Effects of Gum Chewing on Heart Rate, Respiratory Rate, and Short-Term Recall

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Abstract:

Finding novel solutions to increase memory and retention abilities can provide strategies for improved performance in testing situations. Chewing gum has been proposed as a means to increase memory retention abilities and attention to a task. This study tested the effects of chewing sugar-free mint gum on short term recall ability, as well as the physiological basis of effects seen (measured by recording heart rate and respiration rate of subjects). Respiration rate and heart rate were recorded using the Biopac lab system and a heart rate monitor, respectively. While these two parameters were recorded, participants underwent several rounds of a short term recall computer testing in which they were instructed to recall words out loud they had previously been shown for ten seconds. The control group (n=15) performed the test with no intervention. The experimental group (n=15) performed the test while chewing sugar-free mint gum. Participants were age and gender matched between groups. There was no significant difference between groups for either word recall ($p= 0.197525$) or respiration rate ($p= 0.268064$). There was a significant increase in heart rate for those chewing gum when compared to those not chewing gum during the short term recall test ($p= 0.009155$). The large increase in heart rate in the gum chewing condition could be explained by the fact that chewing constitutes heightened physical activity. However, this does not explain the non-significant decreases in short term recall and breathing rate of participants chewing gum. This suggests that strategies other than gum chewing are needed to improve short term recall in testing situations. Further experimentation is needed to determine the full effects of chewing gum on these physiological processes.

Introduction:

Short term recall has been studied extensively in psychology and it is generally accepted that people can hold about seven items in their short term memory (plus or minus 2) (McLeod, 2009). It is also well known that short term memory decays rapidly, after about 15-30 seconds. Items can be held in short term memory longer through rehearsal (repeating the items verbally, either silently or out loud). Short term memory is greatly reduced if rehearsal is prevented and there is a delay between seeing the items and being asked to repeat them (McLeod, 2009). In order to prevent decreases in short term recall, chewing gum has been found to be a relatively inexpensive and safe means to increase attention. When chewing gum, studies have shown improved accuracy, shortened reaction times, and more items recalled during examinations when studying a list of words (Allen et al., 2014).

The belief that mint-flavored chewing gum aids in academic performance and concentration has been widely held across many disciplines. This topic has been one of significant study due to its relevance in the field of learning and memory, which has been desired to be understood for years. As indicated by 2013 statistics, mint gum is the most commonly chewed gum as well as the highest grossing gum in the United States. Therefore, mint flavored gum is the most relevant flavor to use in this study (Statista, 2018). One of the first published works to actually experimentally test this widely held belief was performed by Wilkinson, Scholey, and Wesnes in 2002. Aspects of attention, working memory, and long-term memory were assessed through a series of computerized tests. Results showed an increase in working memory and long term memory function in the participants that were given chewing gum.

However, no increase in attention was observed (Wilkinson et al., 2002). Working memory is defined as "a mental sketchpad where we hold and process all the information we need to access at any given time" (Jacobson). While the results supported the hypothesis that chewing gum improves memory function, the underlying physiological mechanisms that explain this phenomenon were not studied (Wilkinson et al., 2002).

Although the theory of chewing gum and improved cognitive function has not been widely disputed, the effects of mint-flavored chewing gum on physiological parameters has been contested. On the one hand, researchers see the act of mastication as a form of exercise which leads to increased symptoms of alertness by suppressing parasympathetic action throughout the body (Shiba et al., 2002). This activity thus increases the opposing sympathetic parameters and would likely stimulate heart rate, respiration rate, and increase blood pressure. For example, one study showed mastication significantly improved students' abilities to recall words more quickly and correctly. This study specifically indicated that when students chewed gum they had the ability to recall individual letters from a word bank more efficiently than those who did not undergo mastication processes. This indicates that their short term recall improved (Laskaris, 2006). In another study, however, the effects of chewing gum were measured in relation to stress and cortisol secretion. While the findings of this study also found increased levels of alertness in participants that were chewing gum, they also discovered reduced state anxiety and reduced salivary cortisol (Scholey, 2009). Cortisol, a steroid hormone released in response to stress and fear, is a modulator of the sympathetic nervous system. Lower levels of cortisol and reduced state anxiety, therefore, would reduce parameters such as heart rate, respiration rate, and blood pressure. As it is clear to see, different studies regarding the effects of chewing gum on

physiological parameters have opposing results. The purpose of the current study described below is to contribute to the body of knowledge on this subject.

To determine the effects of mint-flavored chewing gum on short-term recall and its physiological mechanism, the present study measured the differences in heart rate, respiration rate, and short-term recall ability between participants with and without chewing gum. Short-term recall was assessed by asking the participants to recall multiple words shown on a computer screen for a limited amount of time, with subsequent levels increasing in difficulty. It was hypothesized that participants who were tested while chewing gum would have an overall better score on the short-term recall test as a result of a reduced stress response that physiologically manifests in a lowered heart rate and lowered respiration rate.

Materials:

Three variables were used in this experiment to determine the effects of chewing gum on memory by testing various physiological parameters. The three variables observed were heart rate, respiratory rate, and short-term recall. Heart rate was determined by using a pulse oximeter/carbon dioxide detector to record the beats per minute (Model number: 9843; Serial Number: 118102981; Made by Nonin Medical Inc., Minneapolis, MN, USA). Respiratory rate was measured using a Biopac Respiratory Transducer SS5LB (Serial number: 1602007568; Manufacturer: BIOPAC Systems, Inc. in 42 Aero Camino, Goleta, CA 93117). Respiratory rate was measured and analyzed using BIOPAC Student Lab System (BSL 4 Software, MP 36). The BIOPAC Systems, Inc. Student Manual (ISO 9001: 2008, BIOPAC Systems, Inc.) was used as a guide for direction in analyzing breaths per minute. The third variable, short-term recall, was

tested using a game created on Microsoft Powerpoint (Microsoft, 2016) by the authors of this paper. The game consisted of 5 Powerpoint slides containing 3, 5, 7, 9, and 11 words, respectively. Words were chosen at random and contained either four or five letters. Each slide had a similar format with two columns of words. Two standard Dell computers from the lab room were issued for the experiment. One computer was used to contain and monitor all Biopac data from the respiratory belt, and the other computer was used for the short term recall test.

Methods:

Screening and Consent:

Students from the University of Wisconsin-Madison Physiology 435 class, Section 601, were selected to participate in this experiment. Each student was required to fill out a consent form prior to their participation in the study that stated the potential risk of an allergic reaction to sugar free gum, that the experiment would take approximately ten minutes, confidentiality, and to contact Kayla Seuferer at kseuferer@wisc.edu regarding questions. Before the experiment was set up, the participant sat down, read over, and signed the consent form.

The students selected were randomly divided into two groups: those that performed a short-term recall test while chewing sugar free mint gum, and those that performed the test without any intervention. Each student selected only partook in the experiment once to avoid previous knowledge of the short-term recall test.

Experimental Set-Up and Baseline Analysis:

At the beginning of the experiment, a powerpoint slide explaining the rules of the test was shown to each participant. This slide was the same for each participant in order to keep

consistency and to avoid giving away too much information about the experiment. While the lead experimenter read the rules of the test, the respiratory belt (SS5LB) was wrapped around the participants chest, specifically around the manubrium of the sternum, and was fastened securely with the strap on the back of the belt by another experimenter. Female participants were assisted by female experimenters and male participants were assisted by male experimenters with the equipment. The respiratory belt lead was connected to channel 1 of the Biopac Systems, Inc. on the computer not facing the participant, designated computer two, to record data. The computer facing the participant, designated computer one, was used to administer the short-term recall test. The pulse oximeter was stationed on the participant's left index finger with the finger facing ventral to the oximeter to obtain a heart rate recording in beats per minute. Oxygen saturation data was not recorded in this experiment. Once both the respiratory belt and pulse oximeter were correctly in place on each participant, a baseline of the pulse and respiration rate were observed. Participants had been sitting for several minutes so the baseline would not be affected by the walk over to the table. This data was used as a negative control for the participant so that physiological changes obtained during the experiment could be compared. Following the baseline recording, participants in the gum experimental group were given a piece of sugar free mint gum and were told to begin chewing. Specific chewing patterns were not controlled for. All subjects were compliant with the chewing task. The recordings of heart rate and respiratory rate were not made visible to participants in order to prevent them from consciously altering their respiratory rate during the experiment. The pulse reading was checked every 5 seconds for 30 seconds and averaged to determine their resting beats per minute before the short-term recall test. Likewise, the average breaths per minute was also recorded on the Biopac software for 30

seconds, and after 30 seconds, the Biopac system was paused until the test began to avoid respiratory interference from talking. During this time, the lead experimenter finished explaining the rules and allowed questions to be asked about the experiment. Once everything was set up, the powerpoint introduction page was moved into the first segment of the test.

Short-Term Recall Test and Data Recording:

Participants were shown a powerpoint slide containing words to be memorized. After ten seconds, the words were replaced with a black screen and participants were asked to recall as many words from the previous slide as possible. There was no delay between seeing the words and being asked to repeat them in order to prevent short term recall decay. Participants were given 20 seconds to recall as many words as possible from the round. Five rounds of the test were administered, starting with three words per slide. Each round increased the amount of words to be memorized by two, ending with 11 words in the final round. All the words were simple and common and had either four or five letters, and each participant was shown the same words in the same allotted time frame. Each word identified correctly was rewarded with one point. The more points, the higher the overall score. The Biopac System is unable to accurately record data while the participant is talking. Therefore, in order to obtain an accurate measurement of breaths per minute while memorizing words, one of the experimenters at the computer containing the Biopac System, Inc. computer data paused the data collection for respirations per minute until the participant was done saying each word he/she remembered. After, the respiration data was unpaused and collected until the next round ended and the participant spoke again. When participants indicated that they had said all the words they could remember and 20 seconds had passed, the plain black slide was switched and a new slide

appeared which signaled the start of the next round. One experimenter had a list of the words on each slide and recorded how many words the participant remembered each round. Throughout the experiment, one of the experimenters documented the beats per minute on the pulse oximeter/carbon dioxide detector every 15 seconds and took the average of the data after the experiment ended. Once the fifth round ended, all data collection stopped and the participant was allowed to leave. A more extensive look at the overall time frame of the experiment can be seen in figure 1.

Data Analysis:

After the experiment, the data for beats per minute, breaths per minute, and total amount of correct words identified were logged for data analysis to juxtapose the difference between baseline and experimental data of the physiological responses. The absolute change between baseline and experimental data was recorded. Data from the pulse oximeter came from averaging the heart rate recorded every 15 seconds during the experiment. Data for the breaths per minute came from analyzing the breaths taken from the beginning to the end of the experiment in BIOPAC 4.0 Student by adding an extra output to the data in order for the breaths per minute to be correctly identified. Channel 1 was selected for "respiration" with its function as rate, breaths per minute (BPM). Next, the same channel was set as a function for peak to peak. Once this was completed, all the data collected in the first 30 seconds was highlighted. This gave the breaths per minute before the experiment and provided the baseline observation for each participant. Once that data was recorded, all of the data after the first 30 seconds was highlighted and used to report breaths per minute throughout the process of word recall. The total number of correctly remembered words over all rounds was recorded and compared between groups.

Negative Control:

As a negative control, one group member wore the respiratory belt and heart rate monitor for ten minutes (the length of the experiment) without performing the short-term recall task or chewing gum. The data for breaths per minute and beats per minute were recorded by the Biopac system and pulse oximeter. This showed that the Biopac system and heart rate monitor were accurately measuring the physiological parameters being tested when no experimentation was occuring.

Positive Control:

The three parameters tested in this experiment were heart rate, respiratory rate, and the total number of words correctly remembered from the short-term recall test. Heart rate was determined by the pulse oximeter/carbon dioxide detector to show the beats per minute. The respiratory rate was shown and analyzed by Biopac Systems, Inc. system to accurately display the correct breaths per minute. Lastly, the memorization was indicated by the amount of words each participant remembered. To test this data, all six group members performed the test. Three underwent the test while chewing gum, whereas the other three performed the test without gum. The baseline data was recorded for all six group members. The data was averaged after each participant went and then averaged again once all members were tested. When looking at the baseline examinations of all six group members, the average breaths per minute were 11.60 and the average beats per minute when examining heart rate was 91.67. When looking at the positive control group that did not chew gum, the average respiration rate was 25.23 breaths per minute, the average heart rate was 89.72 beats per minute, and the average number of words correct from the short-term recall game was 23.67. Figure 2.2 shows an example of the respirations collected

from one of the participants while not chewing gum. When juxtaposing this data to the group members who did chew gum during the examination, the average respiration rate was 23.67 breaths per minute, the average heart rate was 104 beats per minute, while the average total amount of words correct from the short-term recall test was 25.33. Figure 2.1 shows an example of the respiration cycle examined from a group member chewing gum while undergoing the short-term recall game. This positive control data showed differences between the baseline data and the data when undergoing examination. The positive control data also depicted changes in all three of the physiological parameters being observed from the effect of chewing compared to not chewing gum while participating in the short-term recall test. Chewing gum, based on the positive control data alone, depicted an increase in the total amount of words recalled by 1.66 more being correctly identified. The effects of chewing gum also showed the average respirations per minute decreased by 1.58 breaths per minute. On the other hand, the average heart rate increased while chewing gum by 14.28 beats per minute. The large heart rate difference may be due to an outlier effect in our data with such a small sample size causing the data to be skewed in this regard, but the other data regarding respirations and amount of total correct words identified could indicate that gum can alter physiological parameters to improve short-term recall and lower the average respirations per minute. This shows that the equipment is effective at measuring changes in the physiological parameters we are testing.

Results:

A p value of 0.05 or less was accepted as a significant result for all the parameters tested in this experiment.

There was no significant difference between words recalled for participants chewing gum and participants not chewing gum. The two-tailed p value for experimental words recalled was 0.197525 assuming normal, unpaired distribution. The average experimental words recalled for participants chewing gum was 22.67±2.795. The average experimental words recalled for participants not chewing gum was 24.0±0.7037. These data points are visually outlined in Figure 3.

There was a significant difference between the change in heart rate while chewing and not chewing gum during the short term recall test. In the two-tailed T test, the p value was 0.009155 assuming normal, unpaired distribution for heart rate. The experimental average heart rates for those chewing gum was 86.50267± 2.907 beats per minute. The average heart rate for those not chewing gum was 75.93067± 2.415 beats per minute. These results are illustrated in Figure 5. When comparing the baseline heart rate values before the test to the heart rate recorded throughout the short term recall examination, it was determined there was a greater percentage change from baseline in those who chewed gum (13.10931945) compared to those who did not (1.252210241) (Figure 6).

There was no significant difference between experimental breaths per minute for those chewing gum and those not chewing gum. The two-tailed p value was 0.268064 assuming normal, unpaired distribution for experimental breaths. The average experimental breaths per minute for participants chewing gum was 22.936± 1.385. For participants not chewing gum the average was 24.9±1.055 breaths per minute. These averages and p-values are represented in Figure 4. When juxtaposing percentage changes between baseline recordings and data obtained

during the study, there was no significant difference between the percentages with either chewing gum (25.69101814) or not chewing gum (28.8402173) (Figure 7).

Discussion:

There is evidence in the scientific literature that chewing gum can improve some aspects of memory performance. Different aspects of memory have been tested for benefits from gum chewing, and our project contributes to this knowledge by testing short term recall and other physiological parameters. Elucidating this subject can help find strategies for improving attention and memory.

This idea was tested using a short-term recall test and data collection of heart rate and respiratory rate during testing. It was hypothesized that chewing gum would lead to an increase in word recall ability as well as a decrease in heart rate and respiration rate.

Short Term Recall Test:

The results showed that participants who did not chew gum performed better on the recall test (Figure 3), which is not in agreement with our hypothesis . However, the difference between the two groups was not large enough to be significant (as reflected by a p-value > 0.05). Therefore, we cannot conclude from our results that chewing gum is beneficial or detrimental to short term memory.

Heart Rate and Respirations:

We also predicted that chewing gum would lower heart rate and respiration rate. However, our hypothesis was not supported by our findings. There was increased deviation in the heart rate of participants who were not chewing gum in comparison to the experimental

group. This reflects that there was a significant difference between the groups (Figure 6). Participants in the gum condition showed a significant increase in heart rate while chewing gum (Figure 5). Participants chewing gum also showed a decrease in respiration rate (Figure 4), but the result was not found to be significant. It is possible that the physical exertion of chewing caused the increase in heart rate, and whatever calming effects that chewing gum may have had were overpowered by this effect.

Limitations:

This study included data from a small sample size of UW-Madison students. If this study were to be repeated, a larger and more diverse sample size should be used. As well, it is possible that the act of mastication itself could affect memory. It is also possible that distractions from other activities happening in the testing room could have affected results for both groups. Our results could also be confounded due to the individual participants' emotional stress, lack of sleep or focus, and amount of caffeine consumption prior to the test. The act of moving the gum to one side of the mouth before speaking the recalled words could also hinder word recall performance. Participants may have been thinking more about the gum at the time than the words they needed to remember. It is also possible that the small time gap before speaking may have been detrimental to short term recall.

Future Directions:

To further test the effects of gum chewing on memory, it would be beneficial to do a similar study with a larger and more diverse sample size testing people chewing different types of gum to see if different flavors cause different results. For example, future studies should highlight the impact on specifically chewing mint flavored gum juxtaposed to fruity gum to

determine if flavor plays a part in short term recall. One could also factor in information about the subjects and their frequency of gum chewing in their daily lives. This information could be used to see if increased exposure to gum creates long lasting impacts on someone's short term recall. Other processes could also be tested in this experiment, such as providing specific instructions for the chewing process of participants in the study. Instructing people to either chew gum at a more rapid pace or a more relaxed pace could result in different short term recall performance. It may also be beneficial to test participants while chewing a variety of food items to see if the act of chewing itself affects short term recall performance.

Conclusions:

It can be concluded from this study that chewing mint gum does not have a significant effect on short term recall performance or respiration rate. As well, the study showed that chewing gum is correlated with an increased heart rate, presumably due to the exertion of mastication. This finding contributes to the scientific literature on the study of memory and provides a baseline for further investigation of the subject.

Figures:

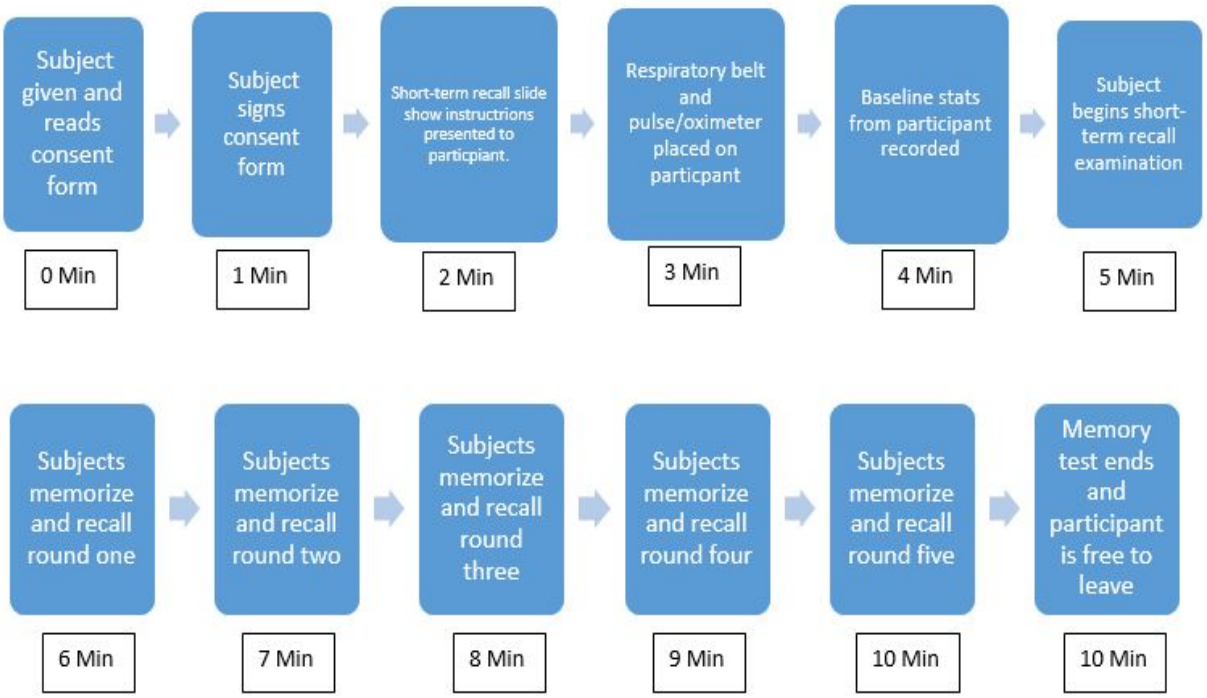

Figure 1: Experimental timeline. The above figure illustrates the approximate timeline of events for each study participant. The participant begins by reading and signing a consent form, followed by an instruction briefing. The participant is then fitted with the experimental equipment and a baseline is recorded. The short-term recall examination then begins, and participants perform 5 rounds of examination. The entirety of preparing and completing this test takes approximately 10 minutes.

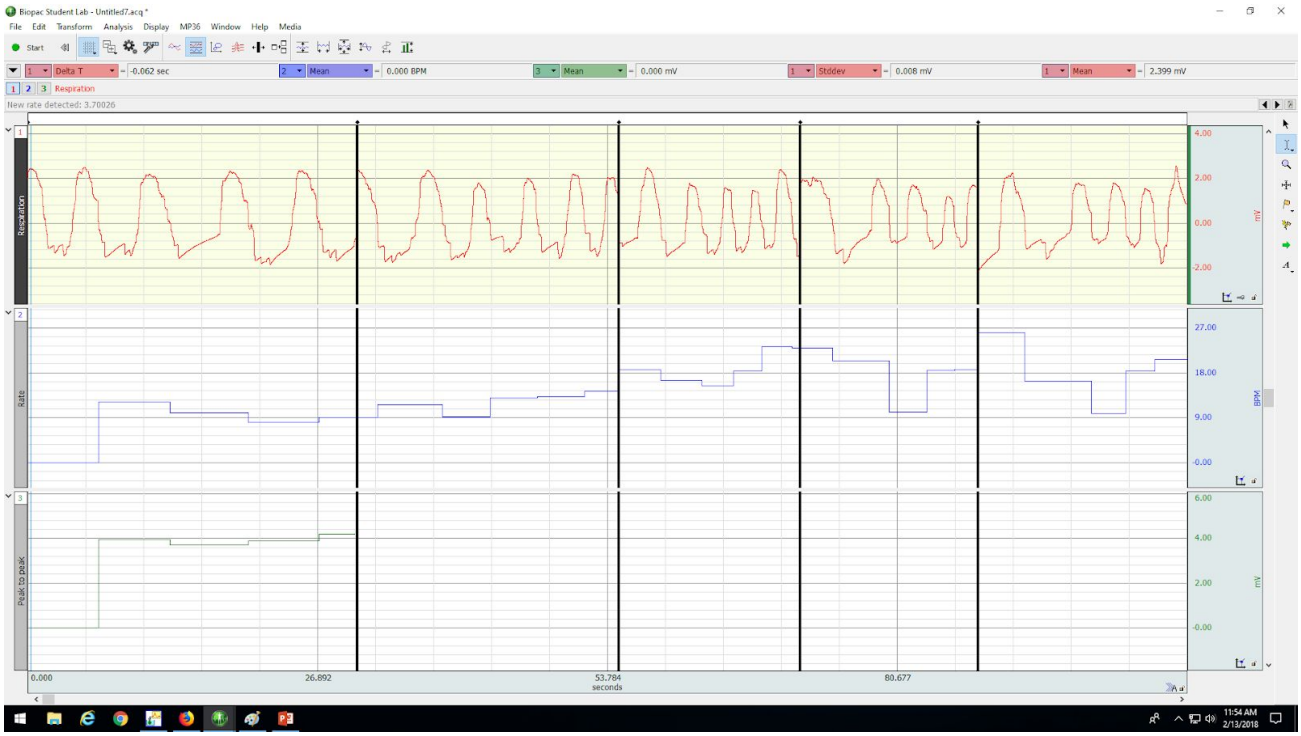

Figure 2.1: Example respiration rate from a study subject while chewing gum. The above figure represents an example of the respiration recordings over time from a participant who was chewing mint gum while performing the short-term recall test. The top row represents the crude respiration waves, while rows two and three represent adjustments made in order to analyze rate (BPM) and peak to peak waveforms, respectively. The vertical black bars separating the data into columns represent where the data recording was stopped; stopping recording was necessary while participants repeated back their recalled words in order to reduce respirating interference.

Figure 2.2: Example respiration rate while not chewing gum from a study subject. The above figure represents an example of the respiration recordings over time from a participant who was not chewing mint gum while performing the short-term recall test. The top row represents the crude respiration waves, while rows two and three represent adjustments made in order to analyze rate (BPM) and peak to peak waveforms, respectively. The vertical black bars separating the data into columns represent where the data recording was stopped; stopping the recording was necessary while participants repeated back their recalled words in order to reduce respirating interference.

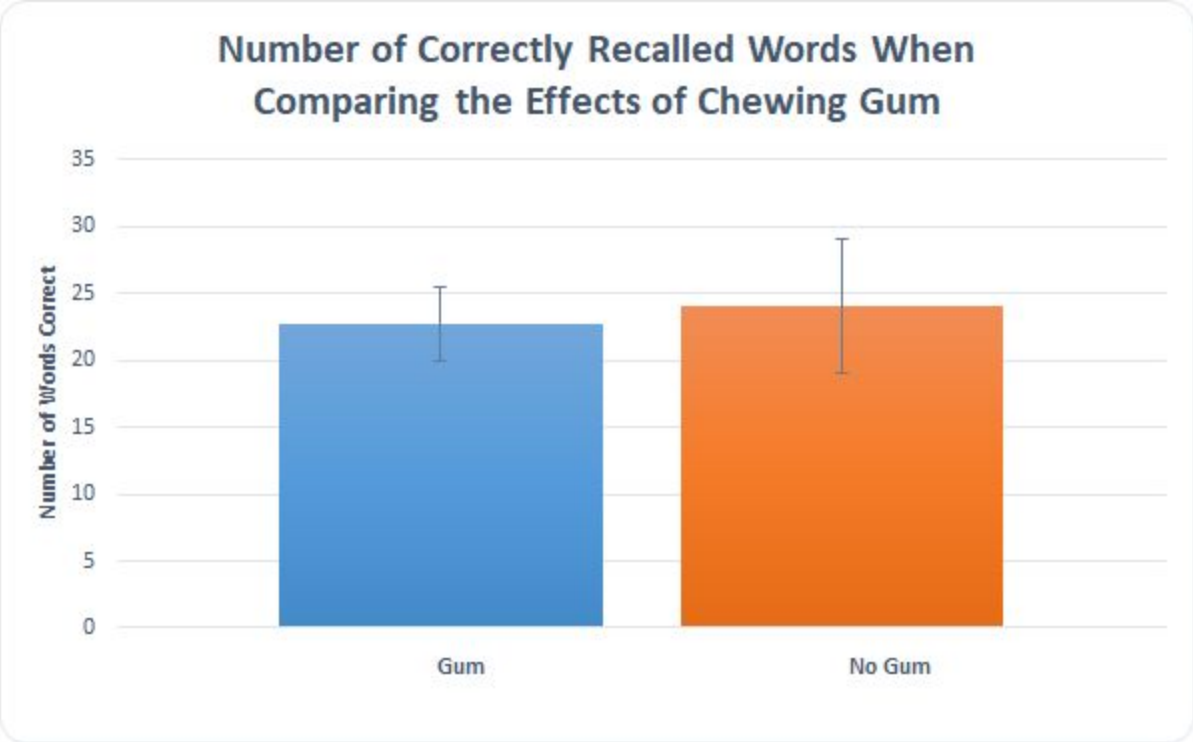

Figure 3: Number of correctly recalled words when comparing the effects of chewing gum. With reference to the number of words correctly recalled during our experiment, this graph shows there was a slightly lower number of recalled words when participants were chewing gum. The data collected for the "gum" group was also more tightly related than for the "no gum" group. The act of chewing gum did not show an increase in short term recall under the experiment's parameters.

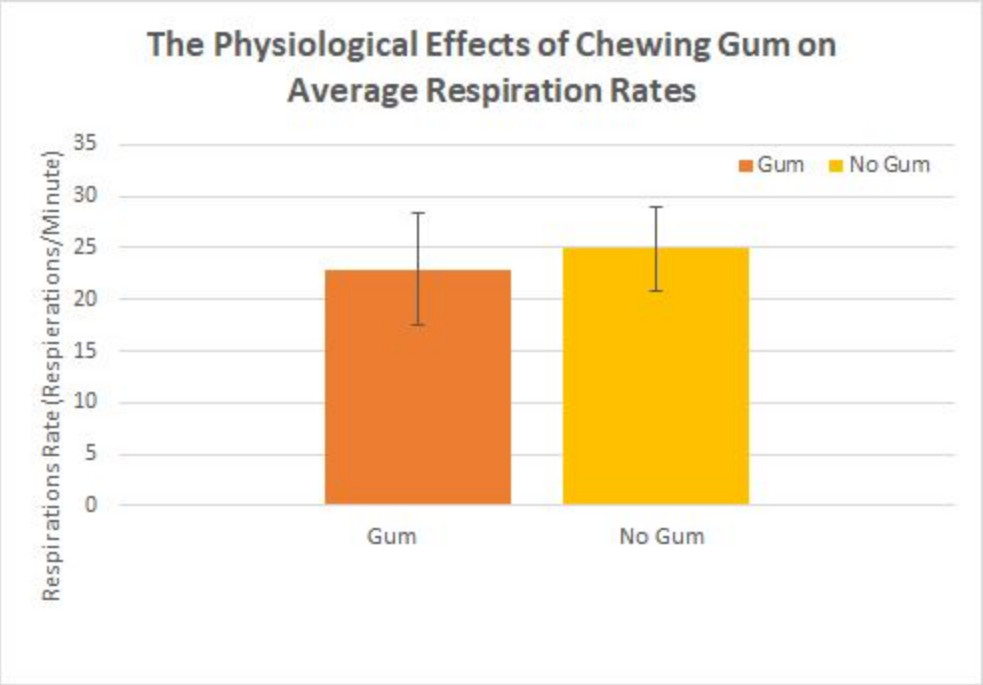

Figure 4: The physiological effects of chewing gum on average respiration rates. The graph juxtaposes respiration rate means per minute. The bar graph shows the alterations in respiration rate by comparing the effects of chewing gum and not chewing gum. Respiration rates were determined to be slightly higher when not chewing gum.

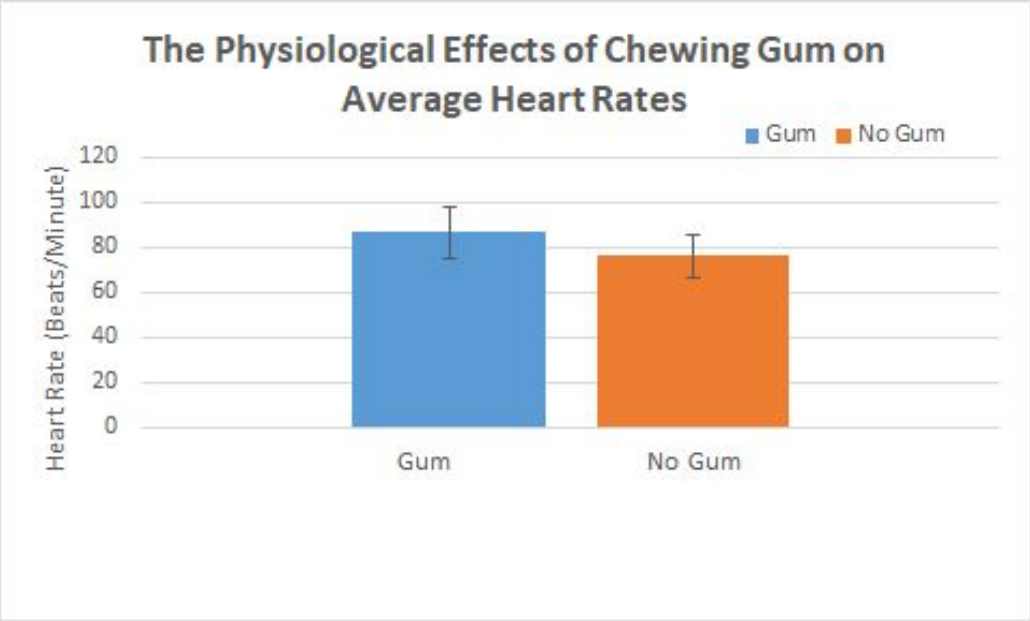

Figure 5. The physiological effects of chewing gum on average heart rates. The graph juxtaposes average heart rate means per minute. The bar graph shows the alterations in heart rate by comparing the effects of chewing gum and not chewing gum. Heart rates were determined to be significantly higher when chewing gum.

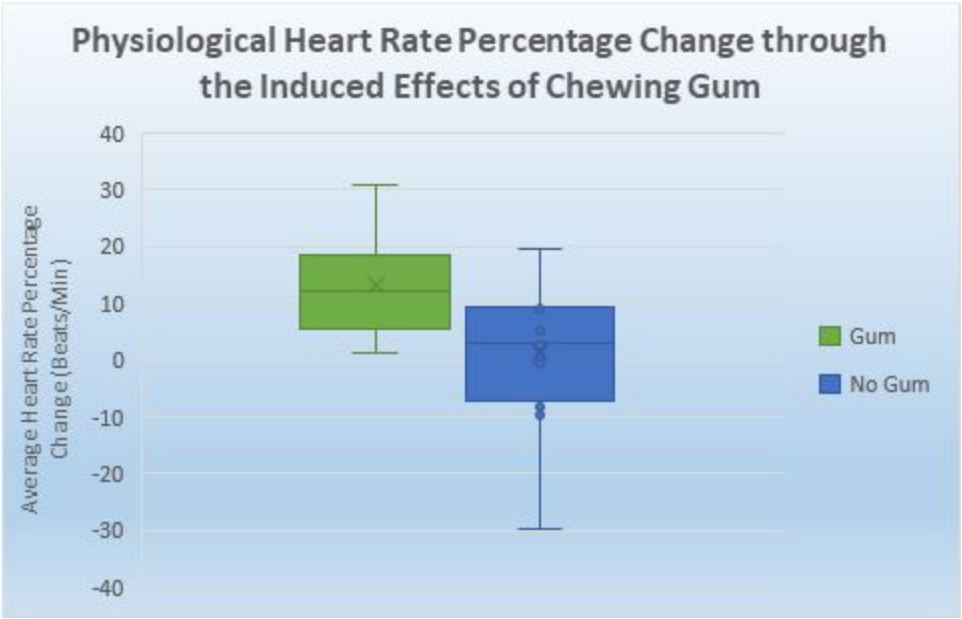

Figure 6: Physiological heart rate percentage change through the induced effects of chewing gum. This box-and-whisker plot takes into consideration the difference in values between a participants baseline heart rate and their experimental heart rate in the form of percent change. As shown, the effect of chewing gum showed a significant increase from the baseline heart rate, while participants who performed the recall test without chewing gum did not show a large difference from their baseline values.

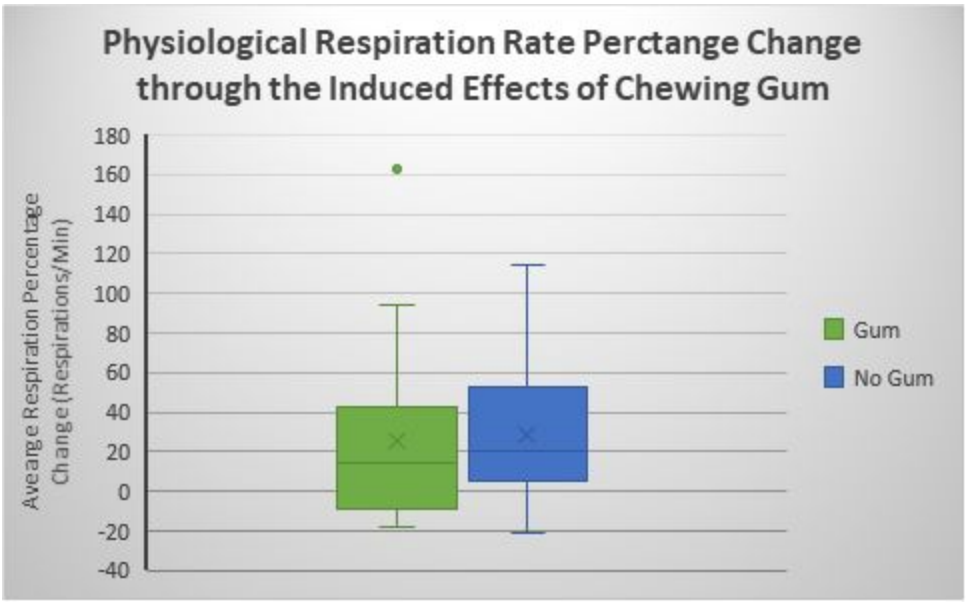

Figure 7. Physiological Respiration Rate Percentage Change through the Induced Effects of Chewing Gum. This box-and-whisker plot takes into consideration the difference in values between a participants baseline respiration rate per minute, and their experimental respiration rate per minute in the form of percent change. As shown, the effect of chewing gum showed no significant increase from the baseline respiration rate. Similar results were observed when not chewing gum. A wider range in respiration rate was seen when not chewing gum.

References

Allen, A., Jacob, T. and A. Smith. 2014. Effects and after-effects of chewing on vigilance, heart rate, EEG and mood. Physiology and Behavior. 133(22): 244-251.

Jacobson, Rae, and Child Mind Institute. "What Is Working Memory?" *Child Mind Institute*, childmind.org/article/what-is-working-memory/.

Laskaris, Donnan J., "The Effects of Mastication on Memory and Recall in Elementary Students" (2006). *All Regis University Theses*. Paper 390.

"Leading U.S. Chewing Gum Brands Based on Sales, 2013 | Statistic." *Statista*, 2018, www.statista.com/statistics/295031/leading-us-chewing-gum-brands-based-on-sales/.

McLeod, S. A. (2009). Short term memory. Retrieved from www.simplypsychology.org/short-term-memory.html

Shiba, Y., Nitta, E., Hirono, C., Sugita, M. and Y. Iwasa. 2002. Evaluation of mastication-induced change in sympatho-vagal balance through spectral analysis of heart rate variability. Journal of oral rehabilitation. 29(10): 956-960.

Scholey, A., Haskell, C., Robertson, B., Kennedy, D., Milne, A. and M. Wetherell. 2009. Chewing gum alleviates negative mood and reduces cortisol during acute laboratory psychological stress. Physiology & behavior. 97(3-4): 304-312.

Wilkinson, L., Scholey, A. and K. Wesnes. 2002. Chewing gum selectively improves aspects of memory in healthy volunteers. Appetite. 38(3): 235-236.