Examining the Physiological Interplay of Memory Formation and Distractive Stimuli

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Abstract

Distractive stimuli divert students' attention and disrupts the memory formation process. Stress, as measured by physiological changes including rise in blood pressure, heart rate and skin conductance, also affect the formation of memories.This research aimed to investigate the human physiological response to distractive auditory stimuli along with the ability to recall material learned in the context of distractive auditory stimuli. Blood pressure, heart rate, and skin conductance were measured for 26 participants. Subjects underwent a 30 second memorization phase, followed by a 3 minute sorting task, and a 1 minute phase to recall the list of 7 words given in the beginning of the experiment. An experimental group listened to the iPhone ringtone "The Opening" during the memorization phase while the control group performed their task in silence. The results indicate that the distracted group recalled on average 20.2% less words than the undistracted group. However, statistical analysis indicates no significant difference between the physiological responses of participants in the distracted group versus the undistracted group. Overall, the experiment clarifies the impact distractive stimuli have on memory formation.

Introduction

Memory is encoded, retrieved, and consolidated through various mechanisms. Memory is not a single item, but rather a myriad of several learned experiences. In particular, literature has noted the existence of three distinct types of memories. Short term memory encodes a limited amount of information and temporarily holds it in a very accessible state. Memories typically exist in the short-term span for up to 30 seconds (Weinstein 2017). Working memory refers to memory that is used to plan and carry out behavior. Long term memory refers to vast store of knowledge and a record of prior events (Cowan 2009). The conversion of short term memory to long term memory is dependent upon time and exposure (Preston 2017). It is theorized that short term memory compared to long term memory is limited by both capacity and duration (Cowan 2009).

In order to form new memories, certain stimuli must be attended to. The division of attention, such as between reading and listening, hinders one's ability to form conscious memories (Chun & Turke-Browne 2007). Distractive stimuli, including irrelevant noises, divert selective attention. Sounds that vary in tone and rhythm tend to be more distracting than

repetitive sounds and, therefore, more significantly inhibit the ability to recall information (Jones, Madden, & Miles 1992). This has practical implications for the locations where people frequently study and learn new information. Areas such as libraries and offices often have open floor plans, which allow sound to travel. One of the most common complaints about these spaces regards noise from people talking and the ringing of telephones (Nemecek & Grandjean 1973). College students often spend upwards of 30 hours a week learning and studying in places where open floor plans and distracting noises coexist.

Institutions of higher education are increasingly incorporating technology into classroom learning. Although technology, particularly smartphones, allows easy access to information and convenient communication, it also accounts for one of the leading distractions in the classroom. Studies have found that 38% of students are not able to go longer than 10 minutes without checking their mobile devices (Kessler 2011). This divided attention both in the classroom and while studying can have a detrimental effect on learning and memory. Ours brains have a restricted ability to divide our attention while retaining detailed information (Gassalay & Rosen 2016). Therefore, distractions pose a risk for absorbing and recalling information.

Our study specifically looked at how the distraction of ringtones affects memory formation and recall. Ringtones pose as an even more significant distraction if the stimulus is unexpected (such as during lecture or while studying), and the disruptive effects linger for a longer period of time (Shelton et. al 2009). Interestingly, irrelevant sound stimuli diminished study participants' ability to perform immediate serial recall (Norris et. al 2003). These distractive stimuli disrupt short term memory formation. It is likely that if an irrelevant stimulus disrupts this process, a stimulus with societal significance will be even more likely to disrupt the memory formation and recall process.

Stress also affects the normal integration of information, as well as the memory formation process. Stress refers to a bodily response that deviates from equilibrium in reaction to a stimulus and can be monitored through changes in physiological variables such as an increase in blood pressure, heart rate, and skin conductance. In times of stress, the body automatically activates the sympathetic nervous system. As a result, heart rate and blood pressure levels increase (Willhaus 2013). Another response of the sympathetic nervous system is an increase in skin conductance (Critchley et. al 2000). Our study aimed to determine whether auditory stimuli were disrupting enough to elicit a stress response. To assess the stress response, physiological variables were measured while performing a memorization task. We chose a generic iPhone ringtone as our distractive stimuli due to the fact that nearly all college students own a cell phone, many of whom own iPhones. Our society places a large significance on telephones and rapid communication. Due to its significance, students have substantial physiological reactions to the sound of a cell phone ringing (Shelton et. al 2009).

Given the current research, we hypothesized that the division of attention as well as the stress induced during memorization and recall, under time restraints, would decrease participants' ability to successfully recall the list of seven words they attempted to memorize. Due to the fact that an increase in heart rate, blood pressure, and skin conductance is associated with detrimental effects on the outcome of memory formation we also predicted an increase in these physiological variables during the memorization and recall phases of the experiment. Finally, we hypothesized that these physiological variables would increase even more significantly for subjects who were distracted during the memorization stage.

Materials and Methods

Materials

The three physiological variables that were measured were heart rate (beats per minute; bpm), blood pressure (mmHg), and skin conductance (ElectroDermal Activity or EDA; millisiemens). These variables were measured while performing a memory recall test, with or without a distractive stimulus (the iPhone ringtone “Opening”). The ringtone was played from a YouTube clip on a laptop through headphones that each participant was asked to wear. Heart rate and blood pressure were measured using an Omron Blood Pressure monitor (Model: 10 Series Plus). ElectroDermal activity was measured using a skin lead (Model SS3LA) and electrode gel on a Biopac System MP36. The electrodes along with electrode gel were connected to the index and middle finger on the participant’s non-dominant hand. EDA was then measured with the Biopac Systems Inc. Acquisition Unit. Similarly, the blood pressure cuff was placed on the non-dominant arm. All participants were instructed to sit with their legs uncrossed and their feet flat on the floor. Their non-dominant arm was placed with the palm facing up on the table for the entire study to ensure accurate blood pressure measurements were recorded. The memory recall test included each of the seven words included in Figure 1.

Participants

Participants included volunteers between the ages of 20 and 23, that were enrolled in the Physiology 435 course at the University of Wisconsin–Madison during the spring of 2018. The subjects included 8 males and 18 females. All participants designated English as their first language. None of the participants designated that they were colorblind. Participants also indicated their dominant hand in order to determine which hand and arm the skin conductance monitor and blood pressure cuff would be placed. All subjects were randomly assigned to either the control or test group using a random number generator (RANDOM.ORG). Odd numbers indicated that the participant would work in silence while even numbers signified the distracted group; participants were blind to which group they were assigned.

Procedure

Prior to the experiment, to ensure the equipment was working properly and would measure the chosen physiological metrics, preliminary data was taken (Figure 4). Two students were tested under the control group, and three students were tested as the experimental group. Data was graphed based on a representative individual, and then all of the data was graphed together in a pooled, averaged graph (Figure 4). Due to the small sample size, some points do not have error bars. These students had the same physiological measurements, thus giving a standard deviation of zero. These positive controls confirmed that our physiological measurements could be accurately measured.

Each trial took place in the classroom near the location students attended lab each week. Upon entering the room, a brief description was given to participants regarding which physiological parameters would be measured and how, the memory recall test they would be performing, and the unrelated sorting task. Following this explanation, the skin conductance leads and pressure cuff were placed on the participant's non-dominant arm and connected to the Biopac and Omron systems. Participants were then allowed to rest before their trial began in order to ensure their heart rate, blood pressure, and skin conductivity were at their baseline, and that their baseline was not later affected by connecting equipment. All participants were told to sit with their non-dominant hand palm up and legs uncrossed in order to ensure body position did not affect each participant's physiological measurements. Once the participants felt comfortable, the equipment was calibrated and subjects' baseline measurements were taken. Subjects' then sat for another minute and their baseline was measured a second time. If no change was observed these values were taken to be the negative control. After the data were recorded, all participants were instructed to put on a pair of headphones. They wore these headphones for the remainder of the experiment. At this time, the distracted group began

listening to the the ringtone while the undistracted group did not listen to anything. Every participant was then instructed to turn over an identical sheet of white 8x11 paper with a typed list of 7 words. This number was chosen due to many findings that short-term memory has the capacity to hold seven items of information at a time (Miller, 1956). In similar studies, participants were given 30 seconds to memorize the list of words, forming the basis for the 30 second memorizing duration to be used in this study (Konantz 2012). The undistracted group memorized the words in silence while the distracted group listened to the iPhone ringtone “Opening” for the memorization period. This ringtone was chosen due to the findings of Shelton et al, that cell phones tones provide a significant distraction for students while in the classroom and interferes with their cognitive performance. This ringtone was identical to that of a common iPhone ringtone and was played only during the memorization phase. While participants memorized the list of words, measurements for heart rate, systolic and diastolic blood pressure, and skin conductance were taken.

At the completion of memorization, the participants were instructed to perform an unrelated, non-cognitively challenging task. This task included sorting 2 inch x 2 inch pieces of paper of 8 different colors into piles of their corresponding color. Before they started, the participants were told that they were not being timed and could work as fast or as slowly as they preferred. An experimenter announced the end of the 3 minute interval and directed the participants to stop sorting. According to Yana Weinstein (2017), information can only be held in short-term memory for 30 seconds. Having the participants wait 3 minutes before reproducing the material suggests that the words had been converted into long-term memory. This is important because converting information into long-term memory is necessary to do well on exams in college.Physiological measurements were taken at the end of the stage.

Subjects were then given 1 minute to recall the list of 7 words they were given in the beginning of the experiment in no particular order. An identical, white, 8x11 piece of paper and a writing utensil were placed in front of the subject so that they could write down their responses. Once again, physiological measurements including heart rate, blood pressure, and skin conductivity were taken during the recollection period. A complete timeline of the procedure can be viewed in Figure 2.

After the participants completed the study their recalled list of words was graded for correctness. If the words were spelled incorrectly or were written in a different tense they were still considered correct.

Statistical Analysis

In terms of statistical analysis, we recorded the percent change from baseline for systolic blood pressure, heart rate, and skin conductance for each subject across each stage of the experiment (Figure 3). Analyses focused on systolic blood pressure due to evidence suggesting that systolic pressure is a greater predictor of cardiovascular risk i.e. stress (Timo E. Strandberg & Kaisu Pitkala 2003). The percent change was statistically summarized for each stage, and the undistracted and distracted groups were compared to one another. From there, a t-test for significant difference between the two groups was completed in order to indicate statistical significance for the project. Additionally, the percent of words recalled correctly were averaged for the undistracted group and the distracted group. A t-test was performed to determine the significant difference between the groups.

Results

Physiological variables were recorded across three distinct stages: memorization, sorting, and recall in order to assess participants stress responses (Figure 5). Percent change

from baseline was calculated within each stage for skin conductance, blood pressure, and heart rate and compared across treatment groups. Recall performance was also analyzed for the distracted and undistracted groups and plotted for comparison.

Task Performance

Task performance was measured by the number of words that were correctly identified during the recall stage by each participant. The average number of words recalled for the undistracted group was 6.167 words and 4.75 words for the distracted group (Figure 6). This indicates that the distracted group recalled 20.2% less words than the undistracted group. A t-test revealed a p-value of 0.003, which determines a strong statistical significance between the two groups.

Skin Conductance

Percent change from baseline in skin conductance displayed an upward trend for both distracted and undistracted groups through the three stages. Surprisingly, the undistracted group percent change measurements were greater on average than that of the distracted group. However, p-values of 0.363, 0.421 and 0.414 for memorization, sorting, and recall phases respectively determine no statistical significance among these results.

Blood Pressure

Percent change from baseline of systolic blood pressure showed variation through each stage of the experiment. The undistracted group showed a positive trend across the stages, while the distracted group increased in percent change from baseline from memorization to sorting, then decreased from sorting to recall. As with skin conductance, the undistracted group recorded greater percent changes in each stage than the distracted group. P-values of 0.739 and 0.522 for the memorization and sorting phases indicate no statistical significance among

the data, while a p-value of 0.018 for the recall stage indicates a statistical significance between the distracted and undistracted groups.

Heart Rate

Measurements for percent change from baseline in heart rate across the stages displayed a similar trend for both groups. Memorization showed high percent changes in heart rates, followed by a large decrease during sorting and an increase during recall. Overall heart rate percent change values were higher for the group exposed to a distractive auditory stimulus. That being said, comparison between groups within each stage indicate no statistical significance between the distracted and undistracted groups with p-values of 0.315, 0.383 and 0.347 respectively.

Discussion

Statistical analysis revealed a p-value of 0.003 for task performance, which supports our hypothesis that participants who received the distractive stimuli would be unable to correctly recall as many of the seven words as the undistracted group. Upon first inspection, there were physiological responses generated through the course of the three stages in response to the experimental conditions. Heart rate in particular seemed to support our hypothesis, because values were increased during the memorization and recall phases and reduced during the sorting phase. That being said, for each of the physiological parameters measured (skin conductance, heart rate, and blood pressure), statistical analyses produced p-values that were greater than the accepted value for statistical significance of 0.05. Therefore, we are unable to reject the null hypothesis, indicating that there is no significant difference in physiological responses between the group receiving the distractive stimulus and the undistracted group. All in all, it can be stated that our distractive stimuli did have an impact on memory recall though it was not due to an elicited stress response.

To account for these results, we hypothesize that participants were consistently stressed throughout all five stages of the experiment which could account for the consistent increase in skin conductance throughout all the stages. Similarly, blood pressure may be a good indicator of stress, however, our procedure may not have been the most effective method for accurate readings due to the frequency of readings. Finally, though the results were not statistically significant, heart rate was the most reliable physiological measurement of stress. It demonstrated how participants were stressed during memorization, calm during sorting and experienced an even higher level of stress during recall, which we originally hypothesized.

Due to our finding that distractive auditory stimuli, such as cell phone sounds, is correlated with decreased recall ability, there are real world implications for the way students study and how professors conduct their classrooms, which may help to understand why certain students may score higher than others. Teachers may be more hesitant to guide instructions with cell phones due to the likelihood that students' cell phones buzzing with texts and the occasional phone call. Students should also consider this implication when deciding where to keep their phone while studying outside of the classroom. Nowadays, with such a dependence on cell phones it is important to realize the impact they have on studying and memory recall.

Various critiques of our study may be made to explain potential errors in our data. For example, although the same brand and model of equipment was used for every participant the exact piece of equipment varied between participants. The equipment was also not fully reliable. Several times the blood pressure monitor failed to take a reading and another measurement was taken immediately after the failure. Different researchers also performed numerous parts of the experiment. This inconsistency could increase the probability of human error in events such as timing and averaging the skin conductivity. Furthermore, the lab room where the experiment was conducted was not isolated. At any time during the experiment students and professors

may walk through the laboratory room unexpectedly, causing a distraction to the participant. Finally, the participants of the experiment were not truly representative of the general population. The participants were self-selected, motivated by reciprocal participation in each of their own experiments; most of the participants were also female (69%) and all participants were exclusively selected because because they were enrolled in UW Madison's Physiology 435 class.

Further directions for future studies may aim to look at a broader range of effects of distractive auditory stimuli. Future studies may employ a similar procedure to the one we carried out, but have participants return a day or week later to determine how these words have assimilated into long-term memory. It may also be important to look at the differences in the ways males and females react to distractive stimuli, both physiologically and their recall ability. This analysis was not possible in our study due to our small sample size of males in comparison to females. Furthermore, a more in depth experiment on the effects of the presence of phones while studying could reinforce and build upon our findings. For example, if subjects were allowed to have their phone placed upwards next to them while carrying out the three stages and if researchers were permitted to send texts, notifications, and make calls throughout the stages, this could be more representative of how many students study. This would then allow researchers to analyze the overall effects of the presence of a phone on physiological variables and memory formation.

Figures and Tables:

BANQUET
EXPRESS
PLAGIARIZE
DEFICIENCY
TROPICAL
INVESTMENT
COMMITMENT

Figure 1: Seven words chosen for memorization and recall.

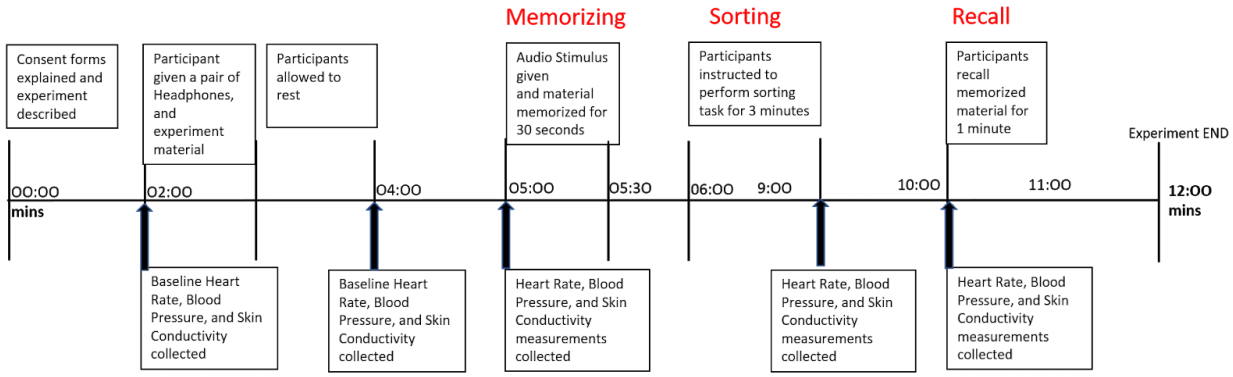


Figure 2: Timeline of the procedure with approximate duration of each stage.

$$Percent\ Change\ In\ Skin\ Conductance\ From\ Baseline = \left(\frac{Instrument\ Values\ at\ Memorzing, Sorting\ or\ Recall\ Stages}{Baseline\ Value}\right) - 1$$

$$Percent\ Change\ In\ Heart\ Rate\ From\ Baseline = \left(\frac{Instrument\ Values\ at\ Memorzing, Sorting\ or\ Recall\ Stages}{Baseline\ Value}\right) - 1$$

$$Percent\ Change\ In\ Systolic\ Blood\ Pressure\ From\ Baseline = \left(\frac{Instrument\ Values\ at\ Memorzing, Sorting\ or\ Recall\ Stages}{Baseline\ Value}\right) - 1$$

Figure 3: Equations used to determine percent change from baseline for skin conductance, heart rate, and systolic blood pressure.

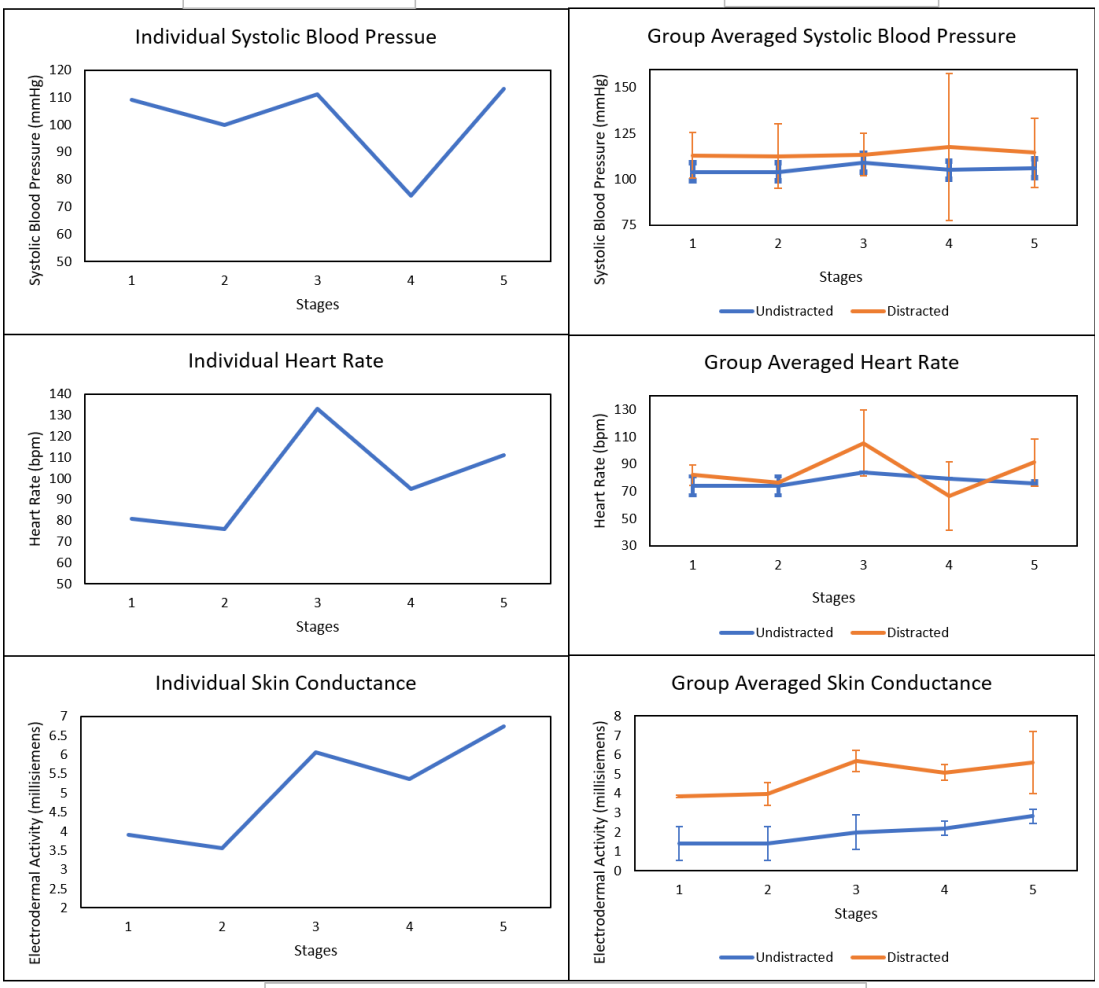
Baseline Measurements

	Undistracted								Distracted														
	Sally (2) 2/14/18				Morgan (3) 2/14/18				Katie (1) 2/14/18				Shujaw (4) 2/14/18					Rachel (5) 2/21/18				
Blood Pressure	99/71	NA	98/70	104/75	109/80	109/65	112/79	108/72	103/75	103/75	153/75	96/67	127/74	125/80	126/90	126/87	134/92	109/80	100/77	111/67	74/44	113/75
Heart Rate	69	84	79	75	79	84	79	77	90	90	48	83	81	76	133	95	111	75	77	93	57	79
Skin Conductance	2.04	2.62	2.47	3.08	0.788	1.36	1.93	2.55	NA	NA	NA	NA	3.9	3.56	6.057	5.373	6.745	3.81	4.39	5.3	4.8	4.46
Dominant Hand?																		Right				
Color Blind?																		No				
Gender?																		Female				
English First Language?																		Yes				
# of Words Correct																		7				
	Stage 1	Stage 3	Stage 4	Stage 5	Stage 1	Stage 3	Stage 4	Stage 5	Stage 1	Stage 3	Stage 4	Stage 5	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
			iphone				iphone				iphone				iphone					iphone		

Stage One: Prior to all activity, immediately after entering room, baseline one
Stage Two: One minute after baseline one, baseline two
Stage Three: 30 seconds, memorizing list of words
Stage Four: 3 minutes, sorting paper
Stage Five: 1 Minute, recalling words

Representative data from one individual

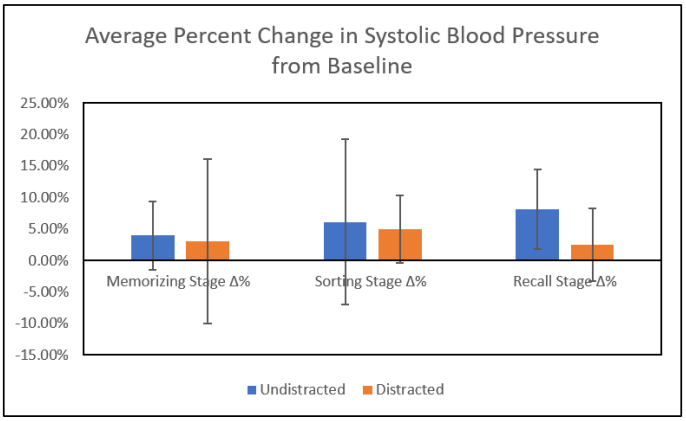
Averaged data from four individuals



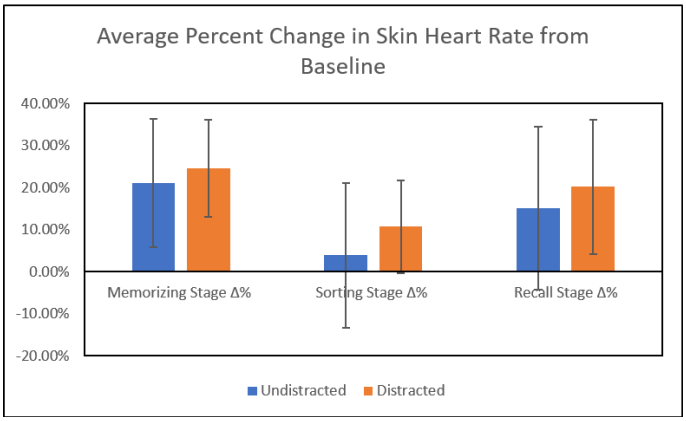
Stage One: Prior to all activity, immediately after entering room, baseline one
Stage Two: One minute after baseline one, baseline two
Stage Three: 30 seconds, memorizing list of words
Stage Four: 3 minutes, sorting paper
Stage Five: 1 Minute, recalling words
*for the group averaged data that have no error bars, this is because indiviudals at this stage had the same data

Figure 4: Preliminary data indicate the equipment has the capability to measure each physiological metric. The data also ensures that the conditions produce a measurable change from baseline for heart rate, skin conductance, and systolic blood pressure.

	Undistracted	Distracted
Averages	Blood Pressure	Blood Pressure
Memorizing Stage Δ%	3.96%	3.07%
Sorting Stage Δ%	6.08%	4.94%
Recall Stage Δ%	8.16%	2.51%



	Undistracted	Distracted
Averages	Heart Rate	Heart Rate
Memorizing Stage Δ%	21.08%	24.56%
Sorting Stage Δ%	3.85%	10.69%
Recall Stage Δ%	15.04%	20.17%



	Undistracted	Distracted
Averages	Skin Conductance	Skin Conductance
Memorizing Stage Δ%	17.64%	13.85%
Sorting Stage Δ%	26.30%	23.31%
Recall Stage Δ%	27.46%	24.47%

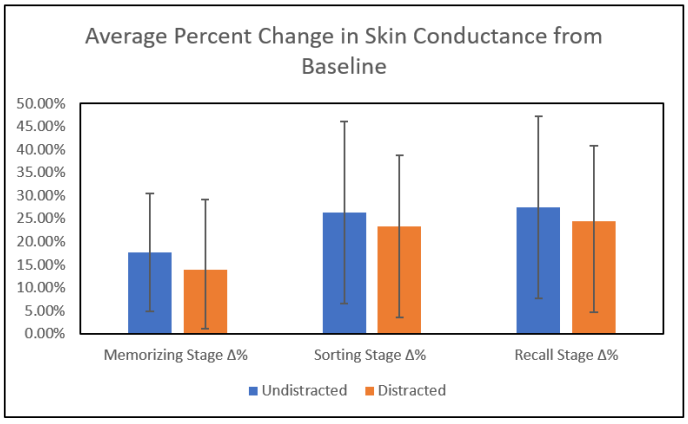
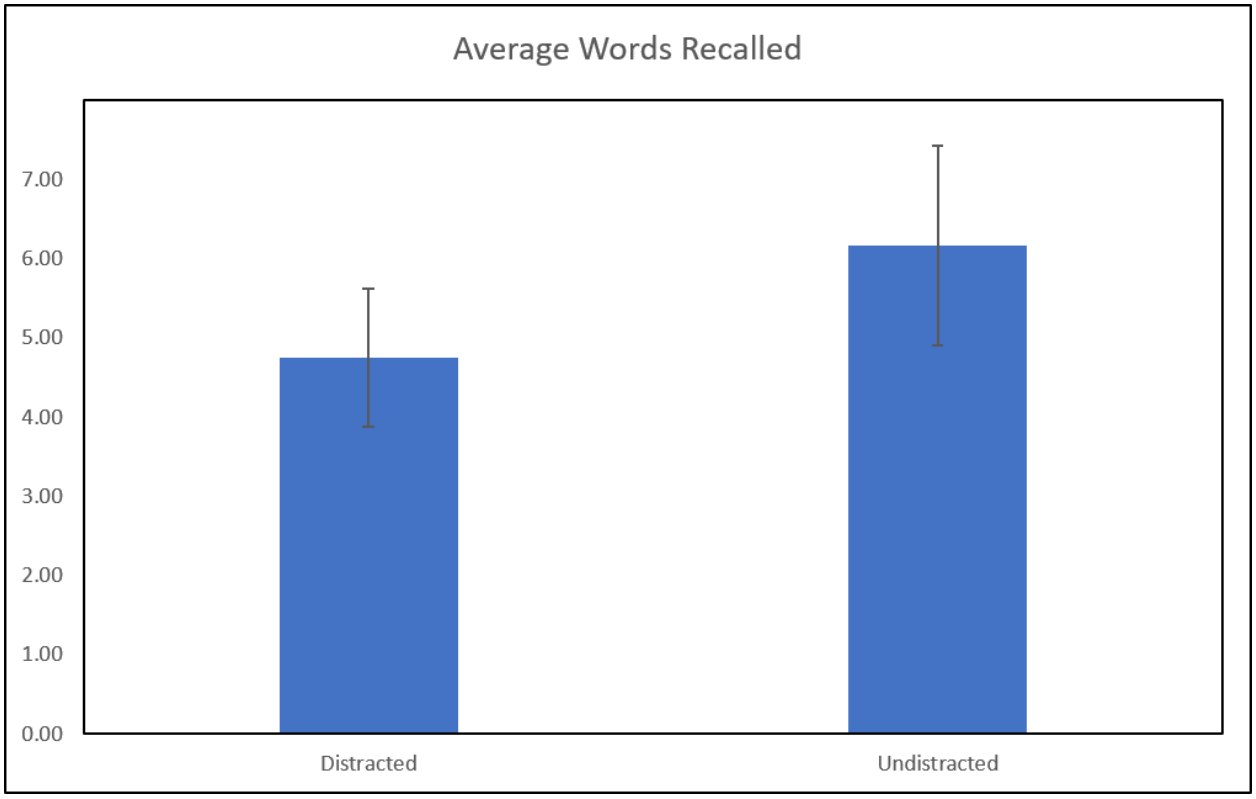


Figure 5: Percent changes from baseline for heart rate, blood pressure, and skin conductance across memorization, sorting, and recall phases for undistracted and distracted groups.



	Average Words Recalled
Distracted	4.75
Undistracted	6.17

Figure 6: Average words recalled for the distracted and undistracted groups.

References

Branbury, Simon P., et al. (2001). Auditory Distraction and Short-Term Memory: Phenomena and Practical Implications. *Human Factors: The Journal of the Human Factors and Ergonomic Society, 43(1)*, 12–29. journals.sagepub.com/doi/pdf/10.1518/001872001775992462.

Chowning, K., & Campbell, N. J. (2009). Development and validation of a measure of academic entitlement: Individual difference in students' externalized responsibility and entitled expectations. *Journal of Educational Psychology, 101*(4), 982-997.http://dx.doi.org .ezproxy.library.wisc.edu/10.1037/a0016351

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research*, *169*, 323–338. http://doi.org/10.1016/S0079-6123(07)00020-9

Chun, Marvin M, and Nicholas B. Turke-Browne. "Interactions between Attention and Memory." *Current Opinion in Neurobiology*, vol. 17, no. 2, Apr. 2007, pp. 177–184., doi:https://doi.org/10.1016/j.conb.2007.03.005.

Critchley, H., Elliot, R., Mathias, Dolan, R. (2000). Neural Activity Relating to Generation and Representation of Galvanic Skin Conductance Responses: A Functional Magnetic Resonance Imaging Study. *Journal of Neuroscience,* 20(8), 3033-3040.

Ericsson, K.A., & Kintsch, W. (1995). Long- term working memory. *Psychological Review, 102(2),* 211-245. doi:hhttp://dx.doi.org.ezproxy.library.wisc.edu/10.1037/0033-295X .012.2.211

Gazzaley, A., & Rosen, L.D. (2016). *The distracted mind: Ancient brains in a high- tech world.* MIT Press, Cambridge, MA. Retrieved from http://search.proquest.com/ezproxy.library.wisc.edu/docview/1855334357?accountid=465

Jones, D., Madden, C., & Miles, C. (1992). Privileged Access by Irrelevant Speech to Short-term Memory: The Role of Changing State. The Quarterly Journal of Experimental Psychology Section A, 44(4), 645-699. doi:10.1080/14640749208401303.

Kessler, S. (2011, May 31). 38% of College Students Can't Go 10 Minutes Without Tech [STATS]. Retrieved March 09, 2018, from https://mashable.com/2011/05/31/college-tech-device-stats/#gL2V6h2MMEq9

Konantz, Emily (2012) "The Effects of Music on Memory for a Word List,"The Huron University College Journal of Learning and Motivation: Vol. 50: Iss. 1, Article 4.

Lang, J. (2017). *The Distracted Classroom.* The Chronicle of Higher Education. Retrieved from https://www.chronicle.com/article/The-Distracted-Classroom/239446

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81-97.

Nemecek, Jan, and Etienne Grandjean. “Noise in Landscaped Offices.” *Applied Ergonomics*, vol. 4, no. 1, Mar. 1973, pp. 19–22., www.sciencedirect.com/science/article/pii/0003687073900069.

Norris, D., Baddeley, A.D. & Page, M. (2003). *Retroactive Effects of Irrelevant Speech on Serial Recall from Short Term Memory.* Retrieved from http://search.ebscohost.com.ezproxy.library.wisc.edu/Community.aspx?authtype=ip&ug

Preston, A. (2017). How does short-term memory work in relation to long-term memory?

Are short-term daily memories somehow transferred to long-term storage while we sleep? Retrieved March 07, 2018, from https://www.scientificamerican.com/article/experts-short-term-memory-to-long-term/

Shelton, J., Elliot, E., Eaves, S., & Exner, A. (2009). *The Distracting Effects of a Ringing Cell Phone: An investigation of the laboratory and the classroom setting.* Retrieved from Proquest Academic.

Strandberg, T.E. & Pitkala, K. (2003). What is the most important component of blood pressure: systolic, diastolic or pulse pressure? *Current Opinion in Nephrology and Hypertension,* 12(3), 293-297.

Vogel, S, et al. “Stress Affects the Neural Ensemble for Integrating New Information and Prior Knowledge.” *Neuroimage*, 21 Feb. 2018, pp. 176–187., doi:10.1016/j.neuroimage.2018.02.038.

Weinstein, Y. (2017, April 13). How long is short-term memory? Shorter than you might think. Retrieved March 07, 2018, from https://arc.duke.edu/how-long-short-term-memory-shorter-you-might-think

Willhaus, J. (2013). Measures of Physiological and Psychological Stress in Novice Health Professions Student During a Simulated Patient Emergency. (Doctoral Dissertation). Washington State University, Pullman, Washington.