Attentional Depletion Across Time and Tasks: Attention as a Limited Resource

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Abstract

Attention depletion is a common phenomenon observed in daily life that can hinder important processes. This study examined the effects that performing various levels of cognitively demanding tasks can have on attention depletion. Undergraduate PSY 118L students from the University of California, Santa Barbara (n=27) were randomly assigned to either the control or experimental condition. In the control condition, participants performed a Single tasking test, and in the experimental condition, participants performed a Multitasking test, presumed to be more cognitively demanding and attentionally depleting. To measure all participants' attention, both conditions took a secondary assessment, the Mackworth Clock Task. We predicted that the Multitasking test would deplete attention more than the Single tasking test and would result in a lower percentage of correct detections and more false detections on the Mackworth Clock Task. As expected, overall correct detection scores were higher in the control condition than in the experimental condition, and false detection scores were lower in the control condition than in the experimental condition, but there was no significant difference in either, so there was no effect of depletion on either condition. Alternative explanations for why we failed to observe an effect are discussed in this paper.

Attentional Depletion Across Time and Tasks:

Attention as a Limited Resource

The ability to attend to the world and specific stimuli within it is crucial for academic success, social etiquette, and many other everyday situations. When this resource is depleted, people can underperform in these situations and can miss important stimuli in their environment, such as a red light while driving, thereby reducing efficiency in life's everyday tasks and potentially increasing risk. As shown in a previous study that measured performance and task aversion in a visual attention task, attention can be depleted from mental fatigue, and willingness to perform tasks can also be lessened from mental fatigue (Boksem et al., 2005). Another similar study showed that mental fatigue can deplete a specific facet of attention, selective attention (Faber et al., 2012). The main focus of our study is to test the degree to which two different stimuli have on mental fatigue, and thus, attention.

One study showed that multitasking, as opposed to single tasking, poses significantly more cognitive strain on the brain (Burgess et al., 1999). More specifically, several cortical regions, such as the left anterior and posterior cingulates, play a role in the cognitive demands that are stimulated by multitasking, and are less activated when one performs a single task (Burgess et al., 1999). Moreover, another study, interested in how people consume media in a multitasking fashion, showed that multitasking while engaging with a media source can interfere with how one processes information from that given media source, such as watching a television show but being distracted on its sequence of events because this person was simultaneously occupied with texting their friend (Kazakova et al., 2015). Evidently, multitasking has an effect on the way people perform on various tasks, representing cognitive demand.

Despite all these significant findings, attention literature is lacking information as to how switching from one cognitively strenuous task to another can alter the amount of attention someone has. Literature on attention depletion focuses on one sustained task that depletes attention over time, but there is a gap in the research when it comes to the introduction of a new task after the initial task. This gap in research is our point of interest, because the introduction of a new difficult task given after a previous difficult task may partially renew attention or could continue to further deplete it.

Our experiment, based on the findings of attention being a limited resource, tested how performing a series of two separate tasks can affect attention levels and if differing levels of difficulty of the initial task cause differing levels of attention available to give to the secondary task. Based on the aforementioned literature, we know that multitasking puts more cognitive demand on the brain, and we also know that attention is a limited resource and can be depleted from cognitive fatigue- so, does multitasking, a cognitively fatiguing activity, deplete attention more so than single tasking, which is a less cognitively fatiguing activity? Furthermore, is the ability to fully attend to a task inhibited by a previous expenditure of attention if that expenditure was caused by a different task? The purpose of our experiment was to solve these questions. We predicted that those in the experimental condition, who performed a more mentally fatiguing task than those in the control condition, would perform worse on a secondary task that tests attention.

Method

Participants

Participants included 27 undergraduate students from the University of California, Santa Barbara (7 males, 20 females) who were all in PSY 118L. The mean age was 21.59 years

(SD=0.84, range 20-23). Of the 27 participants, 1 self-reported left handedness, and 26 self-reported right handedness. All were randomly assigned to either the control (n=13) or experimental (n=14) condition based on a random number generator.

Apparatus and Stimuli

We used three different tasks. Response times and errors made were measured in the validation check of the initial tasks using PsyToolkit's web-based "Single tasking" and "Multitasking" tests. These tasks are normally used as a measure of multitasking ability, a signifier of cognitive performance. PsyToolkit explicitly described the "Multitasking" version to be one of the harder tasks in their experiment library, so we used this as our more cognitively strenuous manipulation. The secondary assessment to measure all participants' attention was also from PsyToolkit's web-based "Mackworth Clock Task". This task is normally used as a measure of vigilance, and low performance is typically indicative of lesser attention.

To administer the various web-based tasks, we used a 13-inch MacBook Pro laptop and had participants sit in a Psychology Department Laboratory room. To record self-reported information from each participant, such as age and gender, we used a pencil and paper. Participants read each tasks' instructions on a typed and printed explanation on paper, and we simultaneously read another copy of the same paper. To run the independent samples t-tests, we used IBM's SPSS. During the two-minute break in between initial and secondary tasks, an iPhone timer kept track of the time.

Procedure

As a part of our PSY 118L class, each student was required to partake in other groups' experiments as a participant. Before initial meeting in the experiment room, experimenters set the bottom foot of the chair to be two inches away from the edge of the desk and set the laptop to be

22 inches forward from the university's desktop computer. During class hours, we verbally recruited individual classmates into the room while they were not occupied with running their own experiments. Upon initial meeting in the experiment room, experimenters asked participants for their participant number, age, gender, and handedness, and recorded the information on a sheet of paper.

Participants were randomly assigned to either the control or experimental condition according to a random number generator, and their assignment was predetermined before they were verbally recruited, based on the order that they participated in our experiment. If they were in the control condition, the experimenter gave the participant the instruction sheet for the Single tasking test, and if they were in the experimental condition, the experimenter gave the participant the instruction sheet for the Multitasking test. Participants were instructed to read the instructions silently, while the experimenter read the instructions out loud. When the experimenter asked the participant if they were ready to begin the initial task and received verbal confirmation, the experimenter instructed the participant to notify them outside when they were done with the initial task and then stepped out of the room to let the participant do the task in the room alone.

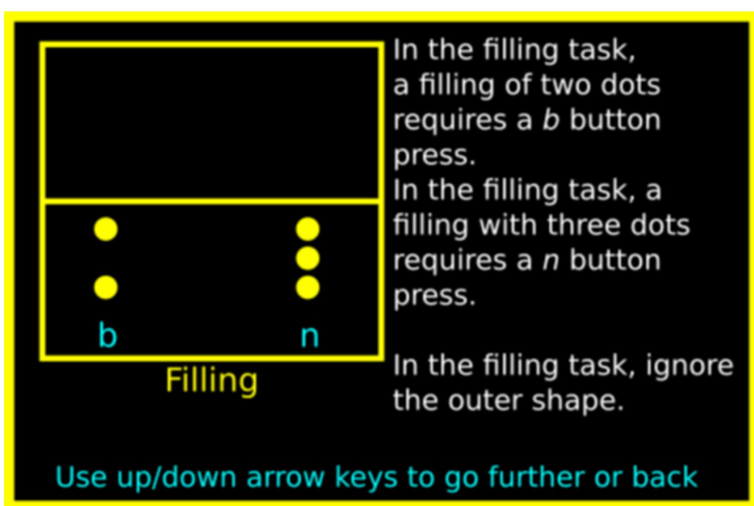

Figure 1. Rules for Single tasking test

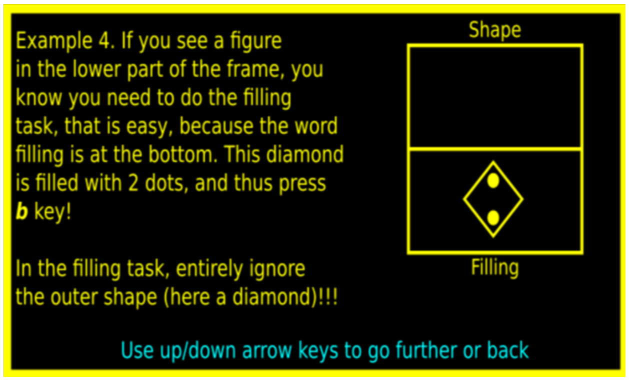

Figure 2. Rules for Single tasking test- 2 dots

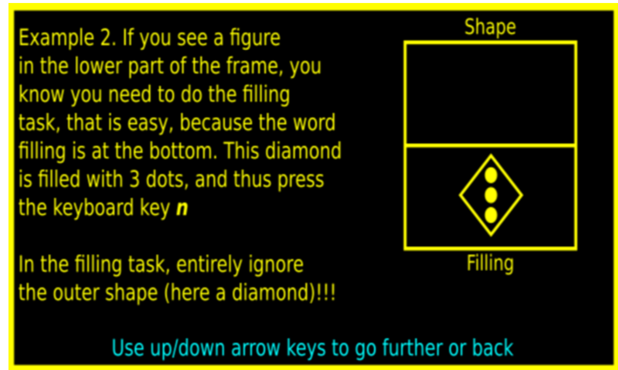

Figure 3. Rules for Single tasking test- 3 dots

Participants in the control condition who did the Single tasking test, pictured above (Fig. 1), only performed a filling task. In this task, a shape would appear on the screen, and within this shape, there would either be two or three dots. If two dots appeared (Fig. 2), participants were instructed to press “B” on the keyboard, and if three dots appeared (Fig. 3), participants were instructed to press “N” on the keyboard. The shape in which the dots appeared did not matter, only the number of dots mattered.

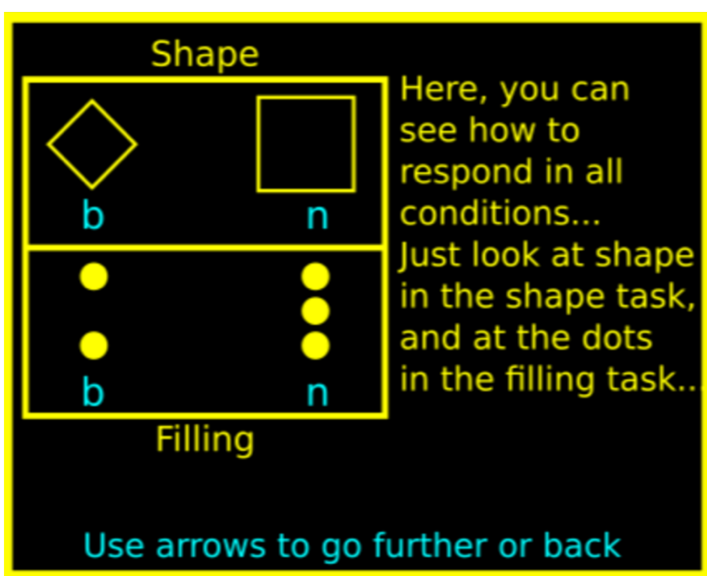

Figure 4. Rules for Multitasking test

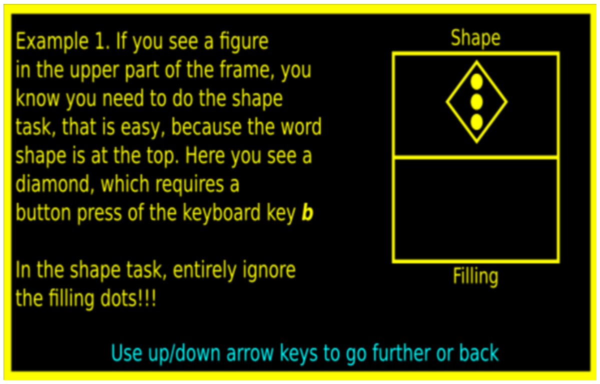

Figure 5. Rules for Multitasking test- shape half with diamond shape

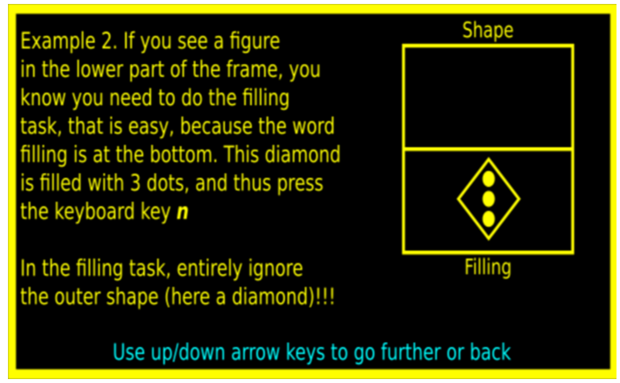

Figure 6. Rules for Multitasking test- filling half with 3 dots

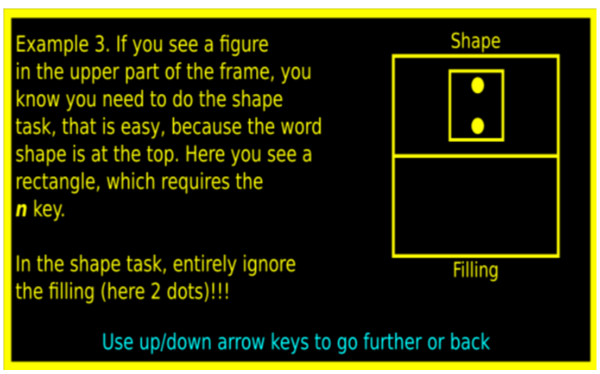

Figure 7. Rules for Multitasking test- shape half with square shape

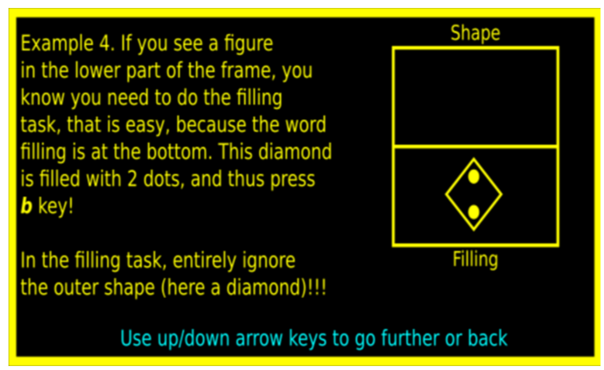

Figure 8. Rules for Multitasking test- filling half with 2 dots

Participants in the experimental condition who did the Multitasking test, pictured above (Fig. 4), performed a filling and a shape task simultaneously, henceforth, multitasking. The previous filling rules from the Single tasking test still applied, however only if the shape with the dots appeared on the bottom half of the screen (Fig. 5-6). If a shape with dots appeared on the top half of the screen, the number of dots was irrelevant, and participants were instructed to pay attention to the type of shape that contained the dots. In the top half of the screen, if a square shape appeared (Fig. 7), participants were instructed to press “B” on the keyboard, and if a diamond shape appeared (Fig. 8), participants were instructed to press “N” on the keyboard. This Multitasking test required participants to pay attention to both halves of the screen and their respective rules in order to perform well.

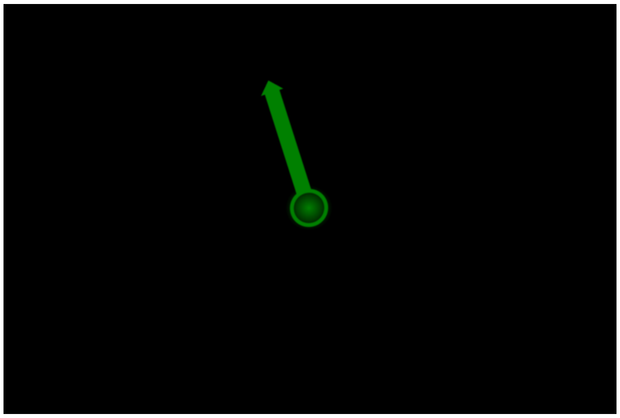

Figure 9. Mackworth Clock Task

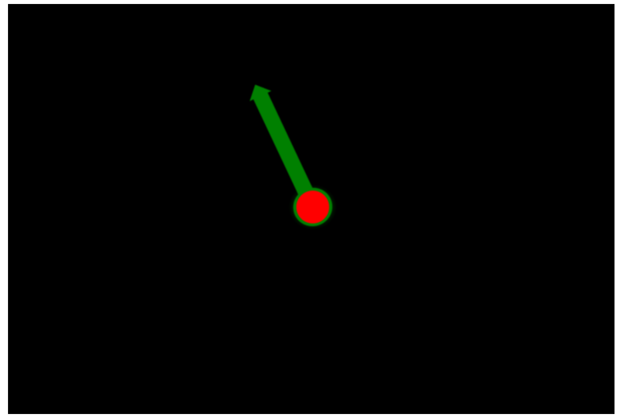

Figure 10. Mackworth Clock Task- negative feedback with a red dot when a jump is missed or a false detection is made

After completing the initial task, participants opened the room’s door and notified experimenters of their completion. Then, participants were told they had a two-minute break while one experimenter started the two-minute iPhone timer, and the other experimenter saved the data onto the laptop in a desktop folder. Two minutes later, the experimenters gave all participants the instructions for the secondary task, the Mackworth Clock Task (Fig. 9). Again, participants were instructed to read the instructions silently, while the experimenter read the instructions out loud. When the experimenter asked the participant if they were ready to begin the final task and received verbal confirmation, the experimenter instructed the participant to notify them outside when they were done with the task and then stepped out of the room to let the participant do the task in the room alone. In this task, participants looked at a clock hand on a screen as it ticked clockwise. When the hand jumped a larger distance than normal, participants were instructed to press the spacebar. Otherwise, participants were instructed to do nothing and keep watching the hand until it jumped again. If participants did not press the space bar when a jump occurred, or if participants mistakenly pressed the space bar when no jump occurred, a red light would flash (Fig. 10).

After completing the Mackworth Clock Task, participants opened the door and notified experimenters of their completion. Then, participants were thanked for their participation and were told they were done with the experiment. After the participant left the room, the experimenters saved the Mackworth Clock Task data onto the laptop and prepared the instruction materials for the next participant, such as rearranging the laptop and chair back into their designated places.

Design

This experiment's design is a between-subjects design, with a control group and an experimental group. The independent variable was the random assignment to either the control group or the experimental group. The control group initially performed the Single tasking test, while the experimental group initially performed the Multitasking test. The dependent variable was the performance on the secondary task, the Mackworth Clock Task, and was measured as the percentage of correct detections and number of false detections made.

Analysis

For the validation check of the independent variable, an independent samples t-test was run on SPSS to compare the mean response times (ms) of the control and experimental conditions along with the mean number of errors made of the control and experimental conditions. Because the Multitasking test had more types of trials than the Single tasking test, we chose the trial that they both had in common, which was the "switchpurefilling" task. We analyzed the response times and errors made from the "switchpurefilling" trials only.

For the experimental results, an independent samples t-test was run on SPSS to compare the mean percentage of correct detections from the control and experimental conditions along with the mean number of false detections from the control and experimental conditions on the Mackworth Clock Task.

Results

To validate desired attention depletion effects of the independent variable, an independent samples t-test was run on the response times and errors made in the "switchpurefilling" trials of the Multitasking and Single tasking experiments. We predicted that response times and errors made would be higher in the experimental condition, as the Multitasking test was presumed to be more cognitively strenuous. Expectedly, there was a pattern of higher values in both response times and errors made (Fig. 11-12). However, there was not a statistically significant difference in the response time (ms) scores between the control condition ($M=524.92$, $SD=41.59$) and the experimental condition ($M=547.36$, $SD=42.44$); $t(25)= -1.386$, $p= .178$. There was also not a statistically significant difference in the amount of errors made between the control condition ($M=2.29$, $SD=1.44$) and the experimental condition ($M=2.94$, $SD=2.16$); $t(25)= -1.65$, $p= .111$.

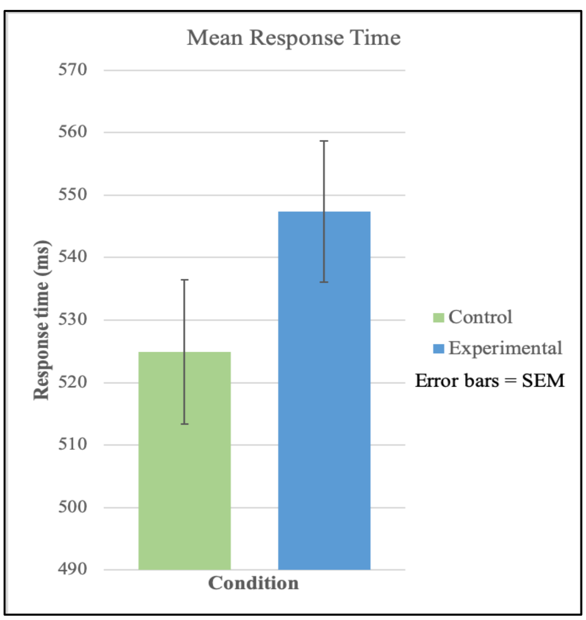

Figure 11. Mean Response Time in milliseconds

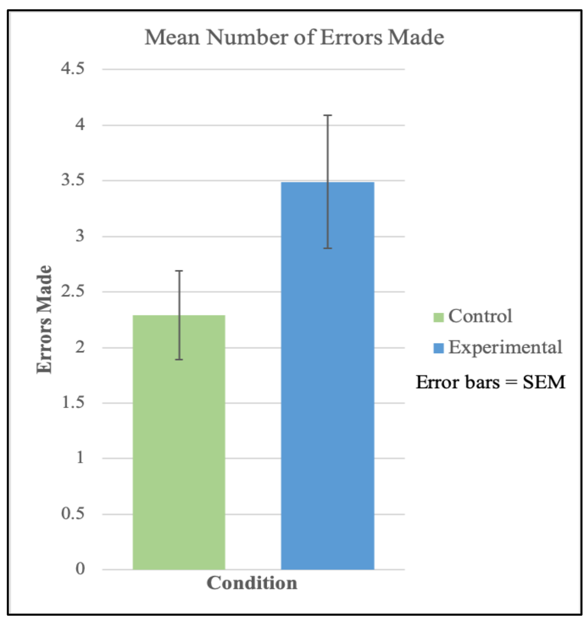

Figure 12. Mean Number of Errors Made

As for the results from the dependent variable data, we predicted that the participants in the experimental condition would have less attention to allocate to the secondary task, the Mackworth Clock Task, and would therefore perform worse on this task than the control group. An independent samples t-test was conducted to compare the percentage of correct detections and number of false detections in the Mackworth Clock Task between the control group, who initially received the Single tasking experiment, and the experimental group, who initially received the Multitasking experiment. "Correct detections" occurred when the clock hand jumped larger than usual, and the participant correctly pressed the space bar on the keyboard. "False detections" occurred when the clock hand ticked like usual, but the participant mistakenly pressed the space bar on the keyboard. Expectedly, there was a pattern of higher percentages of correct detections and lower numbers of errors made in the control condition (Fig. 13-14). However, there was no statistically significant difference in the correct detection scores between the control condition ($M=78.92$, $SD=8.91$) and the experimental condition ($M=71.57$, $SD=11.70$); $t(25)= 1.83$, $p= .08$. There also was no statistically significant difference in the false detection scores between the control condition ($M=2.15$, $SD=1.46$) and the experimental condition ($M=3.07$, $SD=2.09$); $t(25)= -1.31$, $p= .202$. Participants in the control condition performed only slightly better than those in the experimental, but the results were not significant enough to prove anything conclusive.

Table 1. Mean percentage of correct detections and number of false detections by condition

	Correct Detections (%)			False Detections		
Condition	*M*	*SD*	*SEM*	*M*	*SD*	*SEM*
Control	78.92	8.91	2.47	2.15	1.46	0.41
Experimental	71.57	11.7	3.12	3.07	2.09	0.56

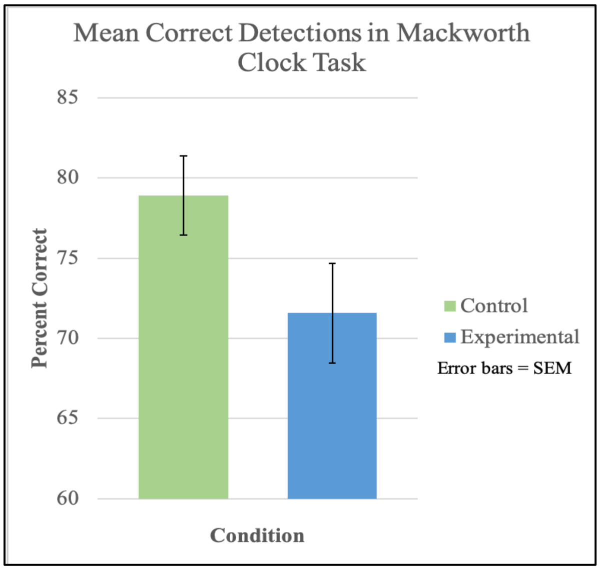

Figure 13, Mean Correct Detections in Mackworth Clock Task

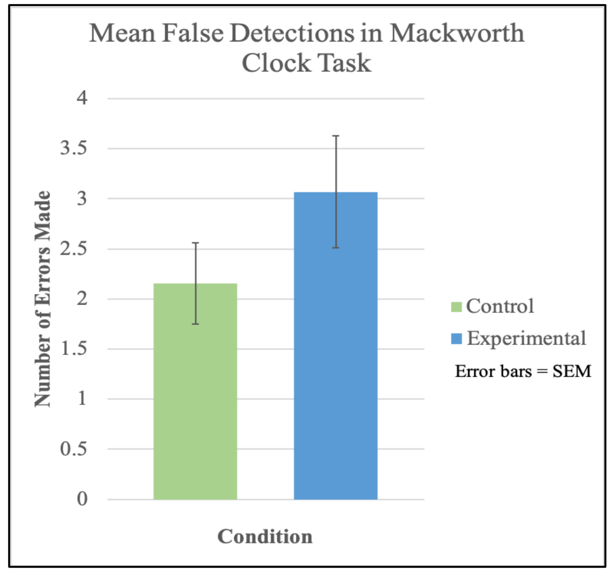

Figure 14, Mean False Detections in Mackworth Clock Task

Discussion

This study attempted to investigate the effects that a mentally fatiguing task can have on attention once a new, also mentally fatiguing, task is introduced. Using two tasks, different in levels of cognitive demand as our initial manipulation, we found that neither task was more cognitively demanding than the other. The lack of statistical significance from this validation check suggests that the two initial tasks were not different enough from each other in terms of cognitive strain and thus, could not cause sufficiently polarized effects of attention depletion. As for our experimental results, although we did find a trend that matched our prediction of more depletion in the experimental condition, the lack of statistical significance in the Mackworth Clock Task scores suggests that the desired effects of attentional depletion from the Multitasking test were not strong enough to cause a significant difference from the Single tasking test.

With this experiment, we attempted to fill the gap in Attention literature that lacks data on depletion caused by time and various levels of cognitive strain. We are unable to conclude anything from our results, but it seems that other studies have also failed to replicate resource depletion effects. More specifically, a study similar to ours used an initial task to attempt to cause ego depletion. These researchers also failed to see significantly different results between the initial "depleting" and "not depleting tasks", and they explained that, in mental resource depletion experiments, a common issue with sequential-task paradigms is that the initial tasks are not different enough in evoking an effect (Hagger et al., 2016).

It is likely that we did not find significant results for a variety of reasons. As previously mentioned, our validation check of the effect initial manipulation provided possible evidence for our overall lack of significance. Because the Single tasking and Multitasking tests were not significantly different in performance scores, we can infer that one was not significantly more mentally fatiguing than the other, at least not at the time of testing. Time of testing could have also influenced our results. Being that all participants were other PSY 118L students, they were also all participating in other groups' experiments, many of which were mentally fatiguing and attentionally depleting. This meant that participants may not have performed our experiment's tasks with their normal level of cognitive ability, and therefore, could have already been mentally fatigued while doing the Single tasking test, which was intended to be a far less cognitively strenuous task.

Another limitation from running our experiment with only PSY 118L students is that the Psychological and Brain Sciences department at the University of California has a female-skewed student demographic. Because of this, our participant pool had a ratio of 7:20, males to females. A previous study suggests that females tend to be better than males at multitasking, at least within the scope of the same Multitasking test that we also administered (Stoet et al., 2013). Having a more even ratio of males to females could have resulted in overall worse performance in the

Multitasking test, shifting the data closer to our prediction. Moreover, our small sample size (n=27) likely played a role in our statistical findings.

Additionally, our experimental design could have been a limitation, in that it interfered with attention depletion. The two-minute break after performing the initial task and before starting the secondary task could have been a recuperating time for participants' possible mental fatigue, and so they could have gained back some mental ability to perform better on the secondary task than they would have if we did not have the two-minute break. Regarding the restoration of mental ability, another possible limitation to our study could have been the introduction of the secondary new task. There was not enough literature to confirm or deny whether the introduction of a new task consistently renews or continues to deplete attention, so, in our experiment, attention could have been renewed upon the introduction of the Mackworth Clock Task.

Because attention is a limited resource, it can be depleted or renewed. In this experiment, we administered two initial tasks with the goal of one task being significantly more depleting than the other. Our tasks were not different enough, in terms of mental fatigue effects, to find statistical significance, but the trend toward significance suggests that we were on to something. Beyond the laboratory though, one can see the detrimental effects that mental fatigue has attention in various settings. Attention is necessary for high performance with drivers, air traffic controllers, students, and many more roles played in society. For example, if a student is severely mentally fatigued from studying for a final exam for multiple hours leading up to it, their grade on the exam could be lessened due to missing important instructions on the exam or misreading answers. This student's attention would be depleted from the mental fatigue, and this instance could have been avoided if the student had given themselves a mental break prior to taking the exam. However, inconclusive results of this experiment leave us to wonder whether the introduction of a new task, such as doing a crossword puzzle, could somewhat renew this student's attention. Further research is necessary to determine how depleted attention can be further depleted or renewed with the introduction of new tasks.

References

Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research*, *25*(1), 107–116. doi: 10.1016/j.cogbrainres.2005.04.011

Burgess, P. W., Veitch, E., Costello, A. D. L., & Shallice, T. (2000). The cognitive and neuroanatomical correlates of multitasking. *Neuropsychologia*, *38*(6), 848–863. doi: 10.1016/s0028-3932(99)00134-7

Faber LG, Maurits NM, Lorist MM (2012) Mental Fatigue Affects Visual Selective Attention. PLoS ONE 7(10): e48073. doi:10.1371/journal.pone.0048073

Hagger, M. S., Chatzisarantis, N. L. D., Alberts, H., Anggono, C. O., Batailler, C., Birt, A. R., … Zwienenberg, M. (2016). A Multilab Preregistered Replication of the Ego-Depletion Effect. Perspectives on Psychological Science, 11(4), 546–573. https://doi.org/10.1177/1745691616652873

Snezhanka Kazakova, Veroline Cauberghe, Mario Pandelaere & Patrick De Pelsmacker (2015) Can't See the Forest for the Trees? The Effect of Media Multitasking on Cognitive Processing Style, Media Psychology, 18:4, 425-450, doi: 10.1080/15213269.2015.1006789

Stoet, G., O’Connor, D.B., Conner, M. *et al.* Are women better than men at multi-tasking?. *BMC Psychol* **1,** 18 (2013) doi:10.1186/2050-7283-1-18