Examining the Effects of Eye-Tracking Strategies and Gender on Multitask Performance and Eye Movements during Sleep Deprivation

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Acknowledgments

I would like to take this opportunity to thank those who have helped me throughout this year to prepare this study. First of all, I would like to thank my supervisor, Dr. Glenn Legault, for all his support, guidance, and for trusting me with this sleep research. Secondly, I would like to thank Dr. Roy-Charland for helping with statistical analysis and for giving me easy access to the equipment used at the Cognitive Health and Research Laboratory. A special thanks to Christian Laforge of the Cognitive Health and Research Laboratory for his assistance with the use of the eye-tracking device and software, statistical analysis, and for being there for me every time I had a question. Another special thanks to Dr. Grewal and Tim Doan from the Computer Science Department for helping with the implementation of the eye-tracking strategies on the SYNWIN multitasking simulator. Lastly, I would like to thank Dr. Urajnik and Dr. Emond for their positive feedback on my proposal and thesis defense.

Abstract

The current study implemented eye-tracking strategies on a computerized multitasking simulator in order to examine its effects on cognitive performance and dwell time on tasks during sleep deprivation. The study also looked at gender differences on multitask performance and dwell time on tasks before and after sleep deprivation. There were training trials before being sleep deprived and a testing trial after being sleep deprived for control and experimental groups. The experimental group had the eye-tracking strategies implemented on the multitasking simulator while the control group did not. It was hypothesised that eye-tracking strategies provided on the multitasking simulator would help individuals score better and equally distribute dwell time on tasks after being sleep deprived. It was also hypothesized that both genders would have similar scores and dwell times. Results showed that regardless of the eye-tracking strategies being provided or not, individuals performed better after being sleep deprived. Dwell times decreased for most of the tasks from training to testing and were not equally distributed. No conclusions in terms of gender differences were made due to limitations of unequal distribution of males and females on experimental and control groups. Results suggested that one night of sleep deprivation may not be enough for cognitive impairment to occur in the population examined. Future studies should look at implementing eye-tracking strategies when there is certainty that cognitive impairment due to sleep deprivation is occurring.

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Examining the Effects of Eye-Tracking Strategies and Gender on Multitask Performance and Eye Movements during Sleep Deprivation

Sleep is defined as a behavioral state that is characterized by a physical disconnect from and unresponsiveness to the external environment (Carskadon & Dement, 2011). During sleep, consciousness is completely or partially lost and a combination of physiological and behavioral processes occur (Carskadon & Dement, 2011). When normal sleep is disrupted and sleep loss occurs, these physiological and behavioral processes can be affected resulting in cognitive deficits. Particular neurocognitive domains like working memory, executive function, and higher cognitive functions are extremely susceptible to sleep deprivation (Durmer & Dinges, 2005). This poses a great danger from an occupational health and safety perspective because many people have to spend overnight hours working and performing different kinds of tasks. The effects of sleep deprivation could then increase human-related accidents in the work environment (Dinges, 1995). In order to appreciate how sleep deprivation disrupts sleep processes and causes cognitive deficits, it is important to discuss aspects of sleep architecture, physiology and function and how some aspects can change with age and gender.

Sleep Architecture and Physiology

Normal sleep has a basic structural organization (Altevogt & Colten, 2006). Physiological sleep can be classified by rapid eye movement (REM) and non-rapid eye movement (NREM) sleep (Altevogt & Colten, 2006). These stages are not only present in humans but also in many other mammals and birds (Carskadon & Dement, 2011). NREM and REM sleep can be differentiated by using an electroencephalogram (EEG). NREM sleep is characterized by waveforms like sleep spindles, slow waves with high voltage, and K-complexes (Carskadon & Dement, 2011). Sleep spindles are rhythmic oscillations of 12-14 Hz that last from

0.5 to 3 seconds whereas K-complexes are waveforms that have slow oscillations (0.5-0.9 and 1-4 Hz) with durations close to 0.5 seconds (Crowley, Trinder, Kim, Carrington & Colrain, 2002). REM sleep is marked by low-voltage, mixed-frequency, lack of muscle tone, and sporadic bursts of rapid eye movements (Carskadon & Dement, 2005; Altevogt & Colten, 2006).

The stages of NREM sleep are stages N1-N3. Stage N1 serves as a transition phase and it usually lasts from one to seven minutes in the initial sleep cycle (Altevogt & Colten, 2006). In EEG recordings, alpha waves describe a wakeful relaxation state with a frequency of eight to thirteen cycles (Carskadon & Dement, 2005; Altevogt & Colten, 2006). In stage N2, stronger stimuli are required in order to return to the wakefulness state (Altevogt & Colten, 2006). N2 sleep is when K-complexes and sleep spindles are present; these waveforms are hypothesized to be involved in memory consolidation (Altevogt & Colten, 2006). Stage N3 is called slow-wave sleep because the EEG shows slow waves when the stage is present. N3 occur mostly during the first third of the night and it accounts for about 15-25% of total sleep (Altevogt & Colten, 2006).

REM sleep is not usually divided into stages but it can be distinguished as having tonic and phasic types (Carskadon & Dement, 2011). The difference between tonic and phasic types is based on short events of eye movements that happen in sequence, separated by episodes of inactiveness (Carskadon & Dement, 2011). In humans, REM sleep phasic activity is characterized by the typical burst of rapid eye movement accompanied with muscle twitches and irregularities in cardiorespiratory activity (Carskadon & Dement, 2011). It is also hypothesized that dreams occur during REM sleep because vivid dreams tend to be recalled generally after about 80% of arousals from this state (Dement & Kleitman, 1957; Carskadon & Dement, 2011).

The two-process model theory proposes that the sleep-wake system is regulated by a process that promotes sleep (process S) and one that maintains the state of wakefulness (process c) (Gillette & Abbott, 2005; Altevogt & Colten, 2006). The homeostatic drive for sleep (process S) builds up during the day, peaks just right before bedtime, and gradually fades throughout the night (Altevogt & Colten, 2006). The wake promoting system (process C) acts to counteract process S to promote wakefulness and alertness (Gillette & Abbott, 2005; Altevogt & Colten, 2006). At bedtime, the system decreases its activity in order to promote the need to sleep. Once the body is fully rested with an adequate night's sleep, the drive for sleep decreases, the wake promoting system increases its activities, and the sequence starts again (Altevogt & Colten, 2006). Total sleep time remains constant and it is divided across day and night when process C is absent (Gillette & Abbott, 2005; Altevogt & Colten, 2006). This is why process C is important for the consolidation of wake and sleep into separate episodes (Gillette & Abbott, 2005; Altevogt & Colten, 2006). In addition, process C also helps in coordinating sleep and wakefulness with the environmental factors of light and dark cycles (Altevogt & Colten, 2006).

Another important aspect of sleep is the 24 hour clock or the circadian rhythms. This biological clock refers to the daily rhythms that control heart rate, muscle tone, food consumption, wake-sleep cycle, body temperature, secretion of hormones, and physical activity (Altevogt & Colten, 2006). The neural structures of the hypothalamus are the ones responsible for the generation of these rhythms (Dunlap, Loros, & DeCoursey, 2004; Altevogt & Colten, 2006). In terms of body temperature, the circadian system works to increase body temperature during the day and decrease it at night (Altevogt & Colten, 2006). The promotion of sleep onset and maintenance is accomplished by decreasing heat production and increasing heat loss (Altevogt & Colten, 2006). However, a few hours before waking, the brain sends commands to body parts in order to promote the increase in heat production and reduction of heat loss (Szymusiak, 2005; Altevogt & Colten, 2006).

Sleep Function and Sleep Patterns Related to Age and Gender

The reason why we sleep has been an intricate mystery in biology. Many theories have tried to explain the function of sleep but some lack strong experimental support and others could only explain a fraction of sleep behavior (Frank, 2006). Nevertheless, most research has concluded that cognition is the neural process most affected by sleep and therefore sleep is not a body phenomenon but a brain phenomenon (Frank, 2006). It is also clear that without sleep, there is loss of the sense of well-being and reductions in cognitive functioning (Krueger, Obál, & Fang, 1999). In relation with unified theories, sleep serves to maintain memories that are acquired and inherited (Krueger et al., 1999). These theories explain that within small neuronal groups, oscillatory activity during sleep induces the production of growth factors that help in mediating the consolidation of new synapses (Krueger et al., 1999). These synapses then help in processing new memory traces (Krueger et al., 1999). Neurophysiological and molecular changes during sleep include interactions between cortical and subcortical areas of the brain to transmit information, changes in single neurons, and changes in genes and proteins (Buzsáki, 1996; Hasselmo, 1999; Sejnowski & Destexhe, 2000; Timofeev et al., 2002; Frank, 2006). Sleep deprivation could then disrupt these neurological processes with subsequent cognitive impairment as sleep mediated physiological processes are unavailable (Frank, 2006).

Sleep patterns can change with age as there are differences in the amount of time spent in each sleep stage, and in the initiation and maintenance of sleep from infancy to adulthood (Altevogt & Colten, 2006). In adulthood, there is earlier wake time and reductions in the consolidation of sleep (Dijk, Duffy, & Czeisler, 2000; Altevogt & Colten, 2006). In younger adults, sleep stays relatively consolidated but brief awakenings are likely to occur during the transition to REM sleep (Altevogt & Colten, 2006). However, arousals that occur mostly during REM sleep suggest that there is a mechanism that prevents awakenings during NREM to increase sleep efficiency (Altevogt & Colten, 2006). The experience of frequent awakenings in older adults is related with the decline in slow-wave and the reduction in the effectiveness of the circadian rhythm during the night (Dijk et al., 2000; (Altevogt & Colten, 2006). Crowley et al. (2002) showed that spindle number, density, and duration, as well as K-complex number and density, were all significantly lower in the elderly compared to the young adults. In addition, there is also a reduced secretion of hormones like melatonin and cortisol, which are hormones involved in sleep regulation (Dijk et al., 2000). In adults, men tend to spend more time in stage N1 sleep and experience more awakenings than women (Bixler, Kales, Jacoby, Soldatos, & Vela-Bueno, 1984; Kobayashi et al., 1998; Altevogt & Colten, 2006). Slow-wave sleep is longer in women and they tend to complain more about having difficulties falling asleep while men have more trouble with daytime sleepiness (Ancoli-Israel, 2000; Altevogt & Colten, 2006).

Sleep Deprivation and Cognitive Performance

The consequences of sleep deprivation on daytime performance are experienced across cultures and are typically linked to financial, social, and human costs (Durmer & Dinges, 2005). Sleep loss is associated with human cost because it increases the risk of accidents caused by human error (Dinges, 1995; Durmer & Dinges, 2005). Motor vehicle crashes due to impaired driving caused by alcohol are normally reported. However, sleep deprivation is able to produce psychomotor impairment at a level similar to that of alcohol or even above the legal limit (Dawson & Reid, 1997; Durmer & Dinges, 2005). Sleep loss poses a great risk in the adequate operation of heavy equipment and when performing activities that require safety precautions (Durmer & Dinges, 2005). Since people like medical residents, shift-workers, and truck drivers are constantly sleep deprived, it is important to conduct studies on sleep deprivation in order to show the risk that this poses and how it can cause fatal consequences (Durmer & Dinges, 2005).

Sleep deprivation can be classified as partial (sleep restriction to <7 hours/24 hours), short-term total sleep deprivation (≤ 45 hours), or long-term total sleep deprivation (>45 hours) (Durmer & Dinges, 2005). All these classifications of sleep deprivation are able to impact mood states, including increased confusion, loss of vitality, sleepiness, and feelings of fatigue (Durmer & Dinges, 2005). Cognitive performance during sleep deprivation is also impaired and becomes progressively worse once time spent on a task increases (Durmer & Dinges, 2005). Nevertheless, even when examining cognitive performance on brief tasks, there are still deficits in working memory, attention, cognitive, and executive function (Dinges, 1992, Durmer & Dinges, 2005). Even acute or partial sleep deprivation is able to cause significant declines in cognitive function (Pilcher & Huffcutt, 1996). Therefore experimentation with partial sleep deprivation on multitasking can be conducted and significant results may be found (Durmer & Dinges, 2005).

Eye Movement, Gender and Sleep Deprivation

A study by Zils, Sprenger, Heide, Born, & Gais (2005) showed the effect of sleep deprivation on eye movements and how they changed as fatigue occurred. The study looked particularly at different types of saccadic eye movements. Saccadic eye movements are irregular movements of the eyes when they change gaze direction in response to a target (Zils et al, 2005). Zils et al. (2005) divided participants into two experimental conditions. For the sleep condition, participants slept for one night in the sleep laboratory and on the next day were measured on memory-guided saccade task (Zils et al, 2005). They stayed at the lab one more night and the next morning they were tested again on the tasks (Zils et al, 2005). The tasks involved subjects having to fixate on a central point for a period of time. For the wake condition, participants were tested on the saccadic tasks in the evening, stayed up all night at the lab, and then they were retested again in the morning. They were retested again a third time following a night of recovery sleep. During the time they were in the lab, participants were not allowed to take part in activities that would strain their eyes, such as reading or watching TV (Zils et al, 2005). Instead, participants spent the night at the lab listening to music or audio books. Different types of saccadic eye movements were recorded by using electrooculography. Zils et al. (2005) were particularly focused in measuring saccadic accuracy, peak velocity, and latency. Saccadic peak velocity refers to saccadic speed in degrees per second (Zils et al, 2005). Saccadic latency is the reaction time from the target to the onset when the saccade begins (Zils et al, 2005). Parameters of accuracy involve the amplitude of the target combined with the amplitude of the saccade (Zils et al, 2005). The results of the study showed that sleep deprivation negatively affects saccadic peak velocity. Sleep deprivation was not seen to have a significant impairment in saccadic latency (Zils et al, 2005). However, accuracy of reflexive saccades was reduced.

Zils et al. (2005) showed that a night of sleep loss affects saccadic eye movements; however, there were limitations in the study. For instance, the study only had male participants and did not show if there are gender differences in eye movements arising from sleep deprivation. Nevertheless, by showing that sleep deprivation affects eye movements, future research can investigate if this effect can be mitigated. The current study will try to provide ways to counteract the effects of sleep deprivation on eye movements.

Miyahira, Morita, Yamaguchi, Nonaka, & Maeda (2000) showed that there are differences in men and women in exploratory eye movements and fixation points when perceiving images. Adult women spent more time gazing at images than adult men (Miyahira et al., 2000). In addition, eye scanning length was longer in men than women (Miyahira et al., 2000). However, the study did not investigate the rate that sleep deprivation may play in these differences.

Gender and Multitasking

There are gaps in the literature with respect to understanding if there are gender differences in multitasking ability as function of sleep deprivation. Research tends to focus on gender differences in multitasking ability when participants are not sleep deprived. There were contradictions in the past literature regarding differences in gender related capacity. Fisher (1999) claims that the division of work from prehistory enabled men and women to develop different aptitudes into their brains. The skills that women gained enabled them to multitask better than men (Fisher 1999; Buser & Peter, 2012). In addition women are also more inclined to multitask than men (Fisher 1999). However, more current research (Buser & Peter, 2012) has shown that there is no difference between genders in multitasking ability.

The study by Buser & Peter (2012) used three treatments during the experiment. In the first treatment, participants worked on two tasks consecutively, with 12 minutes allowed for each task (Buser & Peter, 2012). In the second treatment, participants were forced to switch between the two tasks. In the third treatment, participants could choose which task to attend to (Buser & Peter, 2012). In order to avoid confounds, Buser & Peter (2012) used non-gender specific tasks. These tasks were in the form of games of Sudoku and Word Search. The idea was that when trying to solve a Sudoku puzzle, multitasking would be appealing when there was no clear solution for solving the puzzle (Buser & Peter, 2012). Consequently, participants would switch to the Word Search task and hope to approach the initial problem from a different perspective when switching back (Buser & Peter, 2012). In a similar way, it was expected that participants switched to the Sudoku puzzle once they were unable to find words for a period of time (Buser & Peter, 2012). Multitask performance was based on the sum of the Sudoku plus-points and the Word Search points.

Buser & Peter (2012) found no evidence supporting the idea that women are better or more inclined to multitask than men. The share of switchers was equal for men and women and the average number of switches was higher for men (Buser & Peter 2012). The results of this study suggest that women struggle as much as men when multitasking. The current study will try to investigate if in fact these results could also apply when participants are sleep deprived.

Eye-Tracking Strategies

Eye-tracking refers to the process of locating, following and recording the movement of the point of gaze (Lavine, Sibert, Gokturk, & Dickens, 2002). When a series of gaze points are close together in space and time, the gaze points make up what is called a fixation (Lavine et al., 2002). The total duration of fixations on a particular target is called the dwell time (Lavine et al., 2002). In this sense, an eye-tracking strategy is a method used in order to focus an individual's attention or fixation points to a desired target (Lavine et al., 2002). In a computerized multitasking environment, eye-tracking strategies can be provided in order to help individuals focus on tasks that require immediate attention, helping them to increase their cognitive performance (Zhang & Norman, 1994). This can be accomplished in many ways. For example, by making some parts of the computer interface context-sensitive, individuals are able to know to what information they have to attend to. This is usually done by using the highlighting method in which important information at a specific time is highlighted and the information that does not require attention at that time is disabled or hidden (van Nimwegen et al., 2006). However, the method of combining figure/background colour in a computerized environment has showed to have better effects in performance when attending to different things at the same time (Huang, 2008). This method can be useful especially when individuals are fatigued and need eye-tracking strategies to work on different tasks (Zhang & Norman, 1994).

Huang (2008) investigated the effects of figure/background colour combinations on visual search performance on a liquid crystal display screen. The experiment had participants searching for a target item in an array in the form of a circle. Search performance was measured by the number of errors occurring during each search task and by the search time to complete a search task (Huang, 2008). The results showed that the search time for figure/background combinations with white/yellow and white/blue were significantly shorter than for the other colours used in the experiment. Huang (2008) concluded that this was because higher colour contrast makes it possible for a target to be detected more readily. This gives the capability for better search performance because the figure/background colour combination is a more differentiable aspect of an icon that needs to be identified (Huang 2008). The strategies provided by Huang (2008) were useful because it improved performance. However, the study did not focus on differences in gender when visual strategies are given. In addition, the study did not use any eye-tracking device to show how eye movements changed when different colours were displayed.

Current Study

The purpose of the current study was to look at the effects of eye-tracking strategies and gender differences on eye movements and cognitive performance in a computerized multitasking simulator after a night of sleep deprivation. The study focused on using eye-tracking strategies in order to see if our manipulations were able to mitigate the effects of sleep deprivation on the multitasking simulator. The research evaluated how participants unconsciously changed dwell time spent on tasks before and after being sleep deprived. It was hypothesized that when the multitasking simulator had eye-tracking strategies to guide participants in working with the tasks, their performance would improve compared to the performance of those who did not have eye-tracking strategies on the simulator. It was hypothesized that the eye-tracking strategies would cause less dwell time spent on tasks from those who had to multitask without the manipulation. In terms of gender, no significant difference was expected for dwell time spent on tasks and multitask performance after sleep deprivation since male and female sleep patterns are relatively similar (Bixler, Kales, Jacoby, Soldatos, & Vela-Bueno, 1984 Kobayashi et al., 1998; Altevogt & Colten, 2006). Therefore, sleep disruption should affect eye movements and cognitive performance in a similar way in both genders.

Methods

Participants

Thirty-one undergraduate students (11 males and 20 females; mean age: 19.93) from Laurentian University took part in the experiment. Participants were recruited from different Psychology courses and course credit plus fifty dollars cash incentive was given for their participation. Participants were first required to read a consent form that explained some aspects of the study. The consent form also explained that participation was completely voluntary and participants could withdraw at any point and would still receive the fifty dollars cash incentive. All the participants that came to the laboratory were fully aware that they had to stay awake for a full night because e-mails were sent a week prior of their participation given them this information. The e-mail also explained that only participants that lived on the different residences at Laurentian University were needed. This was done in order to avoid participants from driving after being sleep deprived. After signing the consent form, participants were required to fill out a demographics form (see appendix A). The demographics form was used in order to account for confounds, a prescription drug for example, that could affect cognitive performance.

Materials

The SYNWIN Multitask environment was used in order to track multitask performance. This multitask environment is composed of four tasks presented simultaneously on a computer screen (see Braude, Goldsmith, & Weiss, 2011). The first task is a memory task that involves a set of six letters that are briefly shown and then hidden. At fixed periods of time, a letter is shown and the task of the participant is to decide if the letter in the probe box is part of the set of six letters previously displayed. If the participant answered correctly, then points were awarded. However, if the answer was incorrect, points were deducted (Braude et al., 2011). The second task is a simple arithmetic calculation. An addition problem is displayed and the task of the participant was to add the numbers and press “Done” once the addition has been calculated (Braude et al., 2011). Correct responses are awarded with points while incorrect responses deduct points. The third task is a visual task that requires careful attention to a fuel gauge that moves toward empty. Points were awarded if the participant clicked on the gauge before it reaches empty. The fuel resets back to full every time it is clicked. The points awarded depend on how close the gauge was to being empty before it was clicked (Braude et al., 2011). For the auditory task, a high or low tone is produced at different intervals. The task of the participant was to click on the high frequency button every time a high tone is produced. Points were awarded if the participant clicked on the button in response to the high tone. If a high tone was produced and the participant did not click the button, points were deducted. The memory and arithmetic tasks are timed while the visual and auditory are not. If time runs out and the tasks are not attended, points are deducted. This is done in order to avoid selective attention. However, the time is not shown on the display screen to avoid precipitated responses.

Two versions of the SYNWIN Multitask environment were used for the study. The first version (see appendix B, Figure 1) is similar to the one used by Braude et al. (2011). Nothing is changed in this version and the tasks are displayed as usual. However, for the second version (see appendix B, Figure 2), eye-tracking strategies similar to those provided by Huang (2008) were used. The background for this version changed to yellow and when the timed tasks are close to running out of time, the quadrants turn white. This was done in accordance with the study by Haung (2008) that showed that figure/background combinations with white/yellow improve search performance. Therefore, whenever the memory and arithmetic tasks are close to running out of time, the transformation of the task quadrant to white was expected to draw the participant's attention to that task. White/yellow was preferred over white/blue because of the nature of the SYNWIN program; using white/blue does not allow appropriate vision of the words displayed on the tasks. The visual and auditory tasks did not have visual cues because they required manipulation of the SYNWIN program, making it different from the first version. For example, changing the fuel gauge rate to a different value from the first version to make the right activation between the visual cue and when the gauge is close to being empty. If the auditory task was provided with visual cues, it was required to set the high tone to sound at a specific interval from the low tone; also making it different from the first version in which tones sound at a random order. In order to avoid confounds, both versions were maintained as constant as possible.

Participants responded to both SYNWIN multitasking programs while using a SR Research Eye link 1000 system housed in the Cognitive Health Research Laboratory at Laurentian University. This eye-tracking device allowed the recording of all eye movements. Data Viewer was the eye-tracking software used in order to investigate where participants were focusing on and how long they spent on each task. The Data Viewer software records dwell time in milliseconds. Each trial on the SYNWIN multitask had a timer of five minutes and so the conversion on the software for this period was of 300,000ms. Since the only important time was the one when participants were working on the tasks, every recorded eye movement before multitasking began was deleted from the software. For example, the eye-tracking device recorded eye movements when participants were given a tutorial of each task. Since this time is not important, they were deleted from the software.

Procedure

Participants worked on the multitask simulator while having the eye tracking device attached close to their face, looking at a computer screen that had the eye tracking software that monitored their eye movements. Multitask performance was measured by the composite scores recorded on the SYNWIN score data while dwell time was assessed by the eye tracking measures recorded on the eye tracking software.

The experiment had training and testing phases and participants were randomly assigned to one of two sleep deprived groups. The control group was trained in the evening with the SYNWIN version that had no eye-tracking strategies, stayed up all night, and then was tested in the morning with the same version. For the experimental group, participants were also trained with the SYNWIN version with no eye-tracking strategies and then remained in the laboratory all night. However, participants in the experimental group were tested in the morning with the SYNWIN version that had the eye-tracking strategies implemented in the program. The training phase was done in order to reach a baseline score in the SYNWIN multitask to compare with the score of the testing phase. This would allow comparisons to see if participants did better or worse in the testing phase and if the eye-tracking strategies helped the experimental group get a better score in the testing phase. Since the objective was to investigate if the eye-tracking strategies helped improve performance after the effects of sleep deprivation, the manipulation was only used in the experimental group during the testing phase.

When participants came to the Cognitive Health Research Laboratory at night, they were trained in the multitasking simulator as soon as they finished filling out the informed consent and demographics forms. After they finished the training phase, they remained in the lab and were monitored by the researcher. Participants spent most of their time playing board and card games, reading, and working on school assignments. Participants brought their own food and drinks for the night. However, as stated on the consent formed, they agreed not to consume energy drinks or caffeine. The experiment took place only during weekends or during the week when they had a break from school.

Results

Multitask Performance

Mean composite scores for multitask performance (Figure 1) were evaluated using a mixed-design ANOVA with trials (train1, train2, train3, test) as within subject factors and groups (control, experimental) as between subject factors. Greenhouse-Geisser corrections were used since Mauchly's sphericity test was violated ($p<.05$). Results revealed a significant main effect of trial, $F\ (2.029, 58.839) = 40.669$, $p<.05$, $\eta_p^2 = .584$. Post-hoc analysis indicated that train1 had lower scores than train2, train3, and test. Train2 had higher scores than train1 and lower scores than test. Train3 had higher scores than train1 and lower scores than test. Test had statistically significant higher scores than train1, train2, and train3. The interaction and main effect for group (Figure 2) did not reach significance [group $F<1$].

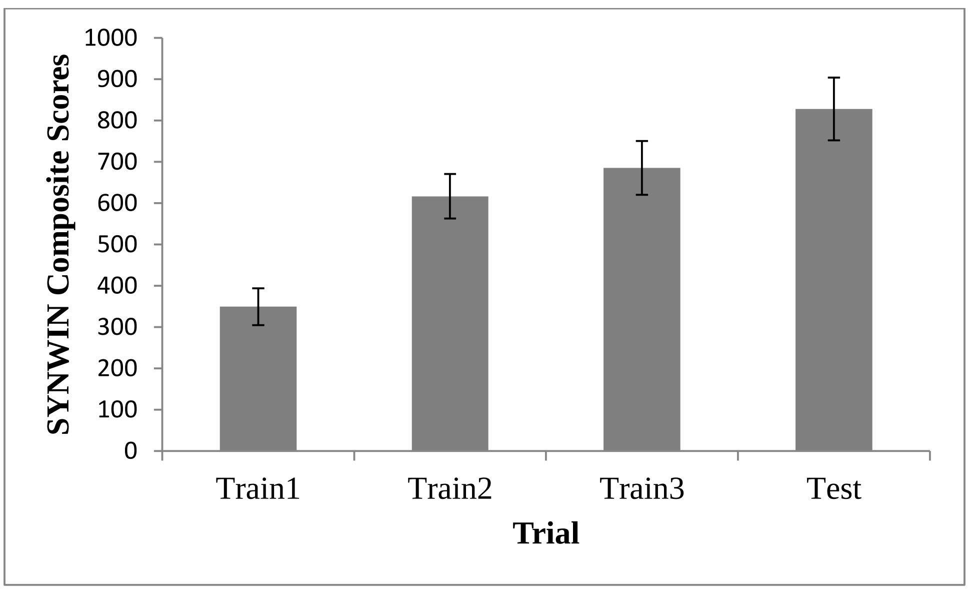

Figure 1. Multitask performance on SYNWIN simulators. Composite scores on multitask performance are shown with the overall means of both SYNWIN versions added together for

each trial. Three different trials are shown for the training phase and one trial for the testing phase. The trial for the testing phase represents the performance when participants were sleep deprived.

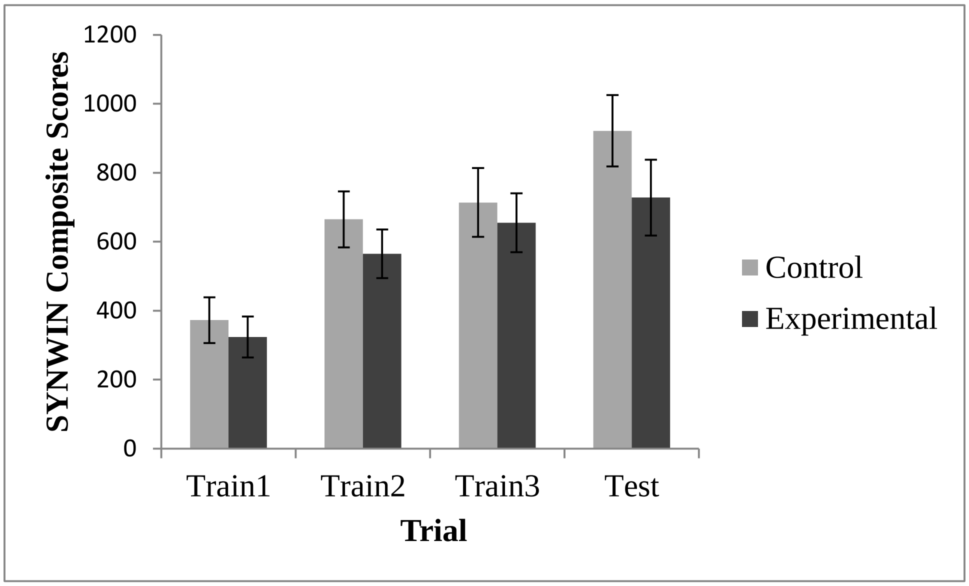

Figure 2. Multitask performance on different SYNWIN simulators. Composite scores are shown for the control group that had no eye-tracking strategies on the simulator, and for the experimental group, which had eye-tracking strategies implemented on the simulator. The trial for the testing phase represents the performance when participants were sleep deprived.

Dwell Time on Tasks

Mean scores for dwell time spent on each task (Figure 3) were evaluated using a mixed-design ANOVA with trials (train1, train2, train3, test) and tasks (memory, arithmetic, visual, auditory) as within subject factors and groups (control, experimental) as between subject factors. Greenhouse-Geisser corrections were used since Mauchly's sphericity test was violated ($p<.05$). Results revealed a significant interaction of trial and task, F (3.012, 87.342) = 4.127 $p<.05$, η_p^2 =

.125. Post-hoc analysis indicated that for the fuel (visual) task, train1 dwell time was higher than dwell time for train3 and train4 (train3 and train4 also statistically significant lower than train1). For the math (arithmetic) task, dwell time for train1 was higher than dwell time for test (test also statistically significant lower than train1). No statistical significance for any of the trials of the memory task was found. For the sound (auditory) task, dwell time for train1 was higher than dwell time for test (test also statistically significant lower than train1). The following interactions did not reach significance: trial and group; task and group; task, trial, and group (All Fs<1). Main effect of group also did not reach significance (F<1). Figure 4 and Figure 5 show the dwell times for the control and experimental groups respectively.

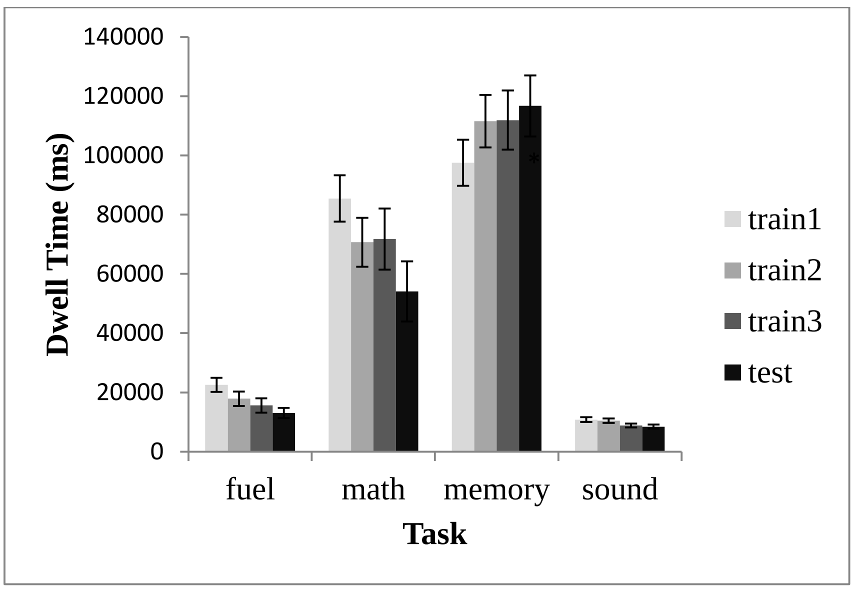

Figure 3. Dwell time on tasks for each trial. Dwell times are shown for both the control and experimental groups added together. Train1, train2, and train3 represent the three trials for the training phase. The test trial represents the trial for the testing phase when participants were sleep deprived. More dwell time is attributed to the math (arithmetic) and memory tasks.

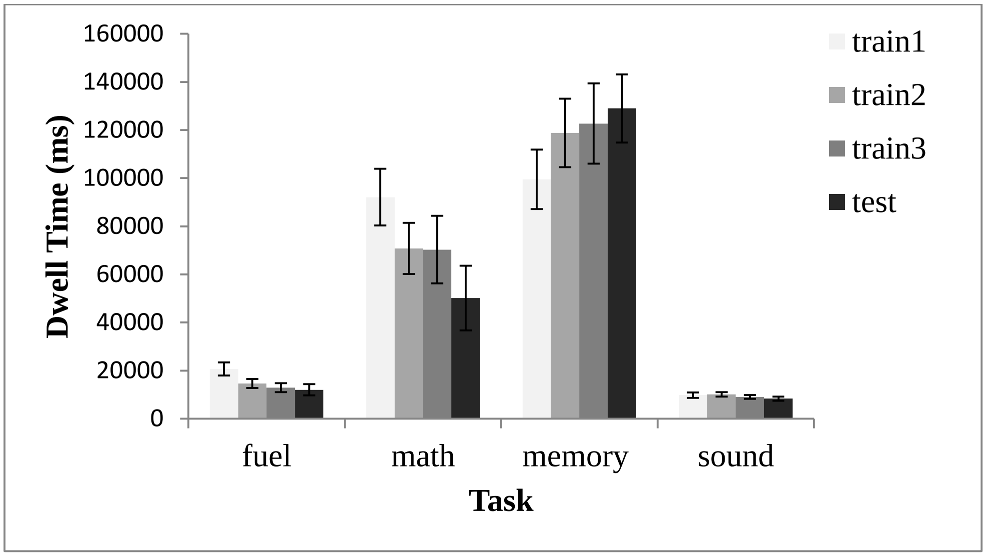

Figure 4. Control group dwell times on tasks. Dwell times are shown for the control group that did not have eye-tracking strategies for the test trial.

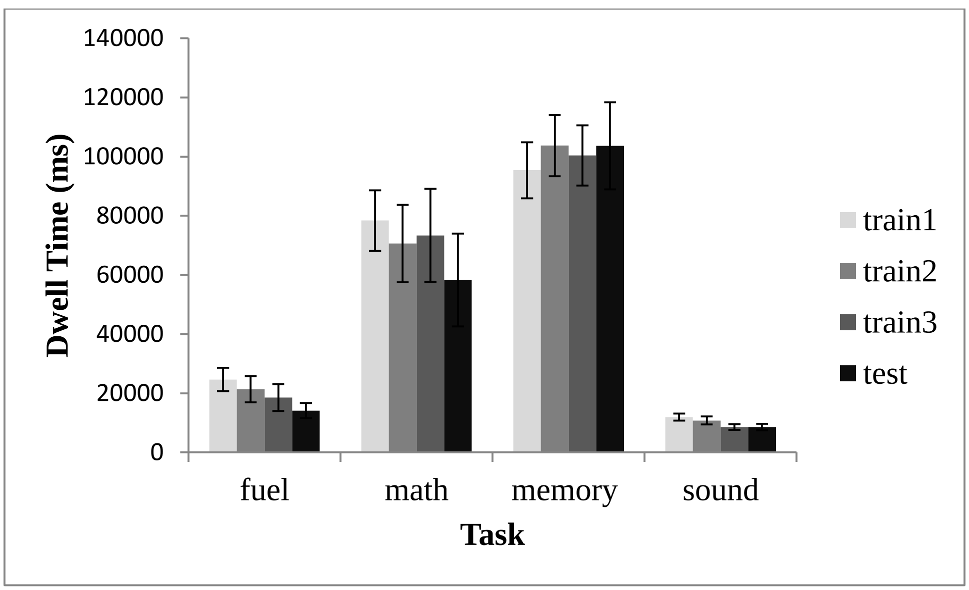

Figure 5. Experimental group dwell times on tasks. Dwell times are shown for the experimental group that had the eye-tracking strategies for the test trial.

Gender Differences

Gender differences were not computed because there were not equal numbers of male and female participants on each group. The control group had a total of sixteen participants and the control group a total of fifteen participants. In the control group, seven participants were females and nine were males. For the experimental group, thirteen were female participants and two were male. Due to the unequal number of male and female participants on each group, gender comparisons in terms of multitasking performance and dwell times spent on each task were not possible.

Discussion

The current study sought to determine whether implementing eye-tracking strategies on the SYNWIN multitasking simulator would mitigate the effects of sleep deprivation on cognitive performance. It was hypothesized that the experimental group would perform better than the control group on the testing phase (morning after sleep deprived) because the experimental group had guidance on what tasks they had to focus. It was predicted that the eye-tracking strategies would cause lesser dwell time spent on tasks for the experimental group than the control group.

Multitasking Performance

Results showed that participants kept getting better at each trial during the training phase. This was expected since after the first trial participants learned how to work on each task. During the following two trials, participants were already used to the tasks. However, our hypothesis about the experimental group performing better than the control group during the testing phase was not supported. Results showed that participants kept getting better at multitasking even after being sleep deprived. This was expected for the experimental group because they had the eye-tracking strategies that would help them work on the different tasks. However, results showed that the control group that did not have the eye-tracking strategies also performed better in the testing phase (sleep deprived) than the training phase (not sleep deprived). No difference was found between both groups in terms of cognitive performance for the testing phase. The figure/background strategy previously used by Huang (2008) was not of greater help for the experimental group. In addition, the results do not support the findings by Pilcher and Huffcutt (1996) when suggesting that partial sleep deprivation is able to cause significant declines in cognitive function.

Results for multitasking performance on both groups may be explained by analysing the age population used in the experiment. Haavisto et al. (2010) found that participants aged 19-29 years old who were sleep deprived for a period of five days for four hours per day did not show large impairments in multitasking performance. Only a few sleep deprived individuals showed large impairments in their performance (Haavisto et al. 2010). Most of the sleep-deprived individuals showed only moderate deteriorations and some individuals’ performance remained unchanged (Haavisto et al. 2010). The current study also had an age population similar to that of Haavisto et al. (2010). This indicates that for this specific age population, impairment on multitasking performance due sleep deprivation may not occur after a couple of nights. This age population may require more days of sleep deprivation in order to show deficits in multitasking performance. Therefore, eye-tracking strategies may be effective after cognitive deficits have actually occurred.

Dwell Time

It was predicted that after sleep deprivation, the control group would spend more time on each task compared to the training phase. According to Haavisto et al. (2010), cognitive deficits after sleep deprivation increase as a function of the time spent on a task. Therefore, it was expected that participants in the control group would spend more time working on the different tasks for the testing phase because they would be fatigued and would require more time to respond to the tasks, especially to the memory and arithmetic tasks. Results showed that participants spent more time working on the arithmetic and memory tasks compared to the other two. However, dwell time for the arithmetic task during the testing phase was less than the dwell time for the training phase. The memory task was the only who showed increases in dwell time for the testing phase compared to the training phase. This may be explained by looking at the overall performance or composite scores on the SYNWIN simulator. The control group performed better after being sleep deprived than before being sleep deprived, indicating that cognitive deficits did not occur. Therefore, participants kept using the same strategies that they developed when working during the training phase and used them for the testing phase as well. Since participants did not show cognitive deficits, sleep deprivation did not affect their use of strategies for the testing phase. This may also explain why the same trend is seen on dwell time for each trial since the same strategies were used at every trial.

For the experimental group, it was hypothesized that the eye-tracking strategies would help them spend less time on each task during the testing phase. Improvement on cognitive performance by means of eye-tracking strategies meant that their dwell time on each task would be less and relatively similar for the testing phase. However, results showed that the control group and experimental group were not significantly different in terms of dwell time spent on each task. The experimental group also used their own strategies learned during the training phase and applied them to the testing phase. The eye-tracking strategies did not cause a significant change on dwell time compared to the control group. As mentioned before, Haavisto et al. (2010) found that deficits in cognitive performance in young adults may not be seen during partial sleep deprivation. The findings of this study are supported by the results shown in the current study. Therefore, it may be that the eye-tracking strategies did not contribute much to dwell time spent on each task because cognitive deficits did not occur in the majority of the participants on the experimental group.

Gender Differences and Limitations

Fisher (1999) claimed that the division of work from prehistory enabled men and women to develop different aptitudes into their brains. The skills that women gained enabled them to multitask better than men. However new evidence has shown that women struggle as much as men when multitasking and are even less inclined to do so when they have the ability to choose if multitasking or not (Buser & Peter (2012). Therefore, for gender differences, it was hypothesized that males and females would perform equally on multitasking performance. Miyahira, et al. (2000) showed that there are differences in men and women in exploratory eye movements and fixation points when perceiving images. Adult women spent more time gazing at images than adult men (Miyahira, et al., 2000). No gender differences were expected for dwell time because the study by Miyahira, et al. (2000) showed these differences when participants did not have cognitive deficits due sleep deprivation. Studies have shown that male and female sleep patterns are relatively similar (Bixler, Kales, Jacoby, Soldatos, & Vela-Bueno, 1984 Kobayashi et al., 1998; Altevogt & Colten, 2006). Therefore, sleep disruption would affect dwell time spent on tasks in a similar way for both genders. These hypotheses were not able to be tested due to the unequal number of males and female participants on each group. This posed a limitation to the study since we were not able to investigate if there were gender differences in multitasking performance in males and females before and after sleep deprivation. In addition, we were not able to investigate if there were gender differences in dwell time spent on each task before sleep deprivation effects and if the eye-tracking strategies helped on gender better than the other.

Another limitation of the current study was that only young adults were tested on multitask performance. This prevented from making age population comparisons that could have shown an older population's performance after a night of sleep deprivation. By implementing the eye-tracking strategies on the older population, results could have shown if the strategies helped the older population. The participants used in the experiment were university students who are most likely used to spend a night without sleep. However, maybe more nights of sleep deprivation could actually show cognitive deficits on this population. The experiment only tested participants after one night of sleep deprivation. This may not apply to the real world where shift workers who have to work overnight for more than one day a week.

The SYNWIN multitasking simulator may have also presented a limitation to the study. It may be that the simulator is not sensitive to the effects of sleep deprivation. Haavisto et al. (2010) used a similar version of the simulator and found that four hours of sleep restriction for a total of five days only caused moderate changes on cognitive performance. Therefore, the SYNWIN multitasking simulator may not be a good indicator of sleep deprivation effects on multitasking performance. In addition, the SYNWIN simulator was programmed for only five minutes per trial. The time-on-task effect is critical in assessing cognitive performance after sleep restriction (Dinges, & Kribbs, 1991). In other words, the more time someone spends on a task after sleep restriction, the more the effects of deterioration of performance in the course of the task session (Dinges, & Kribbs, 1991). Therefore, it may be that the time that the SYNWIN simulator was programmed for was not long enough for participants to start showing impairment on multitasking.

Future Directions

Future studies should examine the validity of the SYNWIN multitasking simulator in evaluating cognitive performance after sleep deprivation. If the simulator shows to be sensitive to effects of sleep deprivation, the program should be modified in a way that would allow all of the tasks to have eye-tracking strategies to see if they can mitigate the effects of sleep deprivation on multitasking performance. Future studies should also investigate different age groups and determine when they show deficits in cognitive performance and changes in eye movements due to sleep deprivation. By doing so, the eye-tracking strategies could be implemented at the right time for each age group.

Conclusions

In conclusion, this study used eye-tracking strategies in order to examine if they could mitigate the effects of cognitive deficits on multitasking performance. The eye-tracking strategies were also used in order to investigate if they had an effect on dwell time spent on different tasks. Gender differences were not examined due to limitations of the study. Results suggested that a night of sleep deprivation may not be sufficient for cognitive deficits to occur in the age population examined (mean age: 19.93).

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Appendix A

Demographics Questionnaire

Unique Study Identification Number: ______

About you:

Gender: Female ☐ Male ☐ Rather not say ☐

Date of Birth: ______________________

Height (cm): ________________________ **Weight (kg): ________________________**

Do you smoke? **Yes or No**

Please indicate how you arrive at school usually:

______ I drive myself. I live approximately____________km from Laurentian University

______ I take public transit

______ I walk as I live close to Laurentian University or I live in the University Residences

Your Normal Sleeping Behaviours:

How many caffeinated beverages (e.g. coffee, tea, cola) do you have each day? (One serving = 1 cup/250 mL, a large Tim Horton's coffee is 2 servings)

[ ] 0 servings [ ] 1P2 servings [ ] 3P4 servings
[ ] 5 servings or more

Are you currently on any medication that has been prescribed by your health care provider?

Yes or No

If yes, please specify: ____

Has a Doctor diagnosed you with a sleep or mood disorder? **Yes or No**

If yes, please specify: ____

Do you have any medical issues (allergies, headaches, high blood pressure, joint pain, diabetes, etc.) that may affect your sleep? **Yes or No**

If yes, please specify: __________________

Are there any illnesses or sleep disorders that run in your family? **Yes or No**

If yes, please specify: ___________________

Have you gained or lost weight in the last 5 years?

[ ] Gained____ (in kilograms) [ ] Lost____ (in kilograms)

Has anyone ever told you that you snore? **Yes or No**

Has anyone ever told you that you talk in your sleep? **Yes or No**

Has anyone ever told you that you kick your feet in your sleep? **Yes or No**

Has anyone ever told you that you choke, gasp, or hold your breath while sleeping? **Yes or No**

What is the **average** number of nights per week that you wake up at least once midPsleep (out of 7 nights):______?

What is the **average** number of times that you wake up per night/sleep: ________times?

When you wake up mid sleep (during the night), how long is it until you fall asleep again? ________minutes

What is the likelihood that you would sleep in if you did not use an alarm clock or have someone/something wake you up?

[ ] Not at all likely[ ] somewhat likely[ ] Quite likely [ ] Extremely likely

How often do you feel refreshed when you wake up for the day?

[ ] Never [ ] Rarely [ ] Often [ ] Always

In a normal week, how many days would you have a nap (out of 7):____days

On average, how long would you nap for: ________minutes

Appendix B

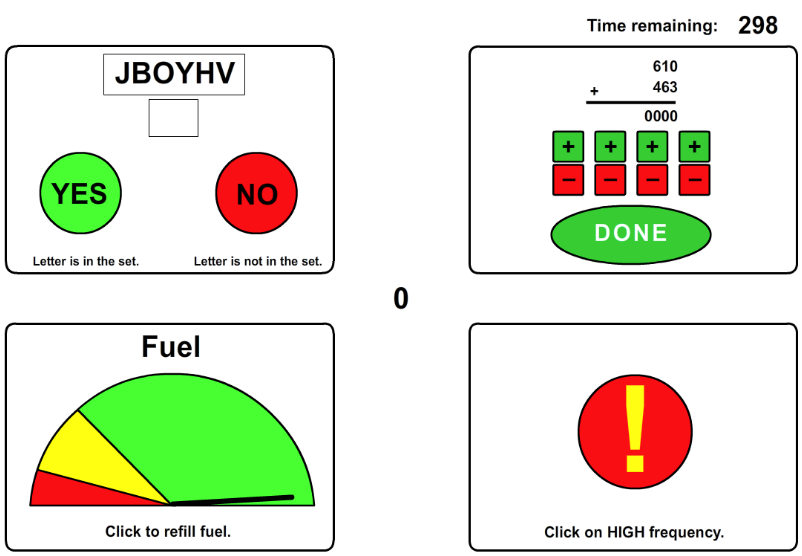

Figure 1. Screenshot of the SYNWIN multitasking work environment with no eye-tracking strategies. Memory-upper left, mathematical-upper right, visual-lower left, and auditory-lower right.

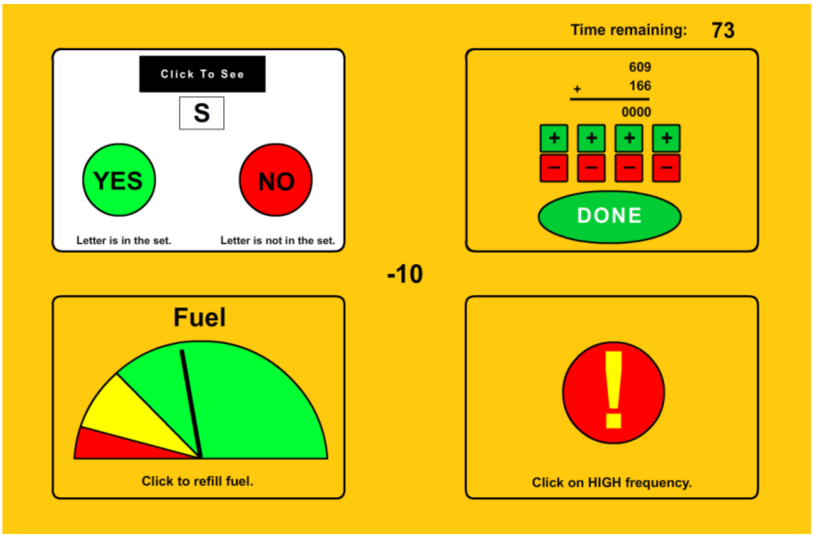

Figure 2. Screenshot of the SYNWIN multitasking work environment with eye-tracking strategies implemented. When the simulator requires the user to work on a particular task, the task quadrant turns white to attract the user’s attention.