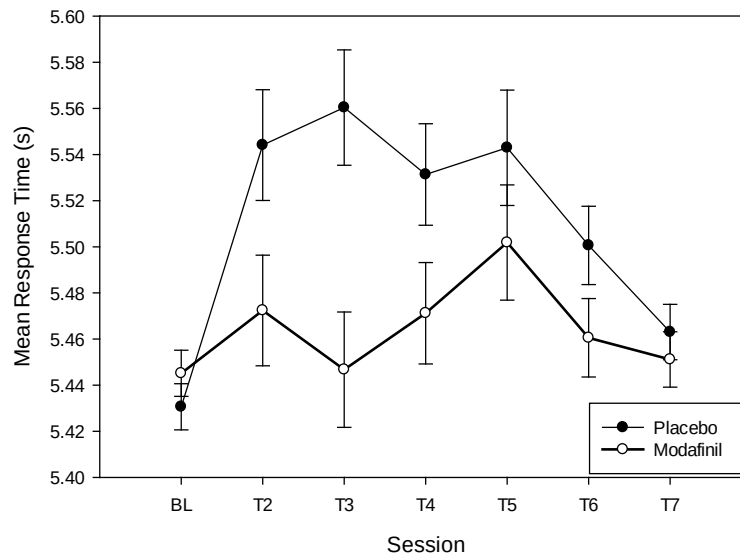


Figure 38. Peripheral Information Processing RT Condition X Session Interaction

There were significant main effects for session ($F(4.945, 108.784) = 9.477, p < .001, \eta_p^2 = .301$). Pairwise comparisons revealed significant differences between BL and T2 ($p < .001$), BL and T3 ($p < .001$), BL and T4 ($p < .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), BL and T7 ($p = .036$), T2 and T7 ($p = .005$), T3 and T7 ($p = .010$), T4 and T7 ($p = .007$), T5 and T6 ($p = .001$), and T5 and T7 ($p = .001$). Results are illustrated in Figure 39.

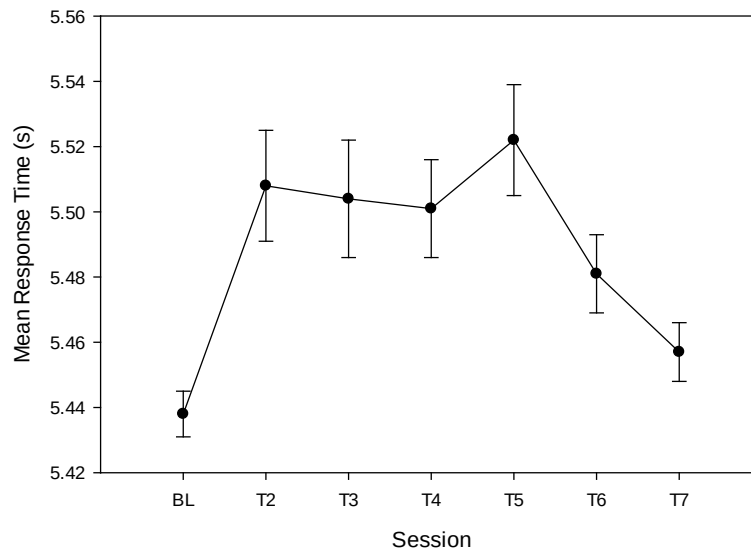


Figure 39. Peripheral Information Processing RT Session Main Effect

There was a significant main effect for condition ($F(1, 22) = 4.561, p = .044, \eta_p^2 = .172$). The means for placebo and modafinil groups were 5.510 and 5.464, respectively, and the standard error for both groups was 0.015.

NHit: One participant from the placebo group was excluded as an outlier for NHit. The assumption of sphericity was violated ($\chi^2(20) = 53.508, p < .001; \varepsilon = .682$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.093, 85.946) = 1.902, p = .116, \eta_p^2 = .083$). There was not a significant main effect for session ($F(4.093, 85.946) = 2.227, p = .071, \eta_p^2 = .096$) or condition ($F(1, 21) = 2.841, p = .107, \eta_p^2 = .119$).

Ncorr: The assumption of sphericity was violated for Ncorr ($\chi^2(20) = 45.837, p = .001; \varepsilon = .827$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.963, 109.186) = 4.038, p = .002, \eta_p^2 = .155$). Simple effects analyses showed significant differences between the groups at T2 ($p = .022$), T3 ($p = .002$), and T6 ($p = .030$). There were not significant differences between the groups at BL ($p = .370$), T4 ($p = .071$), T5 ($p = .234$), or T7 ($p = .328$). Within the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 42.303, p = .004; \varepsilon = .739$). There was a significant main effect for session within the placebo group ($F(4.436, 48.795) = 5.697, p = .001$). Pairwise comparisons revealed significant differences between BL and T2 ($p < .001$), BL and T3 ($p < .001$), BL and T4 ($p = .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), T2 and T7 ($p < .001$), T3 and T4 ($p = .018$), T3 and T6 ($p = .035$), T3 and T7 ($p < .001$), T4 and T7 ($p = .013$), T5 and T7 ($p = .008$), and T6 and T7 ($p = .007$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 34.220, p = .032; \varepsilon = .645$). There was a significant main effect for session within the modafinil group ($F(3.871, 42.579) = 2.695, p = .045$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .015$). Results are illustrated in Figure 40.

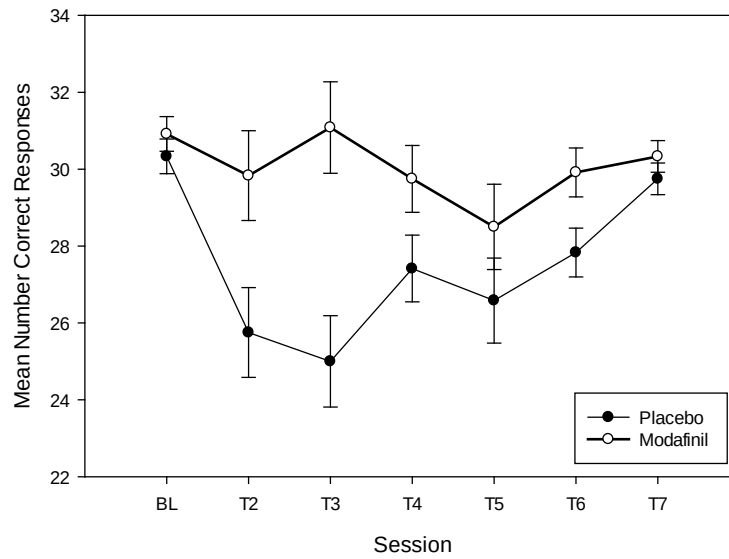


Figure 40. Peripheral Information Processing NCorr Condition X Session Interaction

There was a significant main effect for session ($F(4.963, 109.186) = 5.631, p < .001, \eta_p^2 = .204$). Pairwise comparisons showed significant differences between BL and T2 ($p < .001$), BL and T3 ($p = .003$), BL and T4 ($p = .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), T2 and T7 ($p = .003$), T3 and T7 ($p = .014$), T4 and T7 ($p = .026$), T5 and T6 ($p = .047$), T5 and T7 ($p = .003$), and T6 and T7 ($p = .019$). Results are illustrated in Figure 41.

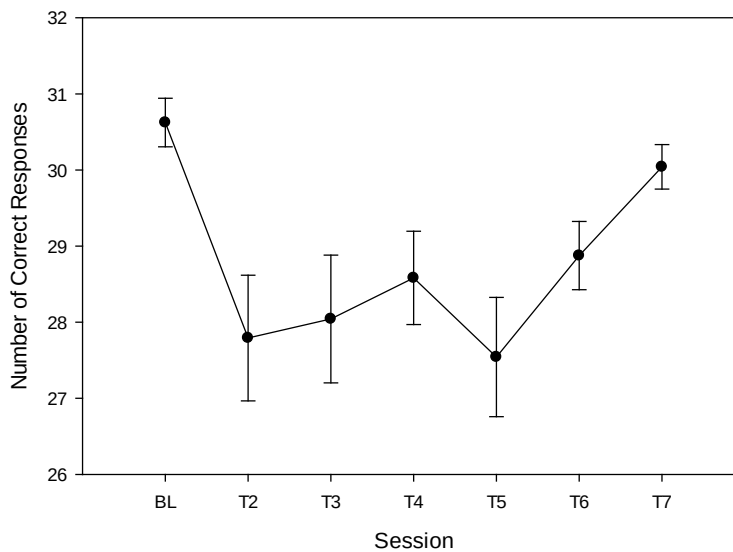


Figure 41. Peripheral Information Processing NCorr Session Main Effect

There was a significant main effect of condition ($F(1, 22) = 8.388, p = .008, \eta_p^2 = .276$). The means for placebo and modafinil groups were 27.524 and 30.048, respectively, and the standard error for both groups was 0.616.

NIncorr: The assumption of sphericity was violated for NIncorr ($\chi^2(20) = 43.310, p = .002; \epsilon = .739$). The mixed model ANOVA showed a significant interaction between condition and session ($F(4.432, 97.514) = 3.143, p = .015, \eta_p^2 = .125$). Simple effects analyses showed significant differences between the groups at T2 ($p = .018$), T3 ($p = .003$), T4 ($p = .044$), and T6 ($p = .020$). There were not significant differences between the groups at BL ($p = .831$), T5 ($p = .168$), or T7 ($p = .100$). Within the placebo group, there was a significant main effect for session ($F(6, 66) = 5.753, p < .001$). Pairwise comparisons revealed significant differences between BL and T2 ($p < .001$), BL and T3 ($p < .001$), BL and T4 ($p < .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), BL and T7 ($p = .021$), T2 and T6 ($p = .023$), T2 and T7 ($p = .001$), T3 and T7 ($p = .001$), T4 and T7 ($p = .007$), T5 and T7 ($p = .003$), and T6 and T7 ($p = .009$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 58.679, p < .001; \epsilon = .472$). There was not a significant main effect of session within the modafinil group ($F(2.835, 31.185) = 2.477, p = .083$). Results are illustrated in Figure 42.

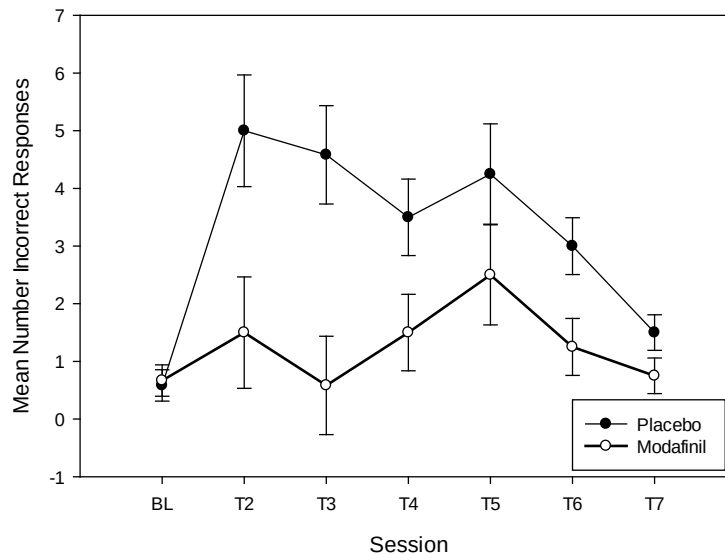


Figure 42. Peripheral Information Processing NIncorr Condition X Session Interaction

There was a significant main effect for session ($F(4.432, 97.514) = 6.518, p < .001, \eta_p^2 = .229$). Pairwise comparisons revealed significant differences between BL and T2 ($p < .001$), BL and T3 ($p = .003$), BL and T4 ($p < .001$), BL and T5 ($p < .001$), BL and T6 ($p < .001$), T2 and T7 ($p = .002$), T3 and T7 ($p = .018$), T4 and T7 ($p = .009$), T5 and T6 ($p = .022$), T5 and T7 ($p = .001$), and T6 and T7 ($p = .013$). Results are illustrated in Figure 43.

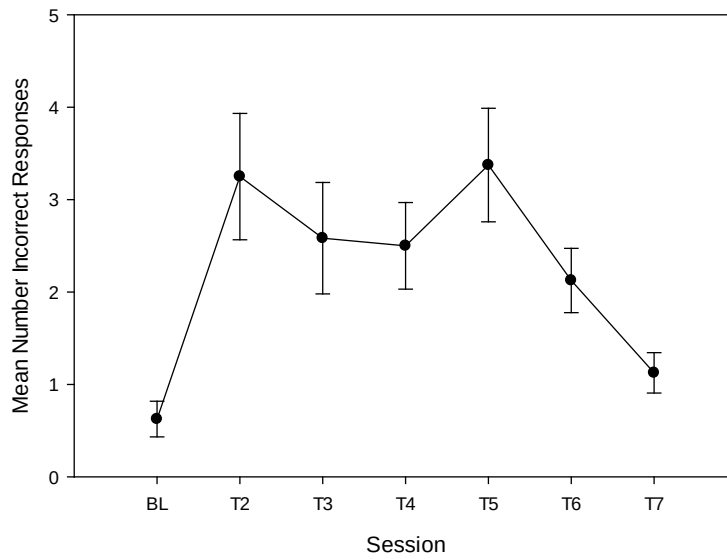


Figure 43. Peripheral Information Processing NIncorr Session Main Effect

There was a significant main effect of condition ($F(1, 22) = 10.116, p = .004, \eta_p^2 = .315$). The means for placebo and modafinil groups were 3.202 and 1.250, respectively, and the standard error for both groups was 0.434.

3.2.1.11 Dichotic Listening (NTI ATSTM).

Ncorr: One participant from the modafinil group was excluded as an outlier for Ncorr. The assumption of sphericity was violated ($\chi^2(20) = 80.708, p < .001; \epsilon = .453$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(2.716, 57.031) = 1.358, p = .266, \eta_p^2 = .061$). There were no significant main effects for session ($F(2.716, 57.031) = 1.461, p = .237, \eta_p^2 = .065$) or condition ($F(1, 21) = 2.402, p = .136, \eta_p^2 = .103$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 155.37, p < .001; \epsilon = .243$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.460, 32.129) = 3.016, p = .077, \eta_p^2 = .121$). There was a significant main effect for session ($F(1.460, 32.129) = 4.163, p = .036, \eta_p^2 = .159$). Pairwise comparisons showed significant differences between BL and T2 ($p = .003$), BL and T3 ($p = .043$), BL and T5 ($p < .001$), BL and T6 ($p = .018$), T3 and T5 ($p = .013$), T4 and T5 ($p = .001$), T5 and T6 ($p = .030$), and T5 and T7 ($p = .014$). Results are illustrated in Figure 44.

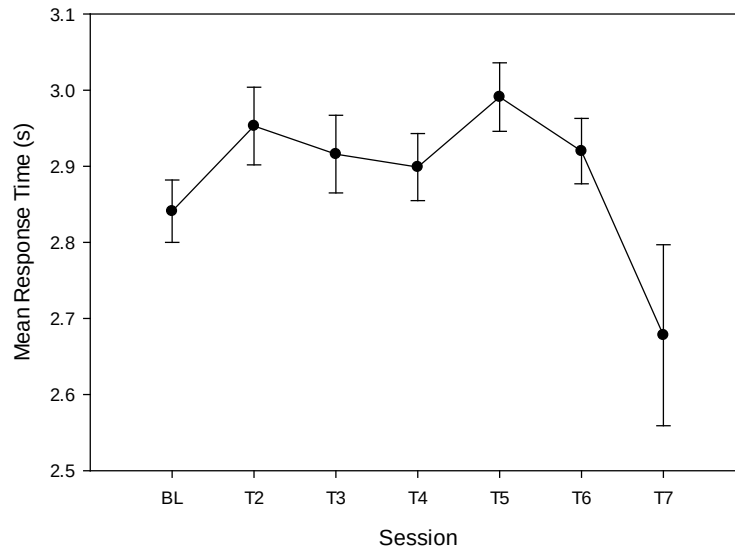


Figure 44. Dichotic Listening CorrRT Session Main Effect

There was not a significant main effect of condition ($F(1, 22) = .811, p = .378, \eta_p^2 = .036$). The means for placebo and modafinil groups were 2.992 and 2.849, respectively, and the standard error for both groups was 0.058.

NIncorr: One participant from the modafinil group was excluded as an outlier for NIncorr. The assumption of sphericity was violated ($\chi^2(20) = 35.856, p = .017; \varepsilon = .849$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.096, 107.015) = 1.419, p = .222, \eta_p^2 = .063$). There was a significant main effect for session ($F(5.096, 107.015) = 3.532, p = .005, \eta_p^2 = .144$). Results are illustrated in Figure 45. Pairwise comparisons revealed significant differences between BL and T5 ($p = .032$), T2 and T4 ($p = .010$), T2 and T7 ($p = .027$), T4 and T5 ($p = .006$), T4 and T6 ($p = .043$), and T5 and T7 ($p = .005$). There was not a significant main effect of condition ($F(1, 21) = .295, p = .593, \eta_p^2 = .014$).

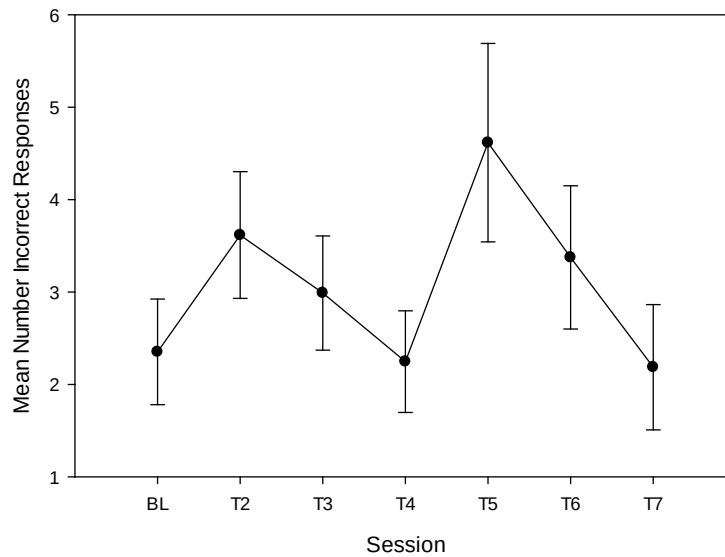


Figure 45. Dichotic Listening NIncorr Session Main Effect

IncorrRT: The assumption of sphericity was violated for IncorrRT ($\chi^2(20) = 36.147, p = .016; \varepsilon = .971$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.829, 128.233) = .389, p = .881, \eta_p^2 = .017$). There was not a significant main effect for session ($F(5.829, 128.233) = 1.907, p = .087, \eta_p^2 = .080$) or condition ($F(1, 22) = .526, p = .476, \eta_p^2 = .023$).

LatCorr: The mixed model ANOVA for LatCorr did not show a significant interaction between condition and session ($F(6, 132) = 1.313, p = .256, \eta_p^2 = .056$). There was not a significant main effect for session ($F(6, 132) = .743, p = .616, \eta_p^2 = .033$) or condition ($F(1, 22) = .385, p = .542, \eta_p^2 = .017$).

LatIncorr: The assumption of sphericity was violated for LatIncorr ($\chi^2(20) = 38.975, p < .007; \varepsilon = .739$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.436, 97.600) = 1.74, p = .141, \eta_p^2 = .073$). There was a significant main effect for session ($F(4.436, 97.600) = 3.485, p = .008, \eta_p^2 = .137$). Pairwise comparisons revealed significant differences between T2 and T3 ($p = .037$), T2 and T4 ($p = .002$), T2 and T7 ($p = .003$), T3 and T5 ($p = .049$), T4 and T5 ($p = .009$), T5 and T7 ($p = .001$), and T6 and T7 ($p = .042$). Results are illustrated in Figure 46. There was not a significant main effect for condition ($F(1, 22) = .188, p = .669, \eta_p^2 = .008$).

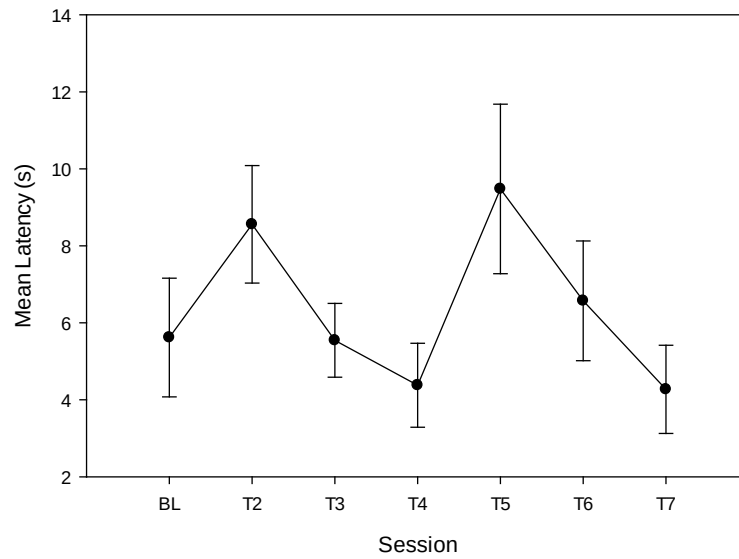


Figure 46. Dichotic Listening LatIncorr Session Main Effect

3.2.1.12 Visual Vigilance (NTI ATSTM).

NCorr: One participant from the placebo group was excluded as an outlier for Ncorr. The assumption of sphericity was violated ($\chi^2(20) = 145.421, p < .001; \epsilon = .300$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.798, 37.765) = 1.167, p = .318, \eta_p^2 = .053$). There was not a significant main effect for session ($F(1.798, 37.765) = .627, p = .523, \eta_p^2 = .029$) or condition ($F(1, 21) = .012, p = .903, \eta_p^2 = .001$).

CorrRT: One participant from the placebo group was excluded as an outlier for CorrRT. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 126) = .817, p = .559, \eta_p^2 = .037$). There was a significant main effect for session ($F(6, 126) = 5.287, p < .001, \eta_p^2 = .201$). Pairwise comparisons showed significant differences between BL and T2 ($p = .005$), BL and T3 ($p = .043$), T2 and T4 ($p = .015$), T2 and T6 ($p = .001$), T2 and T7 ($p < .001$), T3 and T4 ($p = .032$), T3 and T6 ($p = .009$), T3 and T7 ($p < .001$), T5 and T6 ($p = .022$), and T5 and T7 ($p = .004$). Results are illustrated in Figure 47. There was not a significant main effect for condition ($F(1, 21) = .379, p = .545, \eta_p^2 = .018$).

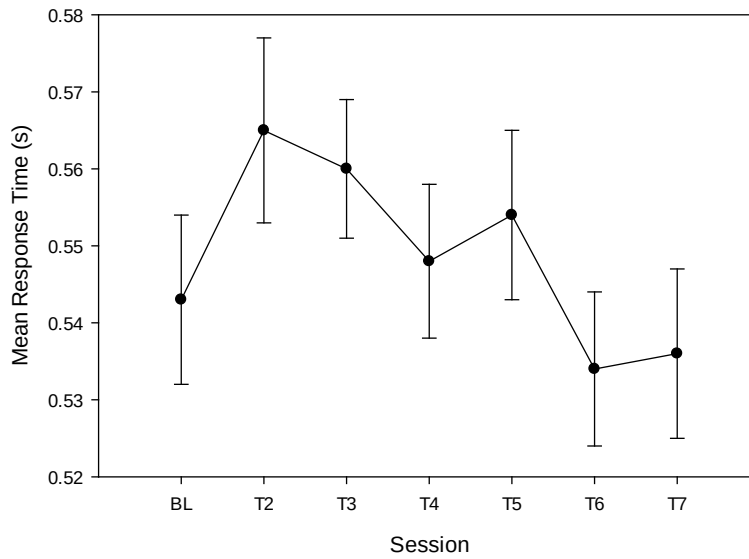


Figure 47. Visual Vigilance CorrRT Session Main Effect

NIncorr: One participant from the placebo group was excluded as an outlier for NIncorr. The assumption of sphericity was violated ($\chi^2(20) = 100.652, p < .001; \epsilon = .338$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(2.027, 42.573) = 1.259, p = .295, \eta_p^2 = .057$). There was not a significant main effect for session ($F(2.027, 42.573) = .881, p = .423, \eta_p^2 = .040$) or condition ($F(1, 21) = .073, p = .790, \eta_p^2 = .003$).

IncorrRT: The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 132) = .658, p = .683, \eta_p^2 = .029$). There was not a significant main effect for session ($F(6, 132) = .623, p = .712, \eta_p^2 = .028$) or condition ($F(1, 22) = 1.991, p = .172, \eta_p^2 = .083$).

NTO: One participant from the placebo group was excluded as an outlier for NTO. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 126) = .781, p = .586, \eta_p^2 = .036$). There was a significant main effect for session ($F(6, 126) = 2.762, p = .015, \eta_p^2 = .116$). Pairwise comparisons revealed significant differences between BL and T3 ($p = .018$), BL and T5 ($p = .049$), T2 and T3 ($p = .041$), T3 and T6 ($p = .049$), T3 and T7 ($p = .012$), and T5 and T7 ($p = .017$). Results are illustrated in Figure 48. There was not a significant main effect for condition ($F(1, 21) = .305, p = .587, \eta_p^2 = .014$).

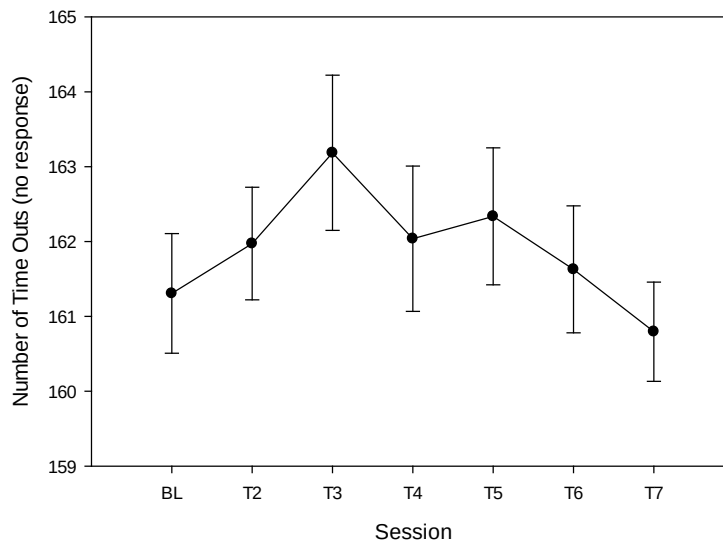


Figure 48. Visual Vigilance NTO Session Main Effect

3.2.1.13 Continuous Memory (NTI ATSTM).

NCorr: The mixed model ANOVA for Ncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.344, p = .242, \eta_p^2 = .058$). There was not a significant main effect for session ($F(6, 132) = 1.364, p = .234, \eta_p^2 = .058$) or condition ($F(1, 22) = 1.593, p = .220, \eta_p^2 = .068$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 53.035, p < .001; \varepsilon = .613$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.678, 80.911) = 1.333, p = .266, \eta_p^2 = .057$). There was a significant main effect for session ($F(3.678, 80.911) = 3.354, p = .016, \eta_p^2 = .132$). Pairwise comparisons revealed significant differences between BL and T6 ($p = .024$), BL and T7 ($p = .002$), T2 and T6 ($p = .014$), T2 and T7 ($p < .001$), T3 and T7 ($p = .007$), T4 and T6 ($p = .009$), and T4 and T7 ($p = .001$). Results are illustrated in Figure 49. There was not a significant main effect of condition ($F(1, 22) = .667, p = .423, \eta_p^2 = .029$).

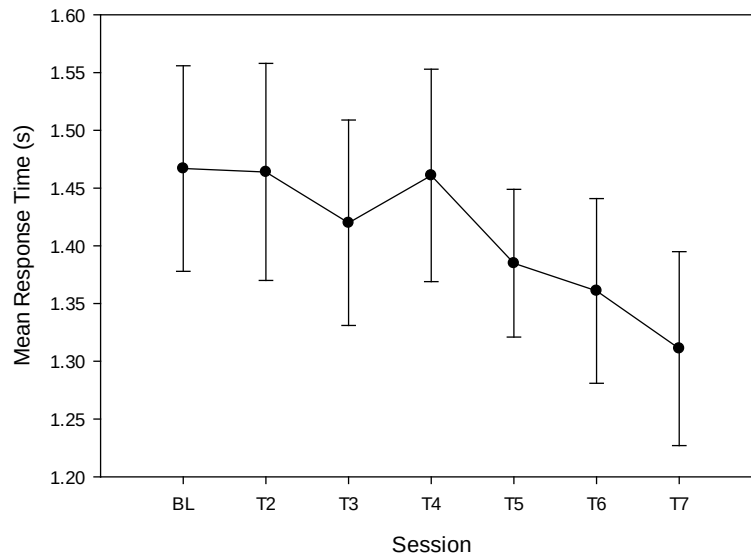


Figure 49. Continuous Memory CorrRT Session Main Effect

NIncorr: The mixed model ANOVA for NIncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.344, p = .242, \eta_p^2 = .058$). There was not a significant main effect for session ($F(6, 132) = 1.364, p = .234, \eta_p^2 = .058$) or condition ($F(1, 22) = 1.593, p = .220, \eta_p^2 = .068$).

IncorrRT: One participant from the modafinil group was excluded as an outlier for IncorrRT. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 132) = .872, p = .517, \eta_p^2 = .040$). There was a significant main effect for session ($F(6, 132) = 2.344, p = .035, \eta_p^2 = .100$). Pairwise comparisons showed significant differences between T3 and T4 ($p = .003$), T3 and T7 ($p = .028$), T4 and T5 ($p = .029$), and T5 and T7 ($p = .034$). Results are illustrated in Figure 50. There was not a significant main effect for condition ($F(1, 21) = 2.764, p = .111, \eta_p^2 = .116$).

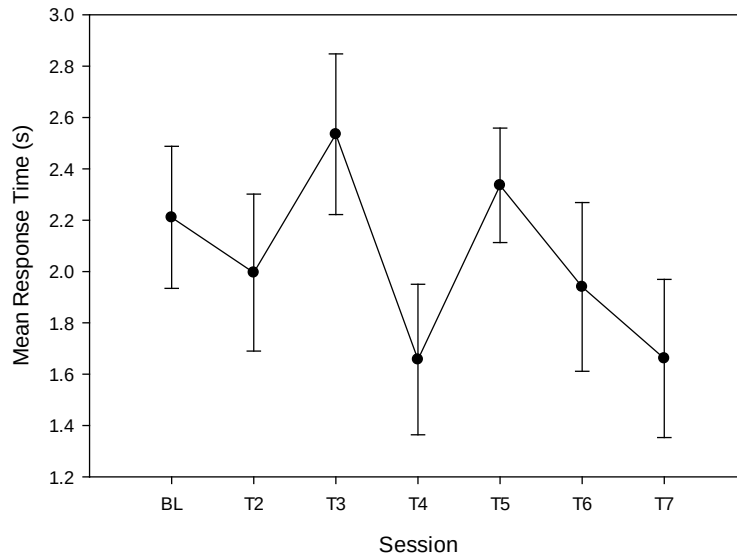


Figure 50. Continuous Memory IncorrRT Session Main Effect

NTO: The assumption of sphericity was violated for NTO ($\chi^2(20) = 50.849, p < .001; \epsilon = .663$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(3.976, 87.463) = 1.131, p = .347, \eta_p^2 = .049$). There was not a significant main effect for session ($F(3.976, 87.463) = 1.370, p = .251, \eta_p^2 = .059$) or condition ($F(1, 22) = 2.13, p = .159, \eta_p^2 = .088$).

3.2.1.14 Manikin Task (NTI ATSTM).

NCorr: The mixed model ANOVA for Ncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.189, p = .316, \eta_p^2 = .051$). There was not a significant main effect for session ($F(6, 132) = 1.644, p = .140, \eta_p^2 = .070$) or condition ($F(1, 22) = .144, p = .708, \eta_p^2 = .007$).

CorrRT: The assumption of sphericity was violated for CorrRT ($\chi^2(20) = 38.015, p = .009; \epsilon = .820$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.921, 108.267) = .406, p = .841, \eta_p^2 = .018$). There was a significant main effect for session ($F(4.921, 108.267) = 4.183, p = .002, \eta_p^2 = .160$). Pairwise comparisons showed significant differences between BL and T2 ($p = .001$), BL and T3 ($p = .003$), BL and T4 ($p = .025$), BL and T6 ($p = .028$), BL and T7 ($p = .003$), T2 and T5 ($p = .022$), T3 and T5 ($p = .016$), T5 and T6 ($p = .021$), and T5 and T7 ($p = .001$). Results are illustrated in Figure 51. There was not a significant main effect for condition ($F(1, 22) = .178, p = .677, \eta_p^2 = .008$).

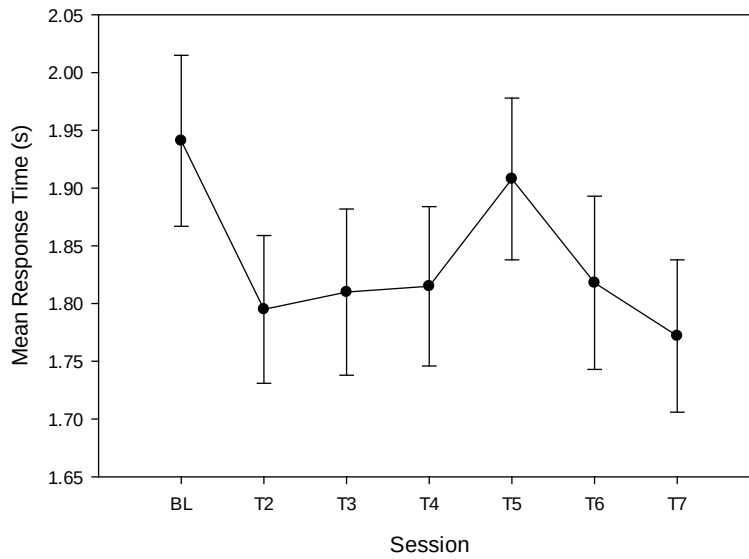


Figure 51. Manikin CorrRT Session Main Effect

NIncorr: The mixed model ANOVA for NIncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.215, p = .303, \eta_p^2 = .052$). There was not a significant main effect for session ($F(6, 132) = 1.747, p = .115, \eta_p^2 = .074$) or condition ($F(1, 22) = .282, p = .601, \eta_p^2 = .013$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .840, p = .541, \eta_p^2 = .037$). There was not a significant main effect for session ($F(6, 132) = 2.136, p = .053, \eta_p^2 = .088$) or condition ($F(1, 22) = 1.676, p = .209, \eta_p^2 = .071$).

NTO: One participant from the placebo group was excluded as an outlier for NTO. The assumption of sphericity was violated ($\chi^2(20) = 105.970, p < .001; \epsilon = .376$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(2.257, 47.406) = 1.007, p = .381, \eta_p^2 = .046$). There was not a main effect for session ($F(2.257, 47.406) = 1.096, p = .348, \eta_p^2 = .050$) or condition ($F(1, 21) = .437, p = .516, \eta_p^2 = .020$).

3.2.1.15 Motion Inference (NTI ATSTM).

Ncorr: The assumption of sphericity was violated for Ncorr ($\chi^2(20) = 37.712, p = .010; \epsilon = .812$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.870, 107.145) = 1.745, p = .132, \eta_p^2 = .073$). There was not a significant main effect for session ($F(4.870, 107.145) = 2.278, p = .053, \eta_p^2 = .094$) or condition ($F(1, 22) = 1.317, p = .264, \eta_p^2 = .056$).

CorrRT: The mixed model ANOVA for CorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.665, p = .134, \eta_p^2 = .070$). There was a significant main effect for session ($F(6, 132) = 3.198, p = .006, \eta_p^2 = .127$). Pairwise comparisons showed significant differences between BL and T7 ($p = .032$), T2 and T6 ($p = .041$), T2 and T7 ($p =$

.002), T3 and T7 ($p = .002$), T4 and T7 ($p = .001$), and T5 and T7 ($p < .001$). Results are illustrated in Figure 52. There was not a significant main effect for condition ($F(1, 22) = .782, p = .386, \eta_p^2 = .034$).

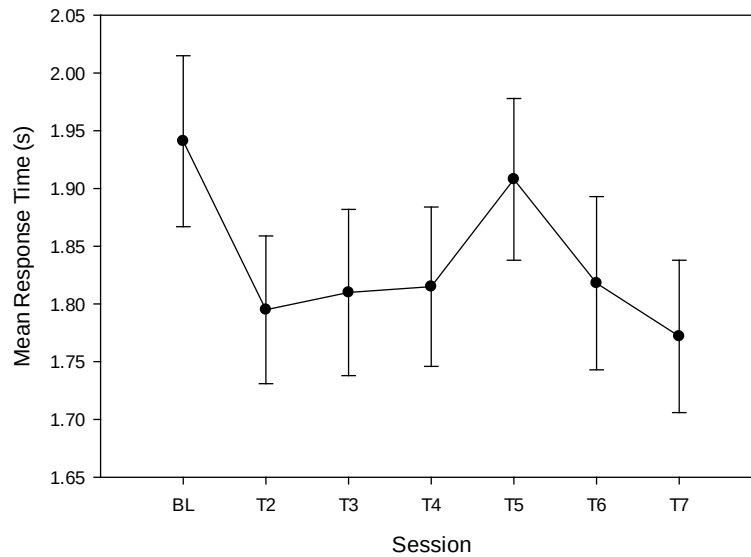


Figure 52. Motion Inference CorrRT Session Main Effect

NIncorr: The assumption of sphericity was violated for NIncorr ($\chi^2(20) = 38.672, p = .008; \epsilon = .777$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.660, 102.511) = 1.315, p = .266, \eta_p^2 = .056$). There was a significant main effect for session ($F(4.660, 102.511) = 2.386, p = .047, \eta_p^2 = .098$). Pairwise comparisons indicated significant differences between T2 and T5 ($p = .040$), T3 and T4 ($p = .025$), T3 and T5 ($p = .001$), and T5 and T6 ($p = .024$). Results are illustrated in Figure 53. There was not a significant main effect for condition ($F(1, 22) = .898, p = .354, \eta_p^2 = .039$).

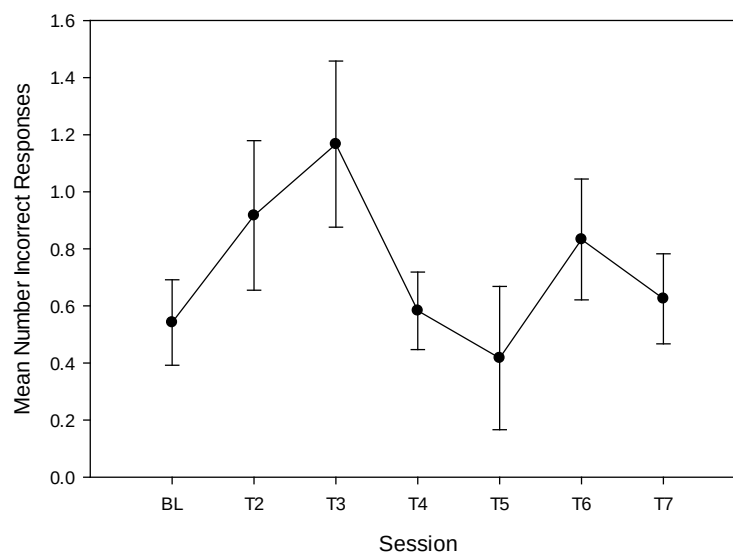


Figure 53. Motion Inference NIncorr Session Main Effect

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .835, p = .545, \eta_p^2 = .037$). There was not a significant main effect for session ($F(6, 132) = 1.051, p = .395, \eta_p^2 = .046$) or condition ($F(1, 22) = .406, p = .531, \eta_p^2 = .018$).

NLow: The mixed model ANOVA for responses before the hash mark (NLow) showed a significant interaction between condition and session ($F(6, 132) = 2.781, p = .014, \eta_p^2 = .112$). Simple effects analyses showed no significant effects between the groups at BL ($p = .304$), T2 ($p = .363$), T3 ($p = .412$), T4 ($p = .484$), T5 ($p = .285$), and T6 ($p = .118$); however, a significant effect was found between groups at T7 ($p = .036$). The placebo group averaged more low responses than the modafinil group. Within the placebo group, there was a significant main effect for session ($F(6, 66) = 4.081, p = .002$). Pairwise comparisons revealed significant differences between BL and T7 ($p = .007$), T2 and T4 ($p = .042$), T2 and T6 ($p = .006$), T2 and T7 ($p = .009$), T3 and T4 ($p = .004$), T3 and T6 ($p = .002$), T3 and T7 ($p = .002$), T5 and T6 ($p = .027$), and T5 and T7 ($p = .004$). Within the modafinil group, there was a significant main effect for session ($F(6, 66) = 2.931, p = .014$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .038$), T2 and T3 ($p = .005$), T2 and T4 ($p = .008$), T2 and T6 ($p = .030$), and T4 and T5 ($p = .037$). Results are illustrated in Figure 54.

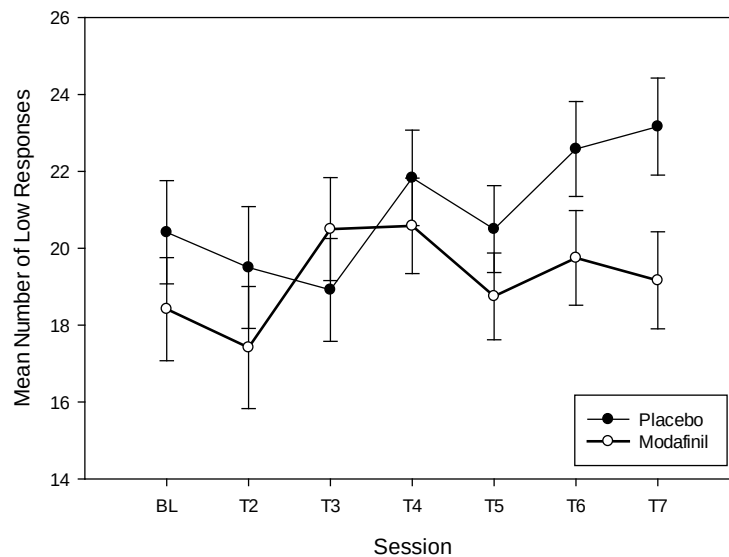


Figure 54. Motion Inference NLow Condition X Session Interaction

There was a significant main effect for session ($F(6, 132) = 4.410, p < .001, \eta_p^2 = .167$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .017$), BL and T7 ($p = .014$), T2 and T4 ($p = .002$), T2 and T6 ($p = .001$), T2 and T7 ($p = .007$), T3 and T4 ($p = .028$), T4 and T5 ($p = .013$), T5 and T6 ($p = .022$), and T5 and T7 ($p = .016$). Results are illustrated in Figure 55. There was not a significant main effect for condition ($F(1, 22) = 1.228, p = .280, \eta_p^2 = .053$).

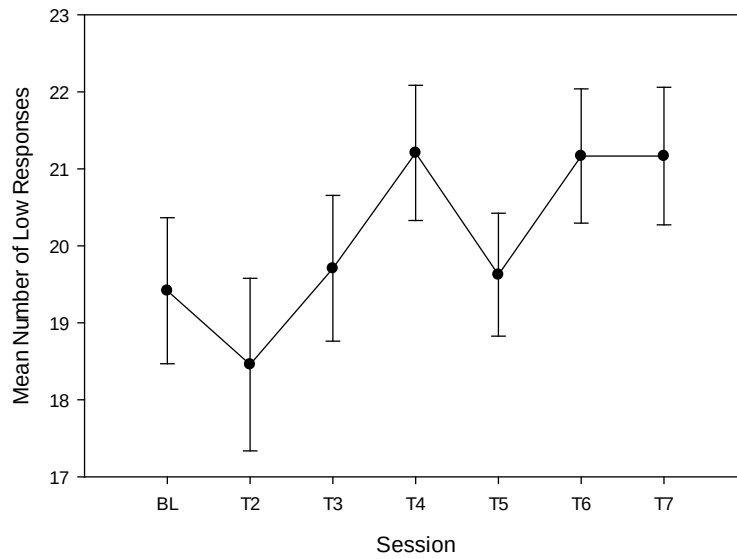


Figure 55. Motion Inference NLow Session Main Effect

LowRT: The mixed model ANOVA for LowRT did not show a significant interaction between condition and session ($F(6, 132) = .915, p = .487, \eta_p^2 = .040$). There was not a significant main effect for session ($F(6, 132) = .859, p = .527, \eta_p^2 = .038$) or condition ($F(1, 22) = 1.518, p = .231, \eta_p^2 = .065$).

NHigh: The mixed model ANOVA for responses after the hash mark (NHigh) showed a significant interaction between condition and session ($F(6, 132) = 2.922, p = .010, \eta_p^2 = .117$). Simple effects analyses showed no significant effects between groups at BL ($p = .304$), T2 ($p = .320$), T3 ($p = .412$), T4 ($p = .484$), T5 ($p = .285$), and T6 ($p = .103$); however, a significant effect was found between groups at T7 ($p = .036$). Within the placebo group, there was a significant main effect for session ($F(6, 66) = 4.258, p = .001$). Pairwise comparisons revealed significant differences between BL and T7 ($p = .007$), T2 and T4 ($p = .048$), T2 and T6 ($p = .007$), T2 and T7 ($p = .010$), T3 and T4 ($p = .004$), T3 and T6 ($p = .001$), T3 and T7 ($p = .002$), T5 and T6 ($p = .020$), and T5 and T7 ($p = .004$). Within the modafinil group, there was a significant main effect for session ($F(6, 66) = 2.931, p = .014$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .038$), T2 and T3 ($p = .004$), T2 and T4 ($p = .006$), T2 and T6 ($p = .031$), and T4 and T5 ($p = .037$). Results are illustrated in Figure 56.

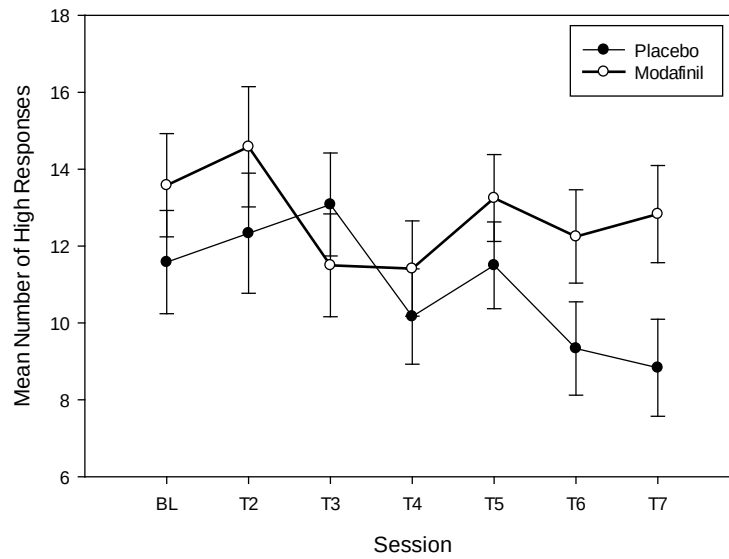


Figure 56. Motion Inference NHigh Condition X Session Interaction

There was a significant main effect for session ($F(6, 132) = 4.438, p < .001, \eta_p^2 = .168$). Pairwise comparisons revealed significant differences between BL and T4 ($p = .017$), BL and T7 ($p = .014$), T2 and T4 ($p = .001$), T2 and T6 ($p = .001$), T2 and T7 ($p = .007$), T3 and T4 ($p = .028$), T3 and T6 ($p = .046$), T4 and T5 ($p = .013$), T5 and T6 ($p = .016$), and T5 and T7 ($p = .016$). Results are illustrated in Figure 57. There was not a significant main effect for condition ($F(1, 22) = 1.28, p = .270, \eta_p^2 = .055$).

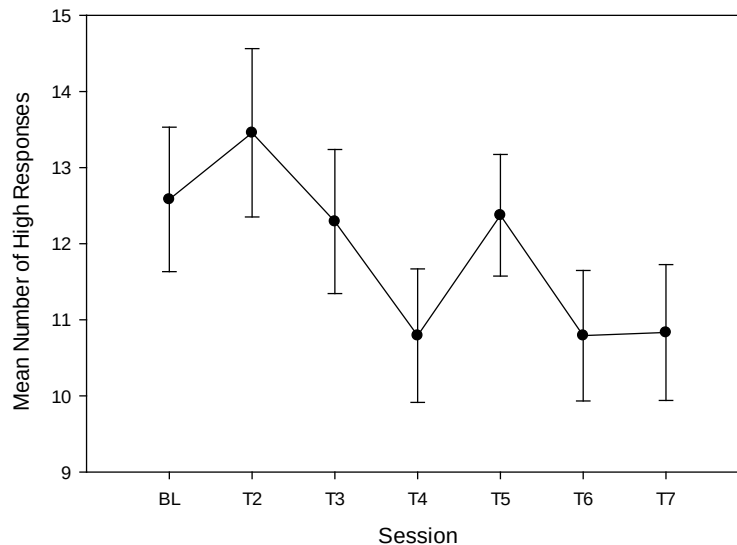


Figure 57. Motion Inference NHigh Session Main Effect

HighRT: The assumption of sphericity was violated for HighRT ($\chi^2(20) = 42.685, p = .002; \epsilon = .819$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.913, 108.084) = 1.481, p = .203, \eta_p^2 = .063$). There was a significant main effect for

session ($F(4.913, 108.084) = 2.593, p = .030, \eta_p^2 = .105$). Pairwise comparisons revealed significant differences between BL and T2 ($p = .012$), BL and T3 ($p = .005$), T2 and T4 ($p = .040$), T2 and T7 ($p = .011$), T3 and T7 ($p = .007$), and T5 and T7 ($p = .017$). Results are illustrated in Figure 58.

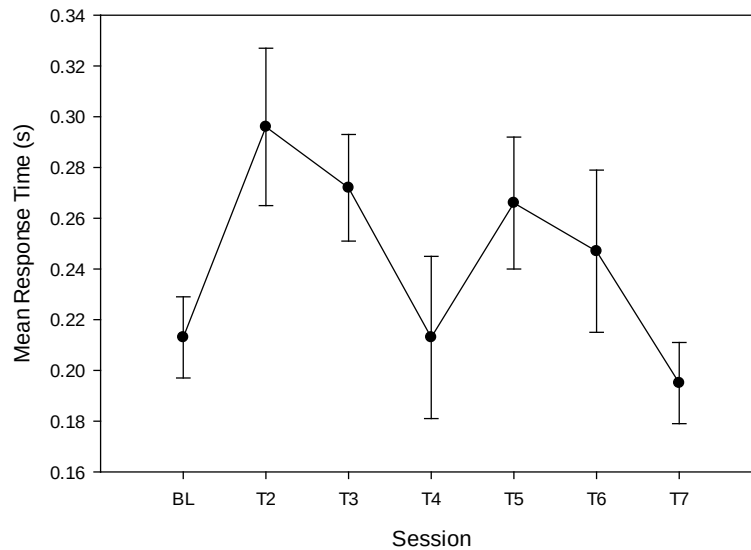


Figure 58. Motion Interference HighRT Session Main Effect

A significant main effect of condition was found ($F(1, 22) = 5.134, p = .034, \eta_p^2 = .189$). The means for placebo and modafinil groups were 30.905 and 31.321, respectively, and the standard error for both groups was .257.

3.2.1.15 Three-Choice Reaction Time (NTI ATSTM).

NCorr: The mixed model ANOVA for Ncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.313, p = .256, \eta_p^2 = .056$). There was not a significant main effect for session ($F(6, 132) = 1.462, p = .196, \eta_p^2 = .062$) or condition ($F(1, 22) = .122, p = .731, \eta_p^2 = .006$).

CorrRT: One participant from the placebo group was excluded as an outlier for CorrRT. The assumption of sphericity was violated ($\chi^2(20) = 44.440, p = .001; \epsilon = .657$). The mixed model ANOVA showed a significant interaction between condition and session ($F(3.945, 82.838) = 2.651, p = .040, \eta_p^2 = .112$). Simple effects analysis did not show any significant differences between the groups at BL ($p = .842$), T2 ($p = .346$), T3 ($p = .100$), T4 ($p = .476$), T5 ($p = .351$), T6 ($p = .766$), or T7 ($p = .632$). Within the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 37.181, p = .016; \epsilon = .542$). There was a significant main effect of session ($F(3.254, 32.537) = 3.008, p = .041$). Pairwise comparisons showed significant differences between BL and T2 ($p = .012$), BL and T3 ($p = .013$), BL and T5 ($p = .004$), T2 and T4 ($p = .049$), T2 and T7 ($p = .011$), T3 and T4 ($p = .028$), T3 and T7 ($p = .014$), T4 and T5 ($p = .034$), T5 and T6 ($p = .041$), and T5 and T7 ($p = .003$). Within the modafinil group, there was not a significant main effect of session ($F(6, 66) = 2.144, p = .060$). Results are illustrated in Figure 59.

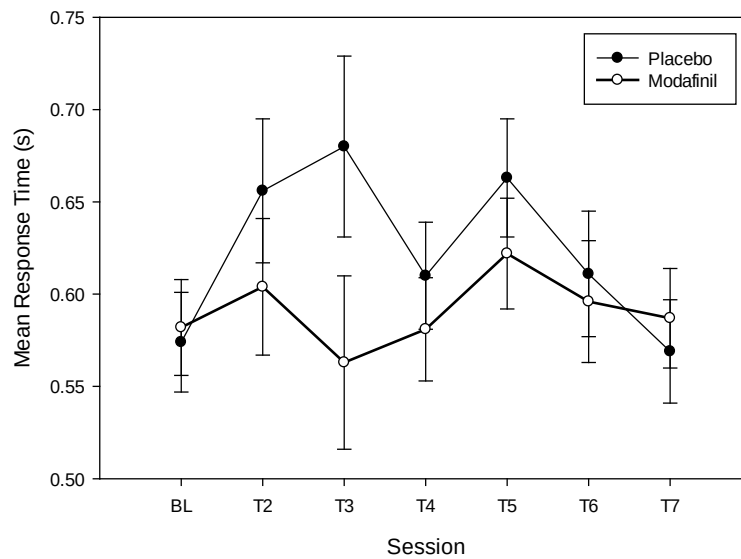


Figure 59. Three-Choice Reaction Time CorrRT Condition X Session Interaction

There was a significant main effect for session ($F(3.945, 82.838) = 3.313, p = .015, \eta_p^2 = .136$). Pairwise comparisons showed significant differences between BL and T2 ($p = .020$), BL and T5 ($p = .003$), T2 and T4 ($p = .034$), T2 and T7 ($p = .026$), T4 and T5 ($p = .009$), T5 and T6 ($p = .030$), and T5 and T7 ($p = .004$). Results are illustrated in Figure 60. There was no significant main effect for condition ($F(1, 21) = .640, p = .433, \eta_p^2 = .030$).

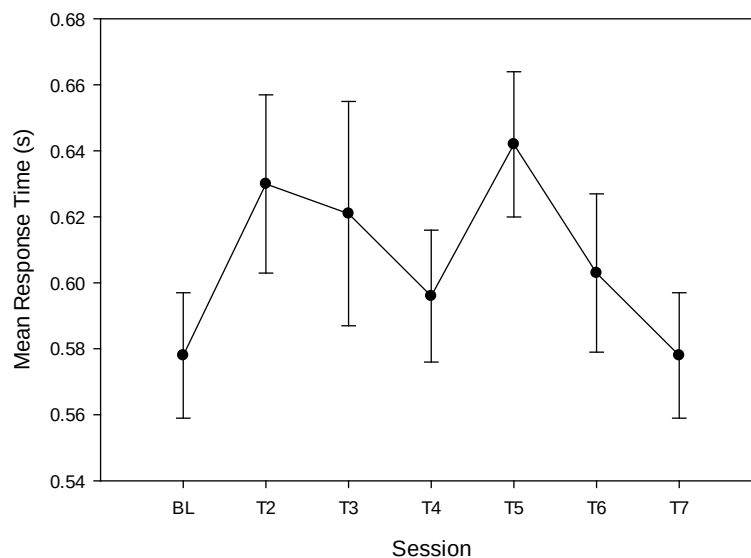


Figure 60. Three-Choice Reaction Time CorrRT Session Main Effect

NIncorr: The mixed model ANOVA for NIncorr did not show a significant interaction between condition and session ($F(6, 132) = 1.313, p = .256, \eta_p^2 = .056$). There was not a significant main effect for session ($F(6, 132) = 1.462, p = .196, \eta_p^2 = .062$) or condition ($F(1, 22) = .122, p = .731, \eta_p^2 = .006$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .305, p = .933, \eta_p^2 = .014$). There was not a significant main effect for session ($F(6, 132) = .914, p = .487, \eta_p^2 = .040$) or condition ($F(1, 22) = .916, p = .349, \eta_p^2 = .040$).

3.2.1.16 Digit span (auditory) (NTI AMSTM).

NCorr: The mixed model ANOVA for Ncorr responses showed a significant interaction between condition and session ($F(6, 132) = 2.253, p = .042, \eta_p^2 = .093$). Simple effects analyses did not show any significant differences between the groups at BL ($p = .277$), T2 ($p = .205$), T3 ($p = .624$), T4 ($p = .601$), T5 ($p = .611$), T6 ($p = .708$), or T7 ($p = .726$). Within the placebo group, there was not a significant main effect of session ($F(6, 66) = 1.042, p = .406$). Within the modafinil group, there was not a significant main effect of session ($F(6, 66) = 2.217, p = .052$). Results are illustrated in Figure 61.

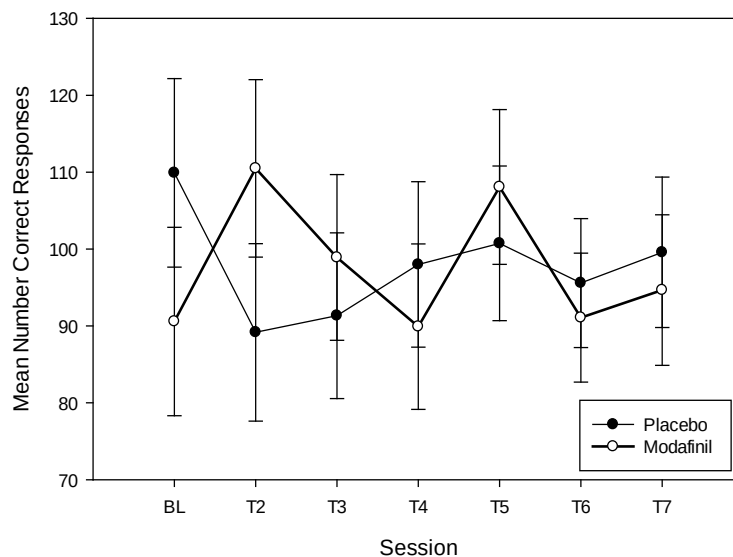


Figure 61. Digit Span NCorr Condition X Session Interaction

There was not a significant main effect for session ($F(6, 132) = .826, p = .552, \eta_p^2 = .036$) or condition ($F(1, 22) = 0, p = .995, \eta_p^2 = .0$).

CorrRT: The mixed model ANOVA for CorrRT did not show a significant interaction between condition and session ($F(6, 132) = 1.563, p = .163, \eta_p^2 = .066$). There was not a significant main effect for session ($F(6, 132) = 1.941, p = .079, \eta_p^2 = .081$) or condition ($F(1, 22) = .513, p = .482, \eta_p^2 = .023$).

NIncorr: One participant from the modafinil group was excluded as an outlier for NIncorr. The assumption of sphericity was violated ($\chi^2(20) = 36.327, p = .015$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.796, 121.724) = .598, p = .726, \eta_p^2 = .028$). There was not a significant main effect for session ($F(5.796, 121.724) = .752, p = .604, \eta_p^2 = .035$) or condition ($F(1, 21) = 2.506, p = .128, \eta_p^2 = .107$).

IncorrRT: The mixed model ANOVA for IncorrRT did not show a significant interaction between condition and session ($F(6, 132) = .982, p = .440, \eta_p^2 = .043$). There was not a significant main effect for session ($F(6, 132) = 1.864, p = .092, \eta_p^2 = .078$) or condition ($F(1, 22) = .002, p = .961, \eta_p^2 = .0$).

NTO: One participant from the placebo group and one participant from the modafinil group were excluded as outliers for NTO. The mixed model ANOVA did not show a significant interaction between condition and session ($F(6, 120) = 1.115, p = .358, \eta_p^2 = .053$). There was not a significant main effect for session ($F(6, 120) = .439, p = .851, \eta_p^2 = .021$) or condition ($F(1, 20) = .500, p = .488, \eta_p^2 = .024$).

3.2.2 Mood and side effects assessments. Mood was measured with two questionnaires, the Profile of Mood States (POMS) and the Visual Analogue Scale (VAS). Participants indicated any side effects they may have experienced on the Side Effects (SE) questionnaire. These assessments were administered at the end of each of the testing sessions. A summary of the significant results are presented in Table 27.

Table 27. Summary statistics for significant factors from the POMS and VAS

Mood Assessment	Factors	Effect	F (df)	p	η_p^2
POMS	Vigor	Condition X Session Interaction	$F(6, 114) = 2.263$	.042	.106
		Session Main Effect	$F(6, 114) = 5.571$	< .001	.227
		Condition X Session Interaction	$F(5.553, 105.503) = 3.461$	.005	.154
	Fatigue	Session Main Effect	$F(5.553, 105.503) = 5.957$	< .001	.239
		Condition Main Effect	$F(1, 19) = 4.669$	.044	.197
		Condition X Session Interaction	$F(2.675, 50.827) = 3.644$	.022	.161
	TMD	Session Main Effect	$F(2.675, 50.827) = 5.286$	.004	.218
		Condition X Session Interaction	$F(6, 120) = 5.026$	< .001	.201
	Alert	Session Main Effect	$F(6, 120) = 3.422$	.004	.146
VAS	Anxious	Session Main Effect	$F(4.538, 90.769) = 3.980$	.004	.166
	Energetic	Condition X Session Interaction	$F(6, 120) = 2.428$	.030	.108
		Session Main Effect	$F(6, 120) = 3.937$	.001	.164
	Confidence	Session Main Effect	$F(4.083, 81.654) = 3.054$	.021	.132
	Sleepiness	Condition X Session Interaction	$F(4.918, 98.355) = 3.647$	.005	.154
	Talkative	Session Main Effect	$F(5.012, 100.232) = 3.350$	.008	.143
		Condition X Session Interaction			

3.2.2.1 *POMS*. All six factors from the *POMS* – tension, depression, anger, vigor, fatigue, and confusion, including the Total Mood Disturbance score – were analyzed. The results from these analyses are presented below. One person from the placebo group and two people from the modafinil group were excluded from the analysis due to missing data. Therefore, unless otherwise noted, there were 11 participants in the placebo group and 10 participants in the modafinil group.

Tension: The assumption of sphericity was violated ($\chi^2(20) = 99.641, p < .001; \epsilon = .324$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.943, 36.909) = 1.145, p = .328, \eta_p^2 = .057$). There was not a significant main effect for session ($F(1.943, 36.909) = 2.822, p = .074, \eta_p^2 = .129$) or condition ($F(1, 19) = 1.589, p = .223, \eta_p^2 = .077$).

Depression: The assumption of sphericity was violated ($\chi^2(20) = 168.470, p < .001; \epsilon = .245$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.471, 27.952) = 2.265, p = .134, \eta_p^2 = .107$). There was not a significant main effect for session ($F(1.471, 27.952) = 1.457, p = .247, \eta_p^2 = .071$) or condition ($F(1, 19) = 2.321, p = .144, \eta_p^2 = .109$).

Anger: An additional participant was excluded from the modafinil group due to being an outlier. The assumption of sphericity was violated ($\chi^2(20) = 124.056, p < .001; \epsilon = .269$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(1.611, 28.999) = 1.778, p = .191, \eta_p^2 = .090$). There was not a significant main effect for session ($F(1.611, 28.999) = 1.019, p = .358, \eta_p^2 = .054$) or condition ($F(1, 18) = 1.039, p = .322, \eta_p^2 = .055$).

Vigor: The mixed model ANOVA revealed a significant interaction between condition and session ($F(6, 114) = 2.263, p = .042, \eta_p^2 = .106$). Simple effects analysis did not show any significant differences between groups at BL ($p = .381$), T2 ($p = .547$), T3 ($p = .373$), T4 ($p = .881$), T5 ($p = .729$), T6 ($p = .309$), and T7 ($p = .854$). Within the placebo group, there was a significant main effect of session ($F(6, 60) = 4.142, p = .002$). Pairwise comparisons showed significant differences between BL and T2 ($p = .003$), BL and T4 ($p = .009$), BL and T5 ($p = .001$), BL and T6 ($p = .037$), and BL and T7 ($p = .004$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 52.203, p < .001; \epsilon = .570$). There was a significant main effect of session ($F(3.419, 30.772) = 3.722, p = .018$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .036$), T2 and T3 ($p = .023$), T3 and T4 ($p = .008$), T3 and T5 ($p = .001$), T3 and T6 ($p = .001$), and T3 and T7 ($p = .015$). Results are illustrated in Figure 62.

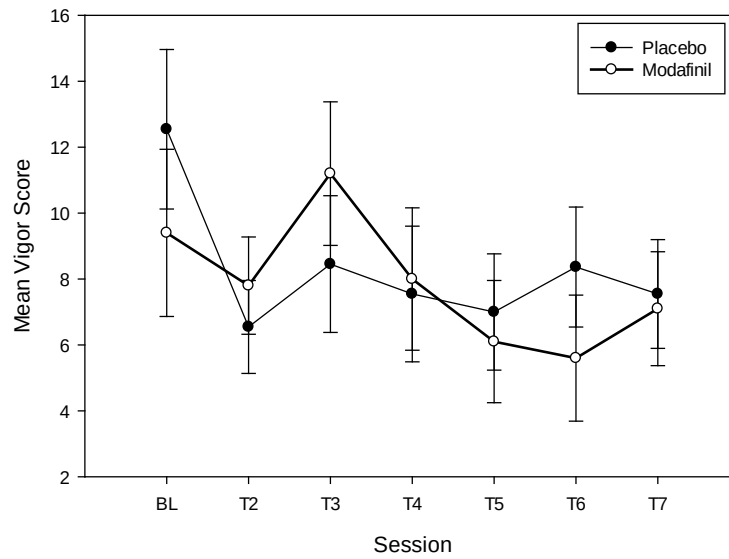


Figure 62. POMS Vigor Condition X Session Interaction

There was a significant main effect for session ($F(6, 114) = 5.571, p < .001, \eta_p^2 = .227$). Pairwise comparisons showed significant differences between BL and T2 ($p = .008$), BL and T4 ($p = .019$), BL and T5 ($p < .001$), BL and T6 ($p = .008$), BL and T7 ($p = .003$), T2 and T3 ($p = .012$), T3 and T4 ($p = .013$), T3 and T5 ($p = .002$), T3 and T6 ($p = .009$), and T3 and T7 ($p = .028$). Results are illustrated in Figure 63. There was not a significant main effect for condition ($F(1, 19) = .027, p = .872, \eta_p^2 = .001$).

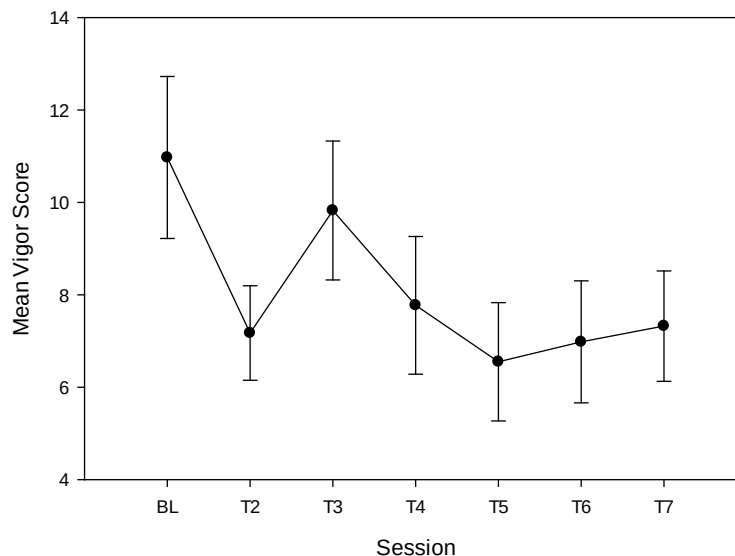


Figure 63. POMS Vigor Session Main Effect

Fatigue: The assumption of sphericity was violated ($\chi^2(20) = 42.359, p = .003; \epsilon = .925$). The mixed model ANOVA revealed a significant interaction between condition and session ($F(5.553, 105.503) = 3.461, p = .005, \eta_p^2 = .154$). Simple effects analysis showed significant differences between groups at BL ($p = .048$), T6 ($p = .004$), and T7 ($p = .009$), and no significant differences

between groups at T2 ($p = .625$), T3 ($p = .976$), T4 ($p = .090$), and T5 ($p = .081$). Within the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 34.012$, $p = .036$; $\epsilon = .880$). There was a significant main effect of session ($F(5.278, 52.776) = 5.152$, $p = .001$). Pairwise comparisons showed significant differences between BL and T2 ($p = .026$), BL and T3 ($p = .037$), BL and T5 ($p = .020$), and BL and T7 ($p = .004$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 33.912$, $p = .040$; $\epsilon = .996$). There was a significant main effect of session ($F(5.973, 53.758) = 4.270$, $p = .001$). Pairwise comparisons showed significant differences between BL and T5 ($p = .020$), BL and T6 ($p = .013$), BL and T7 ($p = .001$), T2 and T5 ($p = .005$), T2 and T6 ($p = .003$), T2 and T7 ($p < .001$), T3 and T4 ($p = .004$), T3 and T5 ($p = .001$), T3 and T6 ($p = .002$), and T3 and T7 ($p < .001$). Results are illustrated in Figure 64.

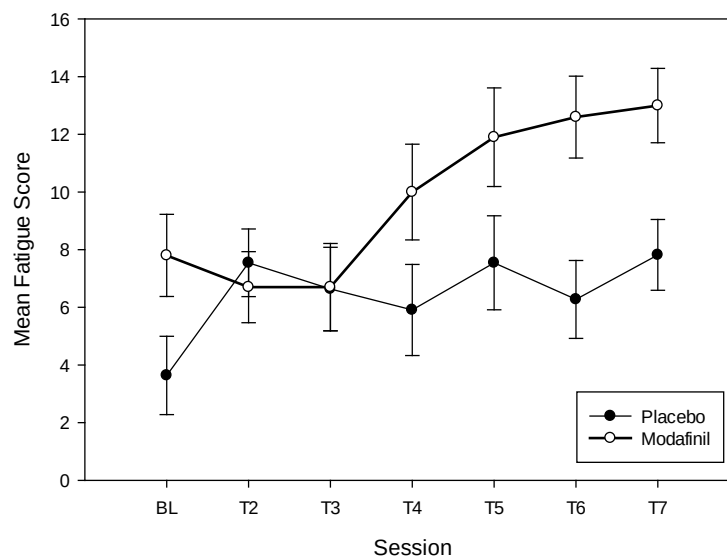


Figure 64. POMS Fatigue Condition X Session Interaction

There was a significant main effect for session ($F(5.553, 105.503) = 5.957$, $p < .001$, $\eta_p^2 = .239$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .002$), BL and T6 ($p = .006$), BL and T7 ($p < .001$), T2 and T5 ($p = .033$), T2 and T7 ($p = .005$), T3 and T5 ($p = .003$), T3 and T6 ($p = .022$), T3 and T7 ($p = .001$), T4 and T5 ($p = .048$), and T4 and T7 ($p = .047$). Results are illustrated in Figure 65.

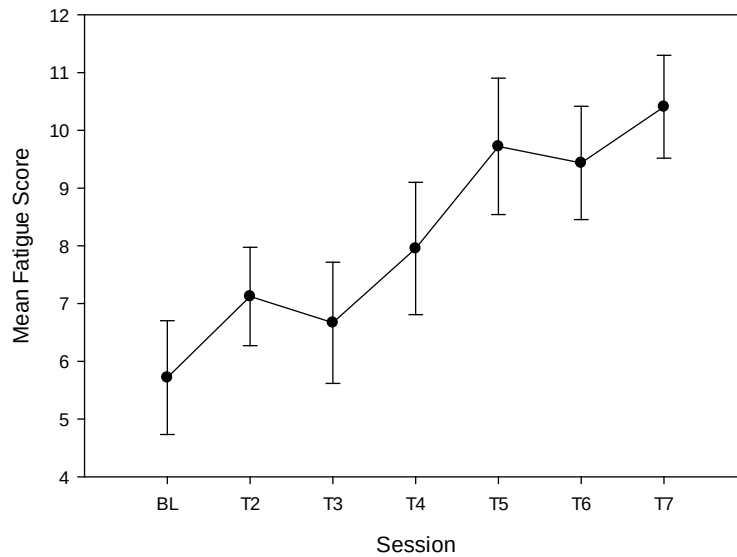


Figure 65. POMS Fatigue Session Main Effect

There are also a significant main effect for condition ($F(1, 19) = 4.669, p = .044, \eta_p^2 = .197$). The means for placebo and modafinil groups were 7.83 and 6.70, respectively. The standard errors for placebo and modafinil groups were 1.107 and 1.239, respectively.

Confusion: For this analysis, an additional participant was excluded from the modafinil group due to being an outlier. The assumption of sphericity was violated ($\chi^2(20) = 85.382, p < .001; \varepsilon = .400$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(2.401, 43.211) = 2.167, p = .118, \eta_p^2 = .107$). There was not a significant main effect for session ($F(2.401, 43.211) = 1.448, p = .245, \eta_p^2 = .074$) or condition ($F(1, 18) = 1.269, p = .275, \eta_p^2 = .066$).

Total Mood Disturbance (TMD): The assumption of sphericity was violated ($\chi^2(20) = 74.850, p < .001; \varepsilon = .446$). The mixed model ANOVA revealed a significant interaction between condition and session ($F(2.675, 50.827) = 3.644, p = .022, \eta_p^2 = .161$). Simple effects analysis showed a significant difference between groups at T6 ($p = .046$), and no significant differences between groups at BL ($p = .055$), T2 ($p = .833$), T3 ($p = .825$), T4 ($p = .183$), T5 ($p = .084$), and T7 ($p = .103$). Within the placebo group, there was a significant main effect of session ($F(6, 60) = 4.034, p = .002$). Pairwise comparisons showed significant differences between BL and T2 ($p = .005$), but not between any of the other sessions. Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 67.230, p < .001; \varepsilon = .407$). There was a significant main effect of session within the modafinil group ($F(2.443, 21.983) = 4.156, p = .023$). Pairwise comparisons showed a significant difference between BL and T5 ($p = .011$), BL and T6 ($p = .017$), BL and T7 ($p = .031$), T2 and T5 ($p = .007$), T2 and T6 ($p = .009$), T2 and T7 ($p = .015$), T3 and T4 ($p = .001$), T3 and T5 ($p < .001$), T3 and T6 ($p < .001$), T3 and T7 ($p = .001$), T4 and T5 ($p = .012$), and T4 and T6 ($p = .014$). Results are illustrated in Figure 66.

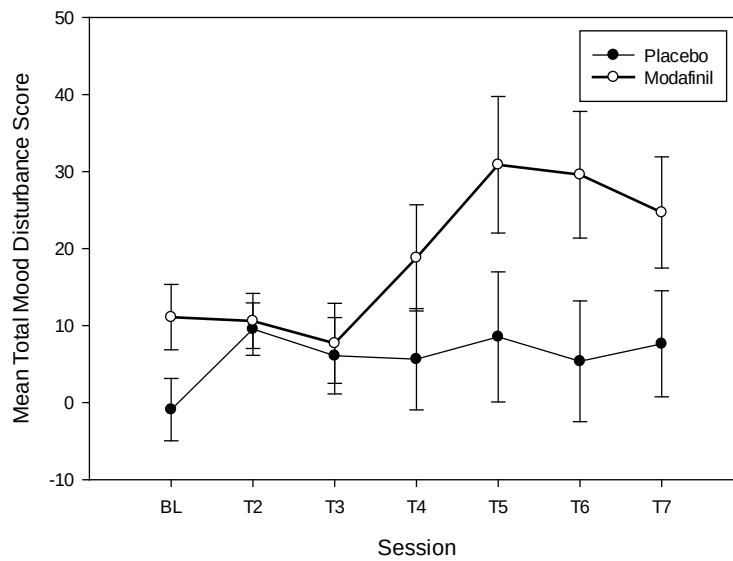


Figure 66. POMS Total Mood Disturbance Condition X Session Interaction

There was a significant main effect for session ($F(2.675, 50.827) = 5.286, p = .004, \eta_p^2 = .218$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .007$), BL and T6 ($p = .020$), BL and T7 ($p = .013$), T2 and T5 ($p = .050$), T3 and T4 ($p = .014$), T3 and T5 ($p = .003$), T3 and T6 ($p = .005$), T3 and T7 ($p = .004$), and T4 and T5 ($p = .021$). Results are illustrated in Figure 67. There was not a significant main effect for condition ($F(1, 19) = 2.710, p = .116, \eta_p^2 = .125$).

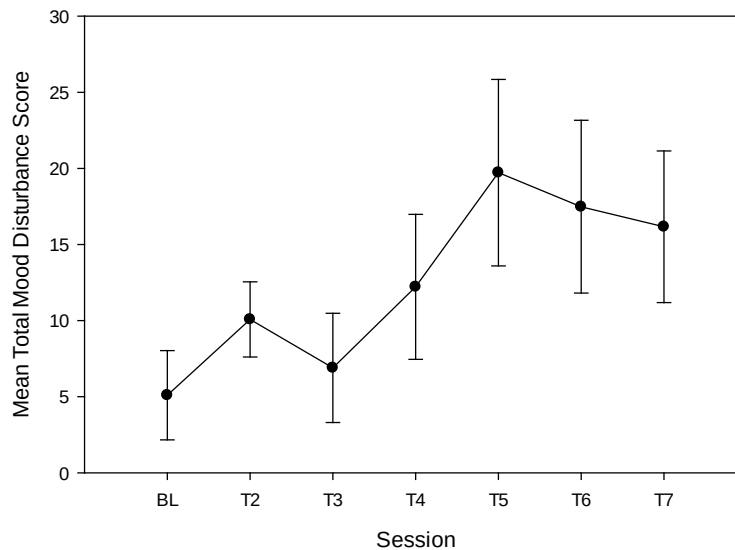


Figure 67. POMS Total Mood Disturbance Session Main Effect

3.2.2.2 VAS. All eight factors from the VAS – able/able to concentrate, anxious, energetic, confidence, irritable, jittery/nervous, sleepiness, and talkative – were analyzed, and the results from these analyses are presented below. As with the POMS, one person from the placebo group and two people from the modafinil group were excluded from the analysis due to missing data.

Therefore, unless otherwise noted, there were 11 participants in the placebo group and 10 participants in the modafinil group.

Alert/able to concentrate: The mixed model ANOVA revealed a significant interaction between condition and session ($F(6, 120) = 5.026, p < .001, \eta_p^2 = .201$). Simple effects analysis showed significant differences between groups at T6 ($p = .003$) and T7 ($p = .015$); however, no significant differences were found between groups at BL ($p = .353$), T2 ($p = .194$), T3 ($p = .299$), T4 ($p = .727$), and T5 ($p = .266$). Within the placebo group, the assumption of sphericity was violated ($\chi^2(20) = 34.758, p = .028; \epsilon = .691$). There was a significant main effect of session ($F(4.146, 45.610) = 3.662, p = .011$). Pairwise comparisons showed significant differences between BL and T2 ($p = .005$), BL and T5 ($p = .012$), T2 and T6 ($p = .010$), T2 and T7 ($p = .007$), T5 and T6 ($p = .016$), and T5 and T7 ($p = .010$). Within the modafinil group, there was a significant main effect of session ($F(6, 54) = 4.566, p = .001$). Pairwise comparisons showed significant differences between BL and T5 ($p = .014$), BL and T6 ($p = .003$), BL and T7 ($p = .050$), T2 and T5 ($p = .004$), T2 and T6 ($p = .002$), T3 and T5 ($p = .001$), T3 and T6 ($p = .001$), T3 and T7 ($p = .038$), T4 and T5 ($p = .031$), and T4 and T6 ($p = .005$). Results are illustrated in Figure 68.

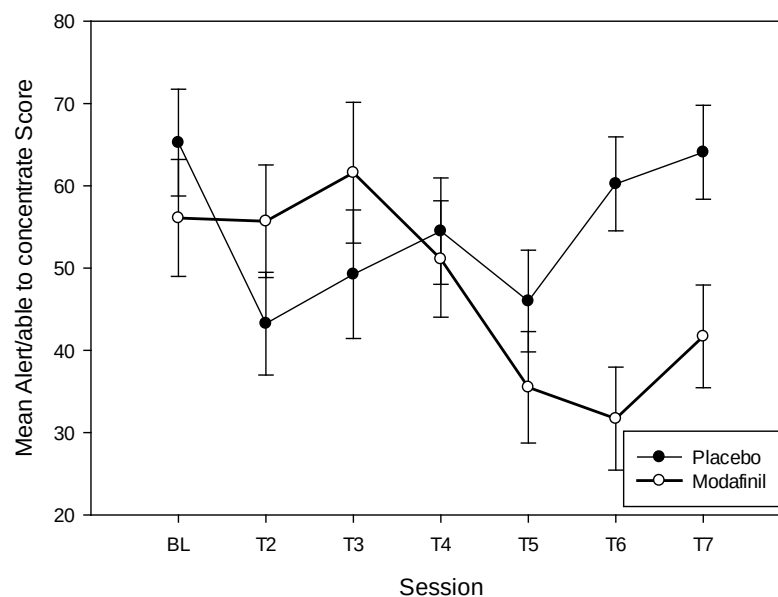


Figure 68. VAS Alert/Able to Concentrate Condition X Session Interaction

There was a significant main effect for session ($F(6, 120) = 3.422, p = .004, \eta_p^2 = .146$). Pairwise comparisons showed significant differences between BL and T2 ($p = .044$), BL and T5 ($p = .001$), BL and T6 ($p = .007$), T3 and T5 ($p = .003$), T4 and T5 ($p = .015$), and T5 and T7 ($p = .018$). Results are illustrated in Figure 69. There was no significant main effect for condition ($F(1, 20) = 1.025, p = .323, \eta_p^2 = .049$).

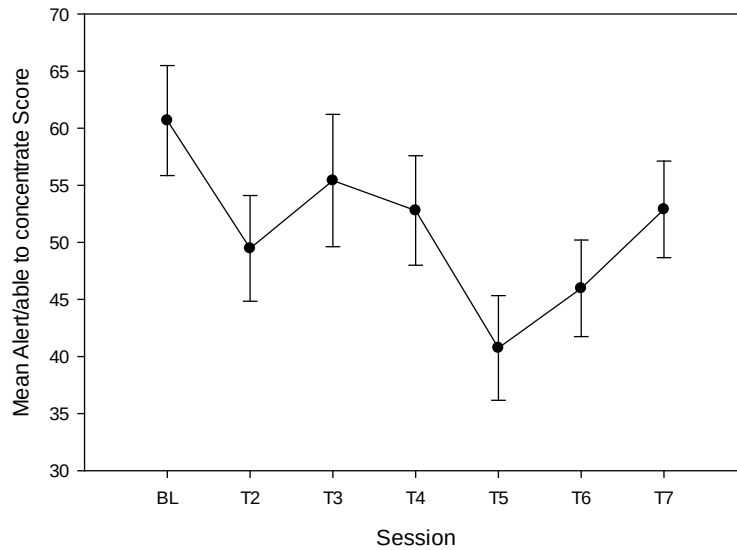


Figure 69. VAS Alert/Able to Concentrate Session Main Effect

Anxious: The assumption of sphericity was violated ($\chi^2(20) = 46.183, p = .001; \epsilon = .756$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.538, 90.769) = 1.668, p = .157, \eta_p^2 = .077$). There was a significant main effect for session ($F(4.538, 90.769) = 3.980, p = .004, \eta_p^2 = .166$). Pairwise comparisons revealed significant differences between BL and T6 ($p = .044$), BL and T7 ($p = .010$), T2 and T5 ($p = .024$), T2 and T6 ($p = .031$), T2 and T7 ($p = .005$), T3 and T7 ($p = .024$), and T4 and T7 ($p = .032$). Results are illustrated in Figure 70. There was no significant main effect of condition ($F(1, 20) = .572, p = .458, \eta_p^2 = .028$).

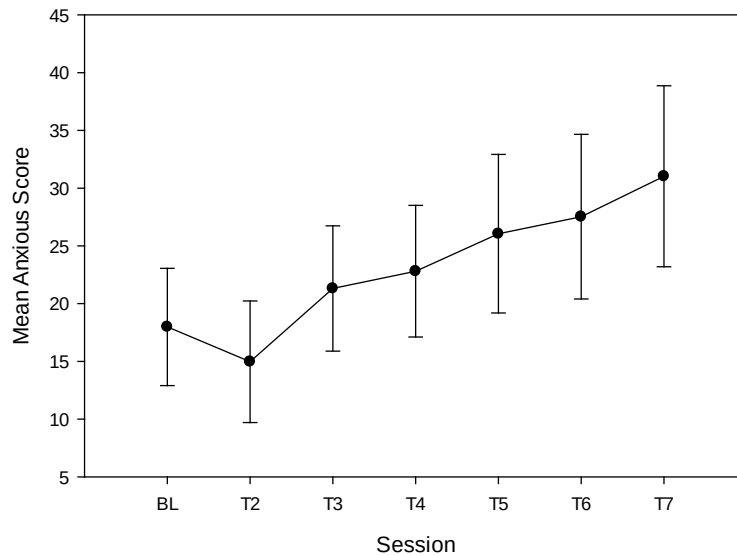


Figure 70. VAS Anxious Session Main Effect

Energetic: The mixed model ANOVA revealed a significant interaction between condition and session ($F(6, 120) = 2.428, p = .030, \eta_p^2 = .108$). Simple effects analysis showed a significant difference between groups at T6 ($p = .048$); however, no significant differences were found between groups at BL ($p = .136$), T2 ($p = .480$), T3 ($p = .496$), T4 ($p = .878$), T5 ($p = .305$) and T7 ($p = .376$). Within the placebo group, there was a significant main effect for session ($F(6, 66) = 3.614, p = .004$). Pairwise comparisons showed significant differences between BL and T2 ($p = .001$), BL and T4 ($p = .034$), BL and T5 ($p = .009$), T2 and T3 ($p = .035$), and T2 and T6 ($p = .046$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 36.064, p = .024; \epsilon = .941$). There was a significant main effect of session ($F(5.643, 50.788) = 2.769, p = .023$). Pairwise comparisons showed significant differences between BL and T6 ($p = .029$), T2 and T3 ($p = .027$), T3 and T5 ($p = .001$), T3 and T6 ($p = .001$), T3 and T7 ($p = .015$), and T4 and T6 ($p = .013$). Results are shown in Figure 71.

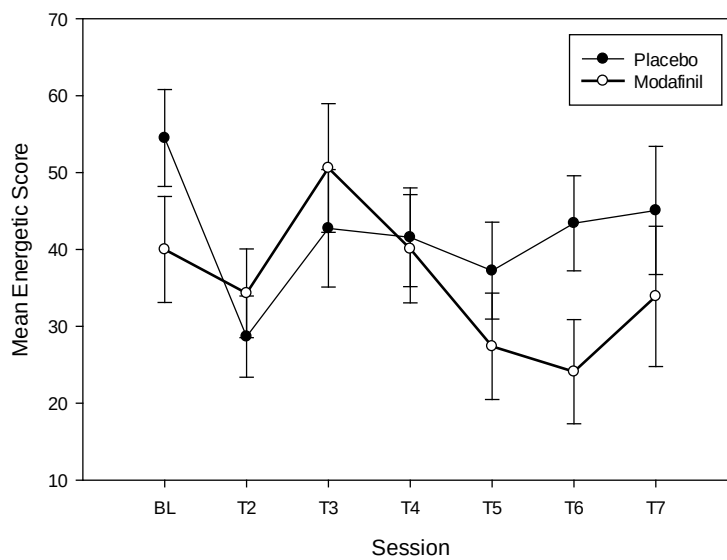


Figure 71. VAS Energetic Condition X Session Interaction

There was a significant main effect for session ($F(6,120) = 3.937, p = .001, \eta_p^2 = .164$). Pairwise comparisons showed significant differences between BL and T2 ($p = .006$), BL and T5 ($p = .003$), BL and T6 ($p = .008$), T2 and T3 ($p = .004$), T3 and T5 ($p = .003$), and T3 and T6 ($p = .011$). Results are illustrated in Figure 72. There was no significant main effect for condition ($F(1, 20) = .611, p = .443, \eta_p^2 = .030$).

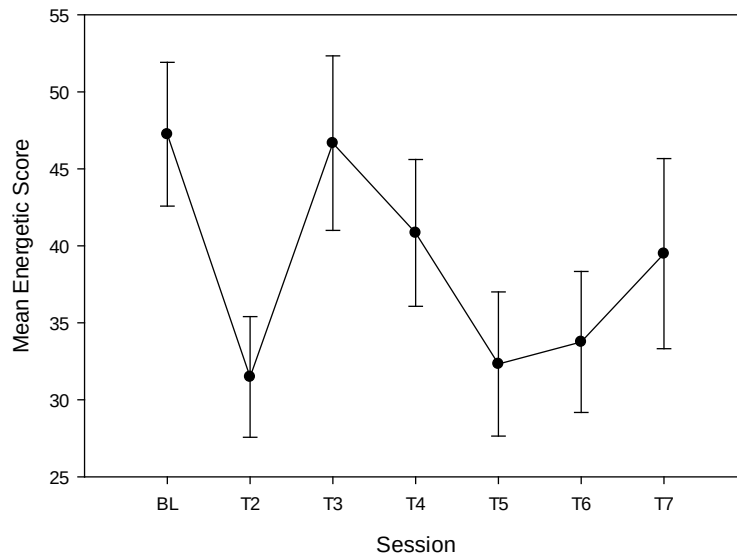


Figure 72. VAS Energetic Session Main Effect

Confidence: The assumption of sphericity was violated ($\chi^2(20) = 47.900, p = .001; \varepsilon = .680$). The mixed model ANOVA did not reveal a significant interaction between condition and session ($F(4.083, 81.654) = 2.162, p = .079, \eta_p^2 = .098$). There was a significant main effect for session ($F(4.083, 81.654) = 3.054, p = .021, \eta_p^2 = .132$). Pairwise comparisons showed significant differences between BL and T2 ($p = .002$), BL and T4 ($p = .042$), BL and T5 ($p = .007$), T2 and T7 ($p = .027$), and T5 and T7 ($p = .005$). Results are illustrated in Figure 73. There was no significant main effect for condition ($F(1, 20) = .685, p = .481, \eta_p^2 = .033$).

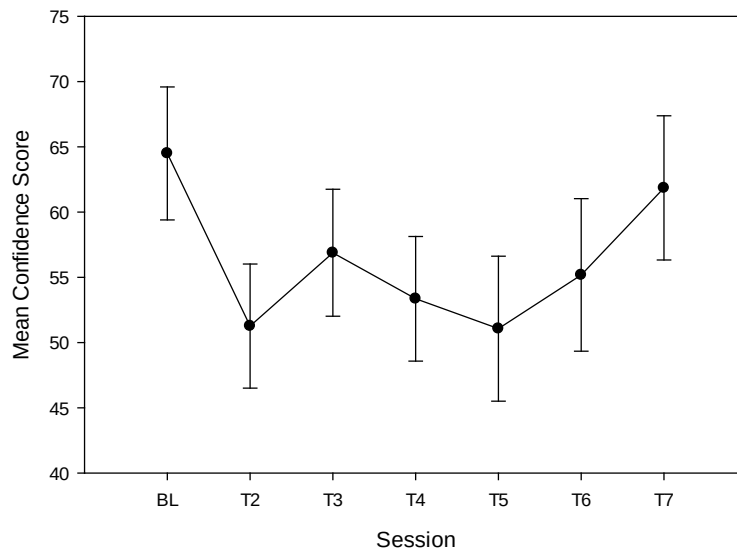


Figure 73. VAS Confidence Session Main Effect

Irritable: The assumption of sphericity was violated ($\chi^2(20) = 54.439, p < .001; \varepsilon = .801$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.809, 96.179) = 1.966, p = .093, \eta_p^2 = .090$). There were no significant main effects for

session ($F(4.809, 96.179) = 1.767, p = .130, \eta_p^2 = .081$) and condition ($F(1, 20) = 1.372, p = .255, \eta_p^2 = .064$).

Jittery: The assumption of sphericity was violated ($\chi^2(20) = 54.226, p < .001; \varepsilon = .669$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(4.015, 80.303) = 1.379, p = .249, \eta_p^2 = .064$). There were no significant main effects for session ($F(4.015, 80.303) = 1.415, p = .236, \eta_p^2 = .066$) and condition ($F(1, 20) = .670, p = .423, \eta_p^2 = .032$).

Sleepiness: The assumption of sphericity was violated ($\chi^2(20) = 35.420, p = .019; \varepsilon = .820$). The mixed model ANOVA revealed a significant interaction between condition and session ($F(4.918, 98.355) = 3.647, p = .005, \eta_p^2 = .154$). Simple effects analysis showed no significant differences between groups at BL ($p = .357$), T2 ($p = .265$), T3 ($p = .128$), T4 ($p = .428$), T5 ($p = .297$), T6 ($p = .057$), and T7 ($p = .082$). Within the placebo group, there was no significant main effect of session ($F(6, 66) = 1.396, p = .230$). Within the modafinil group, the assumption of sphericity was violated ($\chi^2(20) = 36.892, p = .019; \varepsilon = .766$). There was a significant main effect for session ($F(4.596, 41.364) = 4.499, p = .003$). Pairwise comparisons revealed significant differences between BL and T5 ($p = .036$), BL and T6 ($p = .010$), T2 and T6 ($p = .017$), T3 and T4 ($p = .006$), T3 and T5 ($p = .002$), T3 and T6 ($p = .001$), and T3 and T7 ($p = .016$). Results are illustrated in Figure 74.

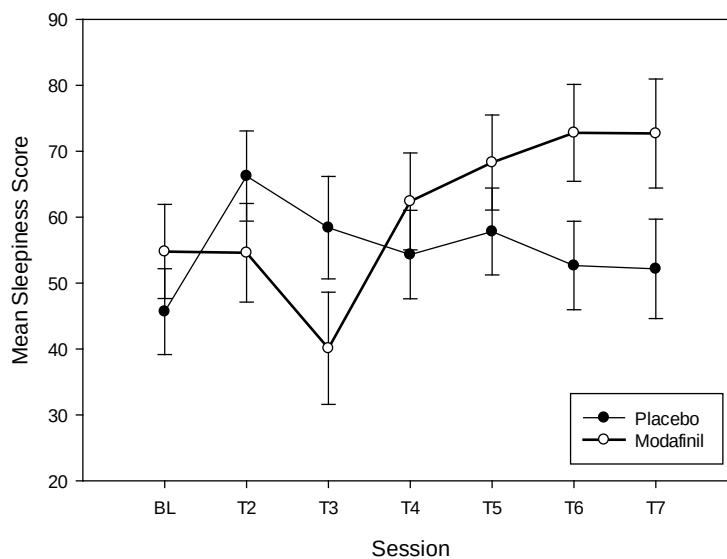


Figure 74. VAS Sleepiness Condition X Session Interaction

There was no significant main effect for session ($F(4.918, 98.355) = 2.281, p = .053, \eta_p^2 = .102$) and condition ($F(1, 20) = .553, p = .466, \eta_p^2 = .027$).

Talkative: The assumption of sphericity was violated ($\chi^2(20) = 40.052, p = .005; \varepsilon = .835$). The mixed model ANOVA did not show a significant interaction between condition and session ($F(5.012, 100.232) = 1.712, p = .138, \eta_p^2 = .079$). There was a significant main effect for session ($F(5.012, 100.232) = 3.350, p = .008, \eta_p^2 = .143$). Pairwise comparisons revealed significant differences between BL and T2 ($p = .005$), T2 and T3 ($p = .001$), T2 and T4 ($p = .009$), T2 and

T7 ($p = .006$), and T3 and T6 ($p = .042$). Results are illustrated in Figure 75. There was no significant main effect for condition ($F(1, 20) = 1.073, p = .313, \eta_p^2 = .051$).

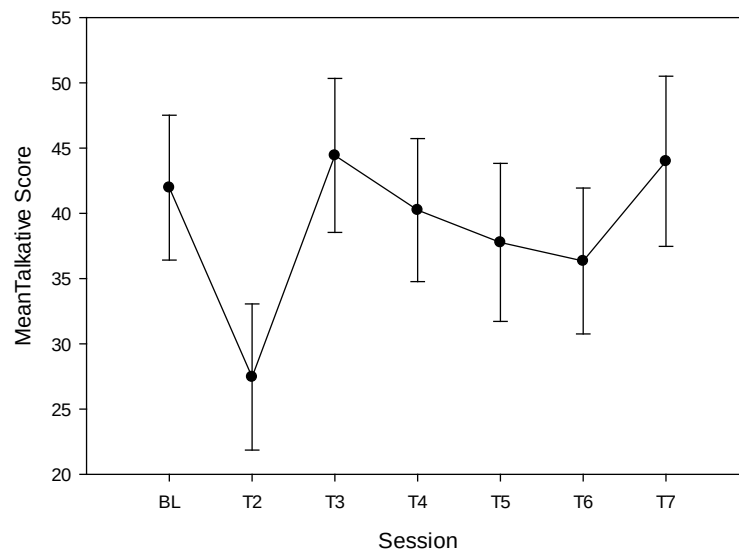


Figure 75. VAS Talkative Session Main Effect

3.2.2.3 Side effects questionnaire. Results examining various side effects were tallied for each factor and are presented in Table 28 below. Each group had 12 participants except for the modafinil group at Test 6; one subject had missing data for this session, leaving 11 participants for all questions. No statistical analyses were performed for responses to side effects. Documentation of these effects were for safety monitoring; therefore, only the tally of responses is presented.

Table 28. Side effects questionnaire responses

	BL		T2		T3		T4		T5		T6		T7	
Trouble staying awake	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	7	5	1	4	1	8	1	4	1	2	3	1	5	3
	5	7	4	4	4	3	4	4	6	3	6	3	5	5
	0	0	6	3	5	1	6	3	4	6	3	6	2	3
	0	0	1	1	2	0	1	1	1	1	0	1	0	1
Dry Mouth	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	9	11	7	10	7	11	8	11	8	11	6	11	6
	1	3	1	3	2	4	1	2	1	3	1	4	1	5
	0	0	0	2	0	0	0	2	0	0	0	0	0	0
	0	0	0	0	0	1	0	0	0	1	0	1	0	1

	BL	T2		T3		T4		T5		T6		T7		
Nervous	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	11	10	9	11	11	10	11	11	10	12	8	11	11
	1	1	2	3	1	1	2	1	1	1	0	2	1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Anxiety	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	10	7	9	7	9	8	10	7	8	7	9	6	7	6
	2	5	2	5	2	4	1	3	3	2	2	3	4	5
	0	0	1	0	1	0	1	2	1	2	1	1	1	0
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Stomach Cramps	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	12	12	9	9	9	9	10	10	9	9	8	9	8	10
	0	0	3	3	2	1	2	0	2	1	4	1	3	1
	0	0	0	0	1	2	0	2	1	1	0	0	1	0
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Visual Illusions	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	11	10	10	8	10	9	10	9	10	9	9	10	8
	1	1	1	2	2	2	2	1	0	0	3	0	2	2
	0	0	1	0	2	0	1	1	3	1	0	1	0	1
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Drugged Feeling	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	10	8	7	7	9	8	9	9	11	7	11	6	11	7
	2	4	3	4	3	2	3	1	1	3	1	4	0	4
	0	0	2	1	0	1	0	1	0	1	0	0	1	0
	0	0	0	0	0	1	0	1	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Light Headed	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	12	11	11	9	10	11	11	11	11	8	11	8	12	9
	0	1	1	3	2	0	1	0	1	2	1	2	0	2
	0	0	0	0	0	1	0	1	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	1	0	1	0	1

	BL	T2		T3		T4		T5		T6		T7		
Difficulty Staying Awake	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	8	6	1	3	2	7	2	4	1	2	3	1	3	2
	4	5	5	5	3	3	7	5	5	3	5	5	7	7
	0	1	5	4	6	2	3	2	5	6	4	4	2	2
	0	0	2	0	1	0	0	1	1	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Irritability	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	6	8	8	8	8	8	7	9	5	9	6	9	5
	1	5	2	1	3	3	2	3	1	3	1	2	2	4
	0	1	2	3	1	1	2	2	2	3	2	2	1	2
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
Loss of Coordination	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	9	10	9	9	8	10	9	9	7	10	7	11	8
	1	3	2	2	3	3	2	2	2	3	2	2	1	3
	0	0	0	1	0	1	0	1	1	1	0	1	0	0
	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	BL	T2		T3		T4		T5		T6		T7		
General Discomfort	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	11	2	8	3	6	4	7	2	7	0	7	1	6	1
	1	8	2	6	4	5	4	6	2	5	2	4	3	5
	0	2	2	3	1	2	1	3	2	6	3	5	3	4
	0	0	0	0	1	1	0	1	1	1	0	1	0	2
	BL	T2		T3		T4		T5		T6		T7		
Fatigue	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	7	0	1	2	0	2	1	0	0	0	1	0	0	0
	5	10	4	4	6	7	6	6	5	4	3	2	2	1
	0	2	7	6	6	2	5	4	7	7	8	7	10	9
	0	0	0	0	0	1	0	2	0	1	0	2	0	2
	BL	T2		T3		T4		T5		T6		T7		
Drowsiness	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
	7	3	2	7	1	4	1	3	1	3	1	1	2	1
	5	6	5	1	7	5	6	5	6	4	2	4	5	4
	0	3	4	4	3	3	5	3	5	4	9	6	5	5
	0	0	1	0	1	0	0	1	0	1	0	0	0	2

	BL		T2		T3		T4		T5		T6		T7	
Headache	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
None	11	6	10	8	7	10	9	9	8	7	8	7	9	8
Slight	1	5	2	4	5	2	3	3	4	4	4	4	3	1
Moderate	0	1	0	0	0	0	0	0	0	1	0	0	0	2
Severe	0	0	0	0	0	0	0	0	0	0	0	0	0	1

	BL		T2		T3		T4		T5		T6		T7	
Nausea	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
None	12	12	11	9	11	9	11	10	11	9	11	9	11	9
Slight	0	0	1	2	0	2	1	1	1	2	1	2	1	3
Moderate	0	0	0	1	1	1	0	1	0	1	0	0	0	0
Severe	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	BL		T2		T3		T4		T5		T6		T7	
Difficulty Concentrating	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil	Placebo	Modafinil
None	10	1	2	4	3	8	3	3	2	3	3	1	4	4
Slight	1	10	6	5	6	2	7	5	7	4	6	2	7	3
Moderate	1	1	4	3	3	1	2	3	2	4	3	5	1	4
Severe	0	0	0	0	0	1	0	1	1	1	0	3	0	1

3.2.3 Polysomnography. The secondary objective determined whether sleep architecture would differ following consumption of 200mg modafinil an hour prior to a 2-hour nap compared to placebo before the nap. A series of t-tests were conducted between the conditions for the following variables: sleep latency, REM sleep latency, time spent awake after sleep onset, sleep efficiency, and time spent in each of the sleep stages N1, N2, N3, and REM sleep.

One participant from the placebo group was excluded as an outlier for sleep latency. One participant from the placebo group was excluded as an outlier for time spent in N1. The *t*-tests did not reveal significant differences between the conditions for sleep latency ($t(21) = -1.573, p = .131$), REM latency ($t(22) = .093, p = .926$), time spent awake after sleep onset ($t(22) = .320, p = .752$), sleep efficiency ($t(22) = -1.026, p = .316$), time spent in N1 ($t(21) = 1.067, p = .298$), time spent in N3 ($t(22) = -1.623, p = .119$), or time spent in REM ($t(22) = -1.636, p = .116$). The *t*-test for time spent in N2 revealed significant differences between the conditions ($t(22) = 2.239, p = .036$). See Figure 76.

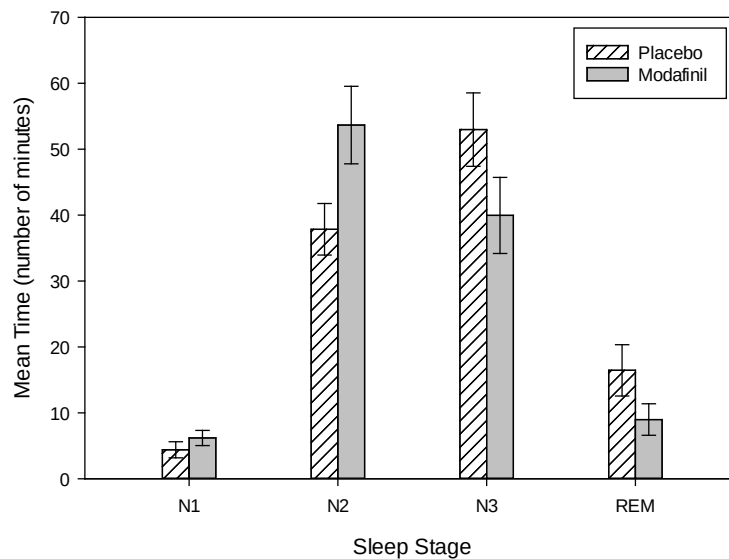


Figure 76. Staged PSG

3.3 Discussion

3.3.1 Hypothesis 1. The first hypothesis for this study was that participants who took 200mg modafinil before a nap would perform better on objective assessments completed immediately after awakening in comparison to participants who received the placebo treatment before the nap. Of the tests taken within 30 minutes after awakening, only the Peripheral Information Processing task and the oculometric assessments showed differences between the two groups. For the Peripheral Information Processing task, both number of correct and incorrect responses as well as reaction time were better in the modafinil group than in the placebo group. For the oculometric measures, people in the modafinil group showed greater saccadic velocity than those in the placebo group.

The lack of significant findings in the present study can be explained in part by previous research using caffeine. A study in which caffeine was consumed prior to a nap benefited performance following the nap (Horne & Reyner, 1996). The present investigation did not find this effect with modafinil. However, the difference in the mechanism of action (MOA) between caffeine and modafinil is important. Caffeine is an adenosine receptor antagonist and attenuates the buildup of sleep propensity, leading to its effects on alertness and performance. The MOA of modafinil is less well-defined than that of caffeine, but it is clear that it is not a stimulant in the classical sense. Instead, modafinil seems to act in a way that prevents the onset of sleep rather than stimulating alertness. The neurological mechanisms underpinning the sleep-wake balance involve simultaneous promotion of wakefulness and suppression of sleep to achieve a waking state, vice versa to achieve the sleeping state. Caffeine both stimulates wakefulness noradrenergically and suppresses sleep by blocking the reception of adenosine in the basal ganglia. Modafinil appears to simply suppress the onset of sleep but without caffeine's concomitant promotion of wakefulness by primarily blocking the action of GABA receptors in the flip-flop circuits of the sleep centers in the brain. Therefore, modafinil's inability to override sleep inertia effects can be explained by its MOA.

Consistent with this explanation, some evidence suggests that modafinil directly activates only a very specific set of brain regions, such as the central nucleus of the amygdala, paraventricular nucleus of the hypothalamus, and the anterior hypothalamus (Mereu, Bonci, Newman, & Tanda, 2013). This specificity may help explain its limited rescue action of certain cognitive functions observed in the present study. In these results, this specificity is best illustrated by the strong group differences on the Peripheral Information Processing (PIP) task and the ocular measure of saccadic velocity. Successful orientation to peripheral stimuli is an evolutionarily-old function, and is therefore partially governed by structures responsible for threat detection and response. For example, the superior colliculus (SC) mediates much of the initial psychomotor response to salient peripheral stimuli (White, Kan, Levy, Itti, & Munoz, 2017). The SC is interconnected with the optic tract circuitry of the hypothalamus, which is a specific target of modafinil via inhibition of GABA action. The amygdala, another direct target of modafinil, is also thought to play a key role in peripheral threat detection and orientation (Almeida, Soares, & Castelo-Branco, 2015). While other brain areas and neurotransmitter receptor types are impacted by modafinil, the effects are indirect and predicated on initial action via these specific structures first (Mereu, Bonci, Newman, & Tanda, 2013). Therefore, the current study's evidence supports the idea that modafinil's highly specific, GABAergic MOA may be best suited for maintenance of wakefulness once that state is successfully created by the structures primarily responsible for the sleep/wake balance via the histamine system, rather than as an initiating agent to spark or speed the shift from sleep to wake, as was the intention in the current study. The notable exception to this conclusion comes from direct sustainment of the peripheral orienting response, which is underpinned by modafinil's limited direct psychoactive effects.

3.3.2 Hypothesis 2. The second hypothesis for this study was that both the subjective and objective assessments would be better for participants who received the 200mg modafinil treatment in conjunction with the nap than for participants who received the nap alone. Of the 18 tests presented to participants, only a few showed the desired interaction effect between drug and time. Most of the significant effects occurred with speed; reaction time tended to be faster for those individuals receiving modafinil than those receiving placebo. This was the case for the PVT, Rapid Decision Making, Match to Sample, Three-Choice Reaction Time, Digit Span, and Peripheral Information Processing tests. The combination of modafinil with a nap showed faster RT and a greater number of correct responses, particularly in the morning hours, when modafinil's alerting effects combined with the nap produced better performance compared to a nap alone. Compared to baseline, RT was faster and performance was better in virtually all the tests presented.

Most of the cognitive tests showed an effect across time, regardless of group, but in the opposite direction one would expect. A decay in performance toward the end of the day is expected due to both sleep pressure as a result of only 2 hours of sleep over the 38 hours of otherwise continuous wakefulness, as well as the declining levels of modafinil in the system. However, this effect did not generally occur. The PVT, which is known to be highly sensitive to the effects of inadequate sleep, did show an increase in reaction time (RT) immediately upon awakening from the nap, but then decreased over the course of the testing period, particularly in the modafinil group. It was the first test administered upon awakening and did show a sleep inertia effect at T2, regardless of

drug group, reflected in the hypothesis 2 analysis session main effect. However, this was generally the only test which showed an effect from the long hours awake.

There are a few potential explanations for the lack of an effect of time awake. One reason could have been due to both the length of the tasks (most were less than 3 minutes in length). Past research indicates that short tests are resilient to the effects of sleep deprivation in that cognitive stimulation may overcome the effects of sleep deprivation (Balkin, 2011). Sleepiness and performance vary during continuous wakefulness, involving wake “state instability” due to the increased homeostatic drive for sleep. However, in certain circumstances, a person can invoke compensatory efforts which allows performance to be relatively normal for short periods of time (Doran, Van Dongen & Dinges, 2001). However, lapses in attention increase with time on task, with shorter tasks less affected by these lapses than longer tasks.

Additionally, many of the tests presented in this study tap higher-order cognitive functioning (i.e., executive functions). Research has shown that tasks that are monotonous and less engaging are affected by sleep loss more than tasks which are engaging (Basner, Mollicone, & Dinges, 2011; Doran et al., 2001; Lim & Dinges, 2010; Whitney, Hinson, & Nusbaum, 2019). Evidence indicates that complex tasks tend to be arousing, which lead to people engaging in compensatory strategies, making performance resilient to the effects of sleep deprivation, particularly when compared to simple attention (Lim & Dinges, 2010; Whitney et al., 2019).

The lack of significant effects of modafinil on performance may have been due to a variety of limiting factors. First, the statistical power may have been too low to uncover some effects. Generally, the observed power of the analyses were between .70 and .80. If the sample size for each group was increased by at least four more participants, significant effects may have overcome the individual difference variability observed in this study sample. Second, the tasks chosen may have been too short in duration to allow attention to wain as generally happens when adequate sleep has not been achieved. Third, cognitive task complexity ranged from high (e.g., Math Processing) to low (e.g., PVT). There is evidence that tasks with low cognitive complexity are more quickly impacted by sleep disruption than high complex tasks (Lim & Dinges, 2010; Wickens, Hutchins, Laux, & Sebok, 2015; Whitney et al., 2019). Fourth, the lack of a “no-nap” condition prevented the ability to isolate the impact of napping and modafinil. Some of the explanations offered here (e.g., the nap alone may have been sufficient) cannot be truly tested without a no-nap control condition. It is possible that modafinil, for the majority of tests examined within this study, simply does not exert any additional influence that cannot be achieved by a nap alone. Unfortunately, without the “no-nap” condition, this cannot be determined.

While the cognitive evaluations did not indicate effects as expected, subjective evaluations of mood from the POMS and VAS indicated differences between the groups for a few of the factors. For those in the modafinil group, subjective ratings of fatigue were higher than for those in the placebo group. Specifically, the Vigor, Fatigue, and Total Mood Scores from the POMS were higher for those in the modafinil group than in the placebo group, generally starting about 8 hours post dose. Similar factors from the VAS (e.g., Energy, Sleepiness, and Ability to Concentrate) presented the same picture of increasing fatigue in the modafinil group. This effect may be due to a comparison of how the individuals felt early in the day when modafinil was

boosting alertness levels; after its effectiveness was gone, the comparison to earlier may have led to increasing levels of subjective fatigue than would have occurred if the modafinil were not on board. One of the characteristics of modafinil is that it doesn't have the common indicators that it is helping alertness and performance. Conversely, the classic stimulants such as caffeine have physiological effects which give the consumer a sensation that there is something helping decrease alertness.

Neither group showed high self-reported side effects attributed to a drug, but did endorse the ones expected during sleep deprivation, such as drowsiness, irritability, etc. Both groups reported similar numbers of incidents related to sleep deprivation, as expected. One of the positive characteristics of modafinil is the lack of side effects.

3.3.3 Sleep architecture. The final objective of this study was to determine whether sleep architecture would differ following consumption of 200mg modafinil an hour prior to a 2-hour nap compared to placebo. Analyses to determine the effects of modafinil on sleep architecture showed an increase in N2 sleep compared to the effects of placebo showing that those in the modafinil group spent more time in N2 sleep rather than in N3 or REM sleep. N2 sleep is marked by a functional reorganization of consciousness, transitioning from response to external stimuli during wakefulness to creation of an internal sensory loop during REM sleep. Much of this transition is predicated on the successful, sustained action of GABA on the ventro-lateral pre-optic nucleus (VLPO) during sleep onset (Moorcroft, 2013). Increased time in N2 sleep suggests a repeated failure and restart of this transition, further supporting the idea that GABA is the key player in the cognitive and physiologic effects observed in the current study. Reduced N2 sleep should have discernable metabolic and cognitive effects downstream. However, in short-term, cross-sectional studies (such as the present study), such effects may be masked by modafinil's wakefulness sustainment.

4.0 CONCLUSIONS

The combination of modafinil with a nap showed mixed results. Given modafinil's theoretical mechanism of action, the current findings reveal that the use of 200mg modafinil is not adequate to combat sleep inertia which occurs immediately upon awakening from sleep. The use of 200mg modafinil slightly alters sleep architecture when taken before sleep, but not to the point where sleep is not restorative, at least during a 2-hour nap. Previous research supports the combined benefit of a nap with caffeine (Hayashi, Masuda, & Hori, 2003; Horne & Reyner, 1996; Schweitzer, Randazzo, Stone, Erman, & Walsh, 2006); however, based on the current study's findings, combining modafinil with a nap does not produce an advantage over a nap alone.

Future Directions. Future research to find operationally-relevant countermeasures for military personnel may investigate the individual differences into fatigue susceptibility to determine whether naps or a pharmaceutical countermeasure will improve alertness and performance. Current military policy states that modafinil can be administered to specific individuals during select operations in doses between 100mg and 200mg, with additional dosing after 8 hours, not to exceed 400mg in a 24-hr period. Additional research can explore combining naps with this dosing regimen and with varying placement of the naps within the mission to determine the optimal dose with naps.

Another research avenue based on this study is exploratory work into individual difference analyses, utilizing PVT as a gold standard for alertness. As a simple test, PVT is easy to administer, and may allow researchers to tease out differences in fatigue susceptibility based on available subjective and objective data. Further work needs to be done to understand the impacts of napping and modafinil exposure; the present study was unable to include a “no-nap” control group. Parallel research may also identify whether fatigue-susceptible individuals respond better to naps, and what nap duration is optimal. Ideally, it is within the realm of possibility that as society moves toward a healthcare trend of personalized medicine, we may also be able to entertain the possibility of evidence-based personalized sleep trends to complement advanced physiologic monitoring.

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SYMBOLS

η_p^2 Partial eta squared

ABBREVIATIONS

BP	Blood pressure
DC	Direct current
DHP	Defense Health Program
ECG	Electrocardiograph
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electrooculogram
FFT	Fast Fourier transformation
FS	False Start
GC-MS	Gas chromatography-mass spectrometry
HR	Heart rate
HSD	Honestly Significant Difference
Hz	Hertz
Mg	Milligram
MPH	Miles per hour
Msec	Millisecond
OTC	Over the counter
PVT	Psychomotor Vigilance Task
RT	Reaction time
RTCR	Reaction time for correct responses
RRT	Reciprocal reaction time
RMS	Root mean square
SE	Side effects
Sd	Standard deviation
TMD	Total Mood Disturbance

ACRONYMS

AFMSA/SG9	Air Force Medical Support Agency Office of Medical Modernization
AFSOC	Air Force Special Operations Command
ANOVA	Analysis of variance
FIT	Fitness Impairment Tester
NAMRU-D	Naval Medical Research Unit Dayton
NEO-PI-R	NEO Personality Inventory Revised
POMS	Profile of Mood States
REM	Rapid eye movement
VAS	Visual Analogue Scale

Appendix I. Hypothesis 1 Statistics

Table A. Performance and physiological measures, *t*-tests

Task	Metric	<i>t</i> (df)	<i>p</i>
PVT	RRT	$t(23) = -0.497$	.624
	Lapses+FS	$t(21) = 0.267$	.792
WSC – CA	W1T6	$t(22) = -0.348$	.731
	W1T18	$t(22) = 0.260$	.797
	W1T12	$t(22) = 0.789$	.438
	W2T6	$t(22) = 1.254$	.223
	W2T18	$t(22) = 1.173$	.253
	W2T12	$t(22) = 0.616$	.544
	W3T6	$t(22) = -0.281$	.781
	W3T18	$t(22) = 0.752$	.460
	W3T12	$t(18.066) = 0.856$	.403
WSC – Err	W1T6	$t(22) = 0.000$	1.000
	W1T18	$t(22) = -0.302$	.766
	W1T12	$t(22) = 0.069$	.946
	W2T6	$t(22) = -1.215$	.237
	W2T18	$t(16.684) = -1.557$	.138
	W2T12	$t(22) = -0.317$	.754
	W3T6	$t(22) = 0.398$	.695
	W3T18	$t(22) = 0.734$	.471
	W3T12	$t(22) = -1.025$	.317
WSC – TotMax	W1T6	$t(9.522) = 1.442$	.181
	W1T18	$t(20) = -0.053$	.958
	W1T12	$t(20) = -1.879$	.075
	W2T6	$t(20) = 1.000$	.339
	W2T18	$t(20) = 1.044$	.309
	W2T12	$t(20) = -1.128$	.273
	W3T6	$t(20) = 1.000$	.339
	W3T18	$t(15.606) = -0.784$	.445
	W3T12	$t(20) = -0.970$	.344
Flight Simulator Performance	Altitude	$t(22) = 1.568$	.131
	Airspeed	$t(22) = -0.159$	.875
	Heading	$t(22) = 0.944$	.355
Oculometric Assessments	Amplitude	$t(22) = 0.759$	.456
	Pupil Diameter	$t(22) = -1.682$	.107
	Latency	$t(22) = -1.081$	.292
	Velocity	$t(22) = -2.167$	.041

Table B. NTI-ATS tasks, *t*-tests

Task	Metric	<i>t</i> (df)	<i>p</i>
Nova Scan – Mankin	NCorr	$t(16.251) = -1.318$	.133
	CorrRT	$t(22) = -1.853$	.077
	NIncorr	$t(16.251) = -1.318$	.206
	IncorrRT	$t(22) = -1.120$	.275
	NTO	$t(22) = 0.789$	.438
Nova Scan – Continuous Memory	NCorr	$t(16.975) = -1.093$	.290
	CorrRT	$t(22) = -0.204$	.840
	NIncorr	$t(16.975) = 1.093$	.290
	IncorrRT	$t(18.468) = 0.835$	.414
	NTO	$t(11.033) = 1.704$	.116
Nova Scan - Dial	NCorr	$t(22) = 0.753$	.460
	CorrRT	$t(22) = -1.008$	.325
	NIncorr	$t(22) = -0.672$	.509
	IncorrRT	$t(22) = 1.430$	.167
	NTO	$t(22) = -0.265$	.793
Rapid Decision Making	NCorr	$t(17.184) = -1.869$	.079
	CorrRT	$t(22) = -0.633$	.533
	NIncorr	$t(22) = 1.773$	.090
	IncorrRT	$t(22) = 0.688$	.498
Math Processing	NCorr	$t(21) = 0.080$	.937
	CorrRT	$t(22) = -0.995$	.331
	NIncorr	$t(22) = -0.498$	.624
	IncorrRT	$t(22) = -0.206$	.839
Delayed Match to Sample	NCorr	$t(22) = 0.411$	.685
	CorrRT	$t(21) = 0.032$	.975
	NIncorr	$t(22) = -0.411$	.685
	IncorrRT	$t(22) = -0.237$	.815
	CorrMem	$t(22) = -0.708$	.486
	IncorrMem	$t(22) = -1.554$	.135
Peripheral Information Processing	AvgRT	$t(22) = 2.121$	.045
	NCorr	$t(14.434) = -2.473$	.026
	NIncorr	$t(15.212) = 2.559$	.022
	NHit	$t(12.256) = -1.422$	.180
Dichotic Listening	NCorr	$t(13.69) = -1.718$	.108
	CorrRT	$t(22) = 1.745$	.095
	NIncorr	$t(17.974) = 1.192$	.249
	IncorrRT	$t(22) = 0.893$	.381
	LatCorr	$t(22) = 0.857$	.401
	LatIncorr	$t(22) = 17.135$	.219
Visual Vigilance	NCorr	$t(21) = 0.608$	.550
	CorrRT	$t(21) = 0.953$	.352
	NIncorr	$t(21) = 0.159$	.875
	IncorrRT	$t(22) = 1.738$	.096
	NTO	$t(21) = -.810$	.427

Table B (Continued). NTI-ATS tasks, *t*-tests

Continuous Memory	<i>NCorr</i>	$t(13.227) = 1.038$	.318
	<i>CorrRT</i>	$t(22) = -0.097$	.342
	<i>NIncorr</i>	$t(13.227) = 1.038$	.318
	<i>IncorrRT</i>	$t(21) = 1.418$	.171
	<i>NTO</i>	$t(11.097) = 1.444$	.176
Manikin	<i>NCorr</i>	$t(22) = -0.178$	.860
	<i>CorrRT</i>	$t(22) = -0.491$	.628
	<i>NIncorr</i>	$t(22) = -0.331$	.743
	<i>IncorrRT</i>	$t(22) = -2.058$	.052
	<i>NTO</i>	$t(21) = 1.047$	.307
Motion Interference	<i>NCorr</i>	$t(16.361) = -1.332$	.201
	<i>CorrRT</i>	$t(11.848) = 1.321$	.211
	<i>NIncorr</i>	$t(22) = 0.953$	.351
	<i>IncorrRT</i>	$t(22) = 0.708$	.487
	<i>NLow</i>	$t(22) = 0.929$	.363
	<i>LowRT</i>	$t(22) = -1.152$	.262
	<i>NHigh</i>	$t(22) = -1.017$	.320
	<i>HighRT</i>	$t(22) = 1.330$	.197
Three-Choice Reaction Time	<i>NCorr</i>	$t(22) = 0.240$	.813
	<i>CorrRT</i>	$t(21) = 0.965$	.346
	<i>NIncorr</i>	$t(22) = 0.240$	.813
	<i>IncorrRT</i>	$t(22) = 0.037$	.971
Digit Span (auditory)	<i>NCorr</i>	$t(22) = 1.307$	.205
	<i>CorrRT</i>	$t(22) = 0.275$	.786
	<i>NIncorr</i>	$t(21) = 1.071$	.296
	<i>IncorrRT</i>	$t(22) = 0.531$	.600
	<i>NTO</i>	$t(10) = 1.000$	.341

Table C. Questionnaires, *t*-tests

Questionnaire	Metric	<i>t</i> (df)	<i>p</i>
POMS	Tension	$t(20) = -1.309$	.205
	Depressed	$t(20) = -0.531$	.601
	Anger	$t(19) = -0.965$	.949
	Vigor	$t(20) = -0.783$	.443
	Fatigue	$t(20) = 0.684$	.502
	Confusion	$t(19) = -0.263$	.795
	TMD	$t(20) = 0.014$	.989
VAS	Alertness	$t(15.268) = -1.436$	.171
	Anxiety	$t(20) = 0.640$	.529
	Energy	$t(20) = -0.719$	.480
	Confidence	$t(20) = -0.827$	.418
	Irritable	$t(20) = 0.493$	.627
	Jittery	$t(20) = 0.558$	.583
	Sleepy	$t(20) = 1.147$	.265
	Talkative	$t(20) = 0.260$	.797

Appendix II. Hypothesis 2 Statistics

Table A. PVT

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
Lapses+FS	Condition X Session Interaction	$F(4.005, 84.106) = 1.539$	.198	.068
	Session Main Effect	$F(4.005, 84.106) = 4.026$	.005	.161
	Condition Main Effect	$F(1, 21) = 0.349$	.561	.016
RRT	Condition X Session Interaction	$F(4.005, 84.106) = 1.539$	.198	.068
	Session Main Effect	$F(4.005, 84.106) = 4.026$	.005	.161
	Condition Main Effect	$F(1, 21) = 0.349$	.561	.016

Table B. Warship Commander – Correct Answers

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
W1T6	Condition X Session Interaction	$F(4.317, 94.981) = .588$	.685	.026
	Session Main Effect	$F(4.317, 94.981) = 1.529$	.196	.065
	Condition Main Effect	$F(1, 22) = .503$	.486	.022
W1T18	Condition X Session Interaction	$F(5.230, 115.063) = .075$	.997	.003
	Session Main Effect	$F(5.230, 115.063) = .741$	.600	.033
	Condition Main Effect	$F(1, 22) = 0$	1.000	.000
W1T12	Condition X Session Interaction	$F(6, 132) = 1.477$	.191	.063
	Session Main Effect	$F(6, 132) = .896$	.500	.039
	Condition Main Effect	$F(1, 22) = 1.905$	.181	.080
W2T6	Condition X Session Interaction	$F(5.918, 130.199) = 1.044$	.400	.045
	Session Main Effect	$F(5.918, 130.199) = 2.009$	.070	.084
	Condition Main Effect	$F(1, 22) = .049$	.826	.002
W2T18	Condition X Session Interaction	$F(6, 132) = 1.094$	.370	.047
	Session Main Effect	$F(6, 132) = 1.115$	.357	.048
	Condition Main Effect	$F(1, 22) = .257$	.617	.012
W2T12	Condition X Session Interaction	$F(6, 132) = .455$	.841	.020
	Session Main Effect	$F(6, 132) = .411$	.870	.018
	Condition Main Effect	$F(1, 22) = 0$	1.000	.000
W3T6	Condition X Session Interaction	$F(6, 132) = 1.283$	.269	.055
	Session Main Effect	$F(6, 132) = .653$	.687	.029
	Condition Main Effect	$F(1, 22) = .343$	.564	.015
W3T18	Condition X Session Interaction	$F(6, 132) = .639$	.698	.028
	Session Main Effect	$F(6, 132) = 1.604$	.151	.068
	Condition Main Effect	$F(1, 22) = .007$	.934	.000
W3T12	Condition X Session Interaction	$F(6, 132) = .744$	.615	.033
	Session Main Effect	$F(6, 132) = .751$	.609	.033
	Condition Main Effect	$F(1, 22) = .937$	.343	.041

Table C. Warship Commander – Errors

Metric	Effect	F (df)	p	η_p^2
W1T6	Condition X Session Interaction	$F(3.892, 85.626) = 1.025$	.398	.045
	Session Main Effect	$F(3.892, 85.626) = 1.295$	.279	.056
	Condition Main Effect	$F(1, 22) = 1.664$	.210	.070
W1T18	Condition X Session Interaction	$F(6, 132) = 1.400$	.219	.060
	Session Main Effect	$F(6, 132) = 1.977$	.073	.082
	Condition Main Effect	$F(1, 22) = 0.046$	.831	.002
W1T12	Condition X Session Interaction	$F(4.580, 100.770) = 0.393$	.838	.018
	Session Main Effect	$F(4.580, 100.770) = 0.812$	.534	.036
	Condition Main Effect	$F(1, 22) = 0.117$	.736	.005
W2T6	Condition X Session Interaction	$F(4.609, 101.391) = 0.176$	.964	.008
	Session Main Effect	$F(4.609, 101.391) = 1.546$	.187	.066
	Condition Main Effect	$F(1, 22) = 2.779$	.110	.112
W2T18	Condition X Session Interaction	$F(4.757, 104.646) = 0.673$	.637	.030
	Session Main Effect	$F(4.757, 104.646) = 1.589$	.173	.067
	Condition Main Effect	$F(1, 22) = 2.820$	.107	.114
W2T12	Condition X Session Interaction	$F(4.256, 93.642) = 0.538$	.719	.024
	Session Main Effect	$F(4.256, 93.642) = 2.020$	.094	.084
	Condition Main Effect	$F(1, 22) = 2.816$	.107	.113
W3T6	Condition X Session Interaction	$F(5.016, 110.347) = 0.791$	.558	.035
	Session Main Effect	$F(5.016, 110.347) = 1.684$	.144	.071
	Condition Main Effect	$F(1, 22) = 0.812$	.377	.036
W3T18	Condition X Session Interaction	$F(5.314, 111.589) = 1.546$	.178	.069
	Session Main Effect	$F(5.314, 111.589) = 2.111$	.065	.091
	Condition Main Effect	$F(1, 21) = 1.895$	.183	.083
W3T12	Condition X Session Interaction	$F(3.800, 79.803) = 0.908$	.460	.041
	Session Main Effect	$F(3.800, 79.803) = 1.051$	.384	.048
	Condition Main Effect	$F(1, 21) = 0.976$	.334	.044

Table D. Warship Commander – TotMax

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
W1T6	Condition X Session Interaction	$F(2.773, 55.455) = 0.945$	.419	.045
	Session Main Effect	$F(2.773, 55.455) = 1.629$	.196	.075
	Condition Main Effect	$F(1, 20) = 1.189$	.289	.056
W1T18	Condition X Session Interaction	$F(6, 120) = 1.346$	.242	.063
	Session Main Effect	$F(6, 120) = 0.983$	.440	.047
	Condition Main Effect	$F(1, 20) = 0.000$	.999	.000
W1T12	Condition X Session Interaction	$F(6, 120) = 0.738$	.620	.036
	Session Main Effect	$F(6, 120) = 1.793$	.106	.082
	Condition Main Effect	$F(1, 20) = 0.996$	.330	.047
W2T6	Condition X Session Interaction	$F(6, 120) = 1.159$	.333	.055
	Session Main Effect	$F(6, 120) = 0.828$	.550	.040
	Condition Main Effect	$F(1, 20) = 0.002$	.968	.000
W2T18	Condition X Session Interaction	$F(6, 120) = 3.019$	.009	.131
	Session Main Effect	$F(6, 120) = 2.835$	.013	.124
	Condition Main Effect	$F(1, 20) = 0.379$	.545	.019
W2T12	Condition X Session Interaction	$F(5.222, 104.438) = 0.754$	.590	.036
	Session Main Effect	$F(5.222, 104.438) = 1.225$	.302	.058
	Condition Main Effect	$F(1, 20) = .294$	.594	.014
W3T6	Condition X Session Interaction	$F(6, 120) = 1.184$	.319	.056
	Session Main Effect	$F(6, 120) = .851$	.533	.041
	Condition Main Effect	$F(1, 20) = .017$	.899	.001
W3T18	Condition X Session Interaction	$F(3.956, 79.119) = 1.613$	.180	.075
	Session Main Effect	$F(3.956, 79.119) = 1.602$	.183	.074
	Condition Main Effect	$F(1, 20) = 0.009$	.924	.000
W3T12	Condition X Session Interaction	$F(6, 120) = 1.186$	.318	.056
	Session Main Effect	$F(6, 120) = 1.668$	.135	.077
	Condition Main Effect	$F(1, 20) = 0.547$	.468	.027

Table E. Flight Simulator Performance

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
Altitude	Condition X Session Interaction	$F(1.659, 36.492) = 2.184$	.135	.090
	Session Main Effect	$F(1.659, 36.492) = 0.647$	.502	.029
	Condition Main Effect	$F(1, 22) = 1.135$	.298	.049
Heading	Condition X Session Interaction	$F(1.185, 26.061) = 1.300$	.272	.056
	Session Main Effect	$F(1.185, 26.061) = 1.041$	.330	.045
	Condition Main Effect	$F(1, 22) = 0.756$	.394	.033
Airspeed	Condition X Session Interaction	$F(3.672, 80.778) = 0.588$	.658	.026
	Session Main Effect	$F(3.672, 80.778) = 3.017$	.026	.121
	Condition Main Effect	$F(1, 22) = 0.183$	.673	.008

Table F. Oculometric Assessments

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
Amplitude	Condition X Session Interaction	$F(4.718, 103.799) = 0.411$	.830	.018
	Session Main Effect	$F(4.718, 103.799) = 4.498$	.001	.170
	Condition Main Effect	$F(1, 22) = 0.833$	.371	.036
Pupil Diameter	Condition X Session Interaction	$F(6, 132) = .721$	.633	.032
	Session Main Effect	$F(6, 132) = 6.403$	< .001	.225
	Condition Main Effect	$F(1, 22) = 1.845$	.188	.077
Constriction Latency	Condition X Session Interaction	$F(3.711, 81.632) = .388$	.803	.017
	Session Main Effect	$F(3.711, 81.632) = 1.379$	.250	.059
	Condition Main Effect	$F(1, 22) = 1.612$	.217	.068
Saccadic Velocity	Condition X Session Interaction	$F(4.799, 105.578) = 1.708$	.142	.072
	Session Main Effect	$F(4.799, 105.578) = 1.761$	.130	.074
	Condition Main Effect	$F(1, 22) = 2.923$	.101	.117

Table G. Nova Scan – Manikin

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 126) = 0.676$	.669	.031
	Session Main Effect	$F(6, 126) = 0.540$	.779	.025
	Condition Main Effect	$F(1, 21) = 1.373$	.254	.061
CorrRT	Condition X Session Interaction	$F(5.085, 111.861) = 1.133$	.347	.049
	Session Main Effect	$F(5.085, 111.861) = 7.328$	< .001	.250
	Condition Main Effect	$F(1, 22) = 1.015$	.325	.044
NIncorr	Condition X Session Interaction	$F(4.388, 96.540) = 0.735$	.582	.032
	Session Main Effect	$F(4.388, 96.540) = 0.281$	.904	.013
	Condition Main Effect	$F(1, 22) = 1.330$	.261	.057
IncorrRT	Condition X Session Interaction	$F(6, 132) = 1.439$	.205	.061
	Session Main Effect	$F(6, 132) = 0.635$	.702	.028
	Condition Main Effect	$F(1, 22) = 0.940$	.343	.041
NTO	Condition X Session Interaction	$F(4.17, 91.739) = 1.242$	.299	.053
	Session Main Effect	$F(4.17, 91.739) = 0.410$	.809	.018
	Condition Main Effect	$F(1, 22) = 0.455$	.507	.020

Table H. Nova Scan – Continuous Memory

Metric	Effect	F (df)	p	η_p^2
NCorr	Condition X Session Interaction	$F(4.666, 102.656) = 2.897$	.020	.116
	Session Main Effect	$F(4.666, 102.656) = 0.833$	.522	.036
	Condition Main Effect	$F(1, 22) = 0.906$	.352	.040
CorrRT	Condition X Session Interaction	$F(4.519, 99.414) = 0.818$	.529	.036
	Session Main Effect	$F(4.519, 99.414) = 7.361$	< .001	.251
	Condition Main Effect	$F(1, 22) = 0.002$	.969	.000
NIncorr	Condition X Session Interaction	$F(4.666, 102.656) = 2.897$	.020	.116
	Session Main Effect	$F(4.666, 102.833) = 0.833$	.522	.036
	Condition Main Effect	$F(1, 22) = 0.906$	.352	.040
IncorrRT	Condition X Session Interaction	$F(6, 132) = 1.348$	.240	.058
	Session Main Effect	$F(6, 132) = 2.638$	.019	.107
	Condition Main Effect	$F(1, 22) = 4.466$	.046	.169
NTO	Condition X Session Interaction	$F(3.153, 69.359) = 2.248$	.087	.093
	Session Main Effect	$F(3.153, 69.359) = 1.337$	.269	.057
	Condition Main Effect	$F(1, 22) = 2.623$	.120	.107

Table I. Nova Scan – Dial

Metric	Effect	F (df)	p	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 0.342$	.913	.015
	Session Main Effect	$F(6, 132) = 1.646$	.139	.070
	Condition Main Effect	$F(1, 22) = 0.240$	.629	.011
CorrRT	Condition X Session Interaction	$F(3.509, 77.201) = 1.311$	.275	.056
	Session Main Effect	$F(3.509, 77.201) = 5.995$	.001	.214
	Condition Main Effect	$F(1, 22) = 0.051$	.823	.002
NIncorr	Condition X Session Interaction	$F(4.864, 107.011) = 0.673$	.640	.030
	Session Main Effect	$F(4.864, 107.011) = 0.325$	.893	.015
	Condition Main Effect	$F(1, 22) = 0.442$	.513	.020
IncorrRT	Condition X Session Interaction	$F(3.773, 83.006) = 1.271$	.289	.055
	Session Main Effect	$F(3.773, 83.006) = 1.011$	.404	.044
	Condition Main Effect	$F(1, 22) = 0.015$	.903	.001
NTO	Condition X Session Interaction	$F(3.854, 84.784) = 1.145$	.340	.049
	Session Main Effect	$F(3.854, 84.784) = 3.008$	.024	.120
	Condition Main Effect	$F(1, 22) = 0.005$	.944	.000

Table J. Rapid Decision Making

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 1.039$	.403	.045
	Session Main Effect	$F(6, 132) = .961$	.454	.042
	Condition Main Effect	$F(1, 22) = 1.021$	.323	.044
CorrRT	Condition X Session Interaction	$F(4.418, 97.201) = 2.719$	.029	.110
	Session Main Effect	$F(4.418, 97.201) = 12.735$	< .001	.367
	Condition Main Effect	$F(1, 22) = 0.063$	.804	.003
NIncorr	Condition X Session Interaction	$F(6, 132) = 0.976$	.444	.042
	Session Main Effect	$F(6, 132) = 0.989$	.435	.043
	Condition Main Effect	$F(1, 22) = 0.927$	.346	.040
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.352$	.908	.016
	Session Main Effect	$F(6, 132) = 0.142$	.990	.006
	Condition Main Effect	$F(1, 22) = 2.235$	.149	.092

Table K. Math Processing

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(3.588, 75.346) = 0.950$	.433	.043
	Session Main Effect	$F(3.588, 75.346) = 1.965$	.116	.086
	Condition Main Effect	$F(1, 21) = 0.029$	.865	.001
CorrRT	Condition X Session Interaction	$F(6, 132) = 1.824$	.099	.077
	Session Main Effect	$F(6, 132) = 6.980$	< .001	.241
	Condition Main Effect	$F(1, 22) = 0.098$	.757	.004

Table L. Delayed Match to Sample

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 2.184$	.048	.090
	Session Main Effect	$F(6, 132) = 0.581$	.745	.026
	Condition Main Effect	$F(1, 22) = 0.039$	.846	.002
CorrRT	Condition X Session Interaction	$F(6, 126) = 2.803$	.014	.118
	Session Main Effect	$F(6, 126) = 4.007$	.001	.160
	Condition Main Effect	$F(1, 21) = 0.319$	.578	.015
NIncorr	Condition X Session Interaction	$F(6, 132) = 2.184$	.048	.090
	Session Main Effect	$F(6, 132) = 0.581$	.745	.026
	Condition Main Effect	$F(1, 22) = 0.039$	.846	.002
IncorrRT	Condition X Session Interaction	$F(6, 132) = 1.174$	.324	.051
	Session Main Effect	$F(6, 132) = 1.961$	.076	.082
	Condition Main Effect	$F(1, 22) = 0.006$	.939	.000
CorrMem	Condition X Session Interaction	$F(4.425, 97.360) = 1.098$	.364	.048
	Session Main Effect	$F(4.425, 97.360) = 3.510$	.008	.138
	Condition Main Effect	$F(1, 22) = 0.990$	.331	.043
IncorrMem	Condition X Session Interaction	$F(6, 132) = 1.511$	.179	.064
	Session Main Effect	$F(6, 132) = 3.377$	.004	.133
	Condition Main Effect	$F(1, 22) = 0.900$	.353	.039

Table M. Peripheral Information Processing

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
RT	Condition X Session Interaction	<i>F</i>(4.945, 108.784) = 4.420	.001	.167
	Session Main Effect	<i>F</i>(4.945, 108.784) = 9.477	< .001	.301
	Condition Main Effect	<i>F</i>(1, 22) = 4.561	.044	.172
NHit	Condition X Session Interaction	<i>F</i> (4.093, 85.946) = 1.902	.116	.083
	Session Main Effect	<i>F</i> (4.093, 85.946) = 2.227	.071	.096
	Condition Main Effect	<i>F</i> (1, 21) = 2.841	.107	.119
NCorr	Condition X Session Interaction	<i>F</i>(4.963, 109.186) = 4.038	.002	.155
	Session Main Effect	<i>F</i>(4.963, 109.186) = 5.631	< .001	.204
	Condition Main Effect	<i>F</i>(1, 22) = 8.388	.008	.276
Incorr	Condition X Session Interaction	<i>F</i>(4.432, 97.514) = 3.143	.015	.125
	Session Main Effect	<i>F</i>(4.432, 97.514) = 6.518	< .001	.229
	Condition Main Effect	<i>F</i>(1, 22) = 10.116	.004	.315

Table N. Dichotic Listening

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	<i>F</i> (2.716, 57.031) = 1.358	.266	.061
	Session Main Effect	<i>F</i> (2.716, 57.031) = 1.461	.237	.065
	Condition Main Effect	<i>F</i> (1, 21) = 2.402	.136	.103
CorrRT	Condition X Session Interaction	<i>F</i> (1.460, 32.129) = 3.016	.077	.121
	Session Main Effect	<i>F</i>(1.460, 32.129) = 4.163	.036	.159
	Condition Main Effect	<i>F</i> (1, 22) = 0.811	.378	.036
NIncorr	Condition X Session Interaction	<i>F</i> (5.096, 107.015) = 1.419	.222	.063
	Session Main Effect	<i>F</i>(5.096, 107.015) = 3.532	.005	.144
	Condition Main Effect	<i>F</i> (1, 21) = 0.295	.593	.014
IncorrRT	Condition X Session Interaction	<i>F</i> (5.829, 128.233) = 0.389	.881	.017
	Session Main Effect	<i>F</i> (5.829, 128.233) = 1.907	.087	.080
	Condition Main Effect	<i>F</i> (1, 22) = 0.526	.476	.023
Lat Corr	Condition X Session Interaction	<i>F</i> (6, 132) = 1.313	.256	.056
	Session Main Effect	<i>F</i> (6, 132) = 0.743	.616	.033
	Condition Main Effect	<i>F</i> (1, 22) = 0.385	.542	.017
Lat Incorr	Condition X Session Interaction	<i>F</i> (4.436, 97.600) = 1.74	.141	.073
	Session Main Effect	<i>F</i>(4.436, 97.600) = 3.485	.008	.137
	Condition Main Effect	<i>F</i> (1, 22) = 0.188	.669	.008

Table O. Visual Vigilance

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(1.798, 37.765) = 1.167$	.318	.053
	Session Main Effect	$F(1.798, 37.765) = 0.627$	.523	.029
	Condition Main Effect	$F(1, 21) = 0.012$	.903	.001
CorrRT	Condition X Session Interaction	$F(6, 126) = 0.817$	.559	.037
	Session Main Effect	$F(6, 126) = 5.287$	< .001	.201
	Condition Main Effect	$F(1, 21) = 0.379$	.545	.018
NIncorr	Condition X Session Interaction	$F(2.027, 42.573) = 1.259$	.295	.057
	Session Main Effect	$F(2.027, 42.573) = 0.881$	.423	.040
	Condition Main Effect	$F(1, 21) = 0.073$	.790	.003
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.658$	.683	.029
	Session Main Effect	$F(6, 132) = 0.623$	.712	.028
	Condition Main Effect	$F(1, 22) = 1.991$	.172	.083
NTO	Condition X Session Interaction	$F(6, 126) = 0.781$	.586	.036
	Session Main Effect	$F(6, 126) = 2.762$	.015	.116
	Condition Main Effect	$F(1, 21) = 0.305$	.587	.014

Table P. Continuous Memory

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 1.344$	.242	.058
	Session Main Effect	$F(6, 132) = 1.364$	.234	.058
	Condition Main Effect	$F(1, 22) = 1.593$	.220	.068
CorrRT	Condition X Session Interaction	$F(3.678, 80.911) = 1.333$	.266	.057
	Session Main Effect	$F(3.678, 80.911) = 3.354$	.016	.132
	Condition Main Effect	$F(1, 22) = 0.667$	.423	.029
NIncorr	Condition X Session Interaction	$F(6, 132) = 1.344$	.242	.058
	Session Main Effect	$F(6, 132) = 1.364$	.234	.058
	Condition Main Effect	$F(1, 22) = 1.593$	.220	.068
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.872$	.517	.040
	Session Main Effect	$F(6, 132) = 2.344$	.035	.100
	Condition Main Effect	$F(1, 21) = 2.764$	.111	.116
NTO	Condition X Session Interaction	$F(3.976, 87.463) = 1.131$	.347	.049
	Session Main Effect	$F(3.976, 87.463) = 1.370$	.251	.059
	Condition Main Effect	$F(1, 22) = 2.130$	.159	.088

Table Q. Manikin

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 1.189$	.316	.051
	Session Main Effect	$F(6, 132) = 1.644$	.140	.070
	Condition Main Effect	$F(1, 22) = 0.144$	.708	.007
CorrRT	Condition X Session Interaction	$F(4.921, 108.267) = 0.406$	.841	.018
	Session Main Effect	$F(4.921, 108.267) = 4.183$	.002	.160
	Condition Main Effect	$F(1, 22) = 0.178$	.677	.008
NIncorr	Condition X Session Interaction	$F(6, 132) = 1.215$	.303	.052
	Session Main Effect	$F(6, 132) = 1.747$	.115	.074
	Condition Main Effect	$F(1, 22) = 0.282$	.601	.013
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.840$	.541	.037
	Session Main Effect	$F(6, 132) = 2.136$	.053	.088
	Condition Main Effect	$F(1, 22) = 1.676$	.209	.071
NTO	Condition X Session Interaction	$F(2.257, 47.406) = 1.007$	.381	.046
	Session Main Effect	$F(2.257, 47.406) = 1.096$	.348	.050
	Condition Main Effect	$F(1, 21) = 0.437$	.516	.020

Table R. Motion Interference

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(4.870, 107.145) = 1.745$	.132	.073
	Session Main Effect	$F(4.870, 107.145) = 2.278$	.053	.094
	Condition Main Effect	$F(1, 22) = 1.317$	.264	.056
CorrRT	Condition X Session Interaction	$F(6, 132) = 1.665$	.134	.070
	Session Main Effect	$F(6, 132) = 3.198$	.006	.127
	Condition Main Effect	$F(1, 22) = 0.782$	.386	.034
NIncorr	Condition X Session Interaction	$F(4.660, 102.511) = 1.315$	.266	.056
	Session Main Effect	$F(4.660, 102.511) = 2.386$	.047	.098
	Condition Main Effect	$F(1, 22) = 0.898$	.354	.039
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.835$	.545	.037
	Session Main Effect	$F(6, 132) = 1.051$	.395	.046
	Condition Main Effect	$F(1, 22) = 0.406$	.531	.018
NLow	Condition X Session Interaction	$F(6, 132) = 2.781$	.014	.112
	Session Main Effect	$F(6, 132) = 4.410$	< .001	.167
	Condition Main Effect	$F(1, 22) = 1.228$	.280	.053
LowRT	Condition X Session Interaction	$F(6, 132) = 0.915$	.487	.040
	Session Main Effect	$F(6, 132) = 0.859$	.527	.038
	Condition Main Effect	$F(1, 22) = 1.518$	.231	.065
NHigh	Condition X Session Interaction	$F(6, 132) = 2.922$	.010	.117
	Session Main Effect	$F(6, 132) = 4.438$	< .001	.168
	Condition Main Effect	$F(1, 22) = 1.280$	.270	.055
HighRT	Condition X Session Interaction	$F(4.913, 108.084) = 1.481$	.203	.063
	Session Main Effect	$F(4.913, 108.084) = 2.593$	.030	.105
	Condition Main Effect	$F(1, 22) = 5.134$	.034	.189

Table S. Three-Choice Reaction Time

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 1.313$	.256	.056
	Session Main Effect	$F(6, 132) = 1.462$	.196	.062
	Condition Main Effect	$F(1, 22) = 0.122$	.731	.006
CorrRT	Condition X Session Interaction	$F(3.945, 82.838) = 2.651$	.040	.112
	Session Main Effect	$F(3.945, 82.838) = 3.313$	.015	.136
	Condition Main Effect	$F(1, 21) = 0.640$	.433	.030
NIncorr	Condition X Session Interaction	$F(6, 132) = 1.313$	.256	.056
	Session Main Effect	$F(6, 132) = 1.462$	.196	.062
	Condition Main Effect	$F(1, 22) = 0.122$	.731	.006
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.305$	.933	.014
	Session Main Effect	$F(6, 132) = 0.914$	.487	.040
	Condition Main Effect	$F(1, 22) = 0.916$	.349	.040

Table T. Digit Span (auditory)

Metric	Effect	<i>F</i> (df)	<i>p</i>	η_p^2
NCorr	Condition X Session Interaction	$F(6, 132) = 2.253$	.042	.093
	Session Main Effect	$F(6, 132) = 0.826$	.552	.036
	Condition Main Effect	$F(1, 22) = 0.000$	.995	.000
CorrRT	Condition X Session Interaction	$F(6, 132) = 1.563$	.163	.066
	Session Main Effect	$F(6, 132) = 1.941$	.079	.081
	Condition Main Effect	$F(1, 22) = 0.513$	.482	.023
NIncorr	Condition X Session Interaction	$F(5.796, 121.724) = 0.598$	.726	.028
	Session Main Effect	$F(5.796, 121.724) = 0.752$	.604	.035
	Condition Main Effect	$F(1, 21) = 2.506$	.128	.107
IncorrRT	Condition X Session Interaction	$F(6, 132) = 0.982$	.440	.043
	Session Main Effect	$F(6, 132) = 1.864$	.092	.078
	Condition Main Effect	$F(1, 22) = 0.002$	.961	.000
NTO	Condition X Session Interaction	$F(6, 120) = 1.115$	.358	.053
	Session Main Effect	$F(6, 120) = 0.439$	.851	.021
	Condition Main Effect	$F(1, 20) = 0.500$	.488	.024

Table U. POMS

Metric	Effect	F (df)	p	η_p^2
Tension	Condition X Session Interaction	$F(1.943, 36.909) = 1.145$	.328	.057
	Session Main Effect	$F(1.943, 36.909) = 2.822$	.074	.129
	Condition Main Effect	$F(1, 19) = 1.589$	.223	.077
Depression	Condition X Session Interaction	$F(1.471, 27.952) = 2.265$	.134	.107
	Session Main Effect	$F(1.471, 27.952) = 1.457$	.247	.071
	Condition Main Effect	$F(1, 19) = 2.321$	.144	.109
Anger	Condition X Session Interaction	$F(1.611, 28.999) = 1.778$	.191	.090
	Session Main Effect	$F(1.611, 28.999) = 1.019$	.358	.054
	Condition Main Effect	$F(1, 18) = 1.039$	.322	.055
Vigor	Condition X Session Interaction	$F(6, 114) = 2.263$	.042	.106
	Session Main Effect	$F(6, 114) = 5.571$	< .001	.227
	Condition Main Effect	$F(1, 19) = 0.027$	.872	.001
Fatigue	Condition X Session Interaction	$F(5.553, 105.503) = 3.461$	.005	.154
	Session Main Effect	$F(5.553, 105.503) = 5.957$	< .001	.239
	Condition Main Effect	$F(1, 19) = 4.669$	.044	.197
Confusion	Condition X Session Interaction	$F(2.401, 43.211) = 2.167$	.118	.107
	Session Main Effect	$F(2.401, 43.211) = 1.448$	.245	.074
	Condition Main Effect	$F(1, 18) = 1.269$	.275	.066
TMD	Condition X Session Interaction	$F(2.675, 50.827) = 3.644$	.022	.161
	Session Main Effect	$F(2.675, 50.827) = 5.286$	.004	.218
	Condition Main Effect	$F(1, 19) = 2.710$	.116	.125

Table V. VAS

Metric	Effect	F (df)	p	η_p^2
Alertness	Condition X Session Interaction	$F(6, 120) = 5.026$	< .001	.201
	Session Main Effect	$F(6, 120) = 3.422$	.004	.146
	Condition Main Effect	$F(6, 20) = 1.025$	.323	.049
Anxious	Condition X Session Interaction	$F(4.538, 90.769) = 1.668$	.157	.077
	Session Main Effect	$F(4.538, 90.769) = 3.980$	.004	.166
	Condition Main Effect	$F(1, 20) = 0.572$	.458	.028
Energetic	Condition X Session Interaction	$F(6, 120) = 2.428$	.030	.108
	Session Main Effect	$F(6, 120) = 3.937$	.001	.164
	Condition Main Effect	$F(1, 20) = 0.611$	.443	.030
Confidence	Condition X Session Interaction	$F(4.083, 81.654) = 2.162$	.079	.098
	Session Main Effect	$F(4.083, 81.654) = 3.054$	.021	.132
	Condition Main Effect	$F(1, 20) = 0.685$	.481	.033
Irritable	Condition X Session Interaction	$F(4.809, 96.179) = 1.966$	.093	.090
	Session Main Effect	$F(4.809, 96.179) = 1.767$	.130	.081
	Condition Main Effect	$F(1, 20) = 1.372$	.255	.064
Jittery	Condition X Session Interaction	$F(4.015, 80.303) = 1.379$	.249	.064
	Session Main Effect	$F(4.015, 80.303) = 1.415$	.236	.066
	Condition Main Effect	$F(1, 20) = 0.670$	.423	.032
Sleepiness	Condition X Session Interaction	$F(4.918, 98.355) = 3.647$	.005	.154
	Session Main Effect	$F(4.918, 98.355) = 2.281$	.053	.102
	Condition Main Effect	$F(1, 20) = 0.553$	.466	.027
Talkative	Condition X Session Interaction	$F(5.012, 100.232) = 1.712$	.138	.079
	Session Main Effect	$F(5.012, 100.232) = 3.350$	.008	.143
	Condition Main Effect	$F(1, 20) = 1.073$	.313	.051

Table W. Polysomnography

Metric	<i>t</i> (df)	<i>p</i>
Sleep Latency	$t(21) = -1.573$	.131
REM Latency	$t(22) = 0.093$	.926
Sleep Onset	$t(22) = 0.320$	.752
Sleep Efficiency	$t(22) = -1.026$	.316
N1	$t(21) = 1.067$	.298
N2	$t(22) = 2.239$	.036
N3	$t(22) = -1.623$	.119
REM	$t(22) = -1.636$	.116