The Effects of Chewing Gum on Physiological Stress Responses and Cognitive Recall

Emily Ausloos, Jessica Paradowski, Annette Marie Ruth, Lauren Strom, Nihal Voruganti

University of Wisconsin - Madison, Department of Physiology

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Lab Section 602, Group 1

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Word Count: 5,602

Abstract

      The objective of this study was to evaluate how chewing gum both affects physiological stress responses directly and short-term memory indirectly. It was hypothesized that chewing gum will directly attenuate the elicited physiological stress response and indirectly enhance cognitive performance. Stress response to verbal and audio stressors was measured through changes in blood pressure (BP), heart rate (HR) via electrocardiography (ECG), and brain wave activity via electroencephalography (EEG). Two subject groups, Group A and Group B, completed a word search task followed by a recall task. The groups differed in the time at which they received a piece of gum within the study. Group A received gum after the stress induced task and Group B received the gum before the stress induced task. Results concluded that, contrary to the hypothesis and the findings of prior studies, chewing gum neither significantly changed the three physiological measurements upon exposure to the stressor, nor did it indirectly enhance cognitive recall performance. Increased systolic BP during the recall task was the only significant result between groups (p=0.039; 95% CI). Chewing gum led to a 5 times greater increase in BP, though marginally statistically insignificant (p=0.053: 95% CI). No significant findings were identified for HR or brain wave activity, either between groups or while chewing gum (vs. baseline). Increasing the amount of participants and improving quality of equipment could improve future studies.

Introduction

Stress has been experienced by everyone in some form or another. Stress can manifest itself as psychological, neurological, or physiological changes. Stress, in regard to physiology, can be defined as a state of threatened homeostasis caused by intrinsic or extrinsic adverse forces (Tsigos et al., 2016). A stress response is thus employed as a way to re-establish the body's equilibrium (Tsigos et al., 2016). The human stress response can be altered, however, as individuals have varying ways of coping and reducing personal stress.

One such way that could potentially reduce stress is chewing gum. Looking at available literature on correlations between stress and gum chewing, it was found that chewing gum has been proven to reduce blood pressure, cholesterol and levels of stress at work (Smith et al., 2013). A second study looked at the effect of chewing gum over a period of fourteen days, and identified significantly reduced anxiety levels after the two weeks (Sasaki-Otamaru et al., 2011). In addition, a study by *Scholey et al.* specifically states that, "chewing a flavored gum may have additive effects in terms of positive mood and anti-stress properties" as well as increased levels of alertness (2009). *Johnson et al.* found similar results in regards to the effect of gum on alertness, but added that the increase may be attributable to a minty-flavored gum (2011).

The direct effect of gum on stress can be measured via various physiological variables. The three variables used in this study are blood pressure, heart rate via electrocardiography (ECG), and brain wave activity, measured using electroencephalography (EEG). All three of these variables deviate from baseline when subjected to a stressor (see *Pilot Study* in Results).

It is well documented that increased stress causes an increase in sympathetic nervous system (SNS) activity (Publishing Harvard Health, n.d.; The Physiology of Stress, 2011). Hormones released via the SNS cause an increase in heart rate and vasoconstriction, or increased

blood pressure. In this study, the heart rate in response to stress will be measured using ECG, and the blood pressure measured using an automatic blood pressure cuff.

EEG measures electrical potentials from neuronal activity and reflects cognitive function. Increased EEG activity is associated with increased brain activity (Giannakakis et al., 2015). When exposed to a stressor, the brain induces a stress response system that also involves the stimulation of the SNS. In response to stress, brain activity in the frontal lobe is increased, which can be identified in the EEG recordings (Giannakakis et al., 2015).

Based on the literature, it is expected that chewing gum will decrease the stress response, which will be measured by assessing deviation from baseline for each of the three physiological measurements, explained in detail above. However, the link between cognitive recall and gum has yet to be determined. Conversely, the link between cognitive recall and stress has been well-defined. Cognitive recall is typically impaired in response to stress, largely due to elevation in cortisol levels. The hippocampus is a region of the brain responsible for memory processing and contains numerous cortisol receptors. Increased levels of cortisol during the stress response can cause the hippocampus to become overwhelmed, effectively interfering in memory production. Multiple studies have found that elevated stress levels lead to poorer cognitive recall ability and that chronically elevated stress hormone levels can inhibit memory ("Stress Hormone Hinders Memory Recall", 2013). Furthermore, a meta-analysis study by *Tucha et al*. found that gum may have both positive and adverse effects on cognitive recall (2012). Of the 16 studies reviewed, 8 found beneficial effects of chewing gum on cognitive recall ability, 4 found a detrimental effect on cognitive recall ability, and 4 found neither a detrimental or beneficial effect of chewing gum on cognitive recall (Tucha et al., 2012).

Multiple studies found a negative correlation between stress and chewing gum, but all failed to examine the effects of introducing gum at various time points (Johnson et al, 2011; Sasaki-Otomaru et al., 2011; Scholey et al, 2009; Smith, 2013; Tucha et al., 2012). Introducing gum before or after a stressor could have varying effects on either reduction or prevention of high stress responses. This consideration necessitates testing the effect of chewing gum for a period prior to the induced stressor and after stress has been induced. A second aspect that this study will test is how chewing gum indirectly effects cognitive performance on a task by directly measuring the effect of gum on physiological responses, which are known to be affected by stress. This will examine the link between gum's direct impact on stress response and any of its indirect effects on cognitive performance. Furthermore, the literature is inconclusive on whether or not gum directly affects cognitive recall. However, many studies did not consider the indirect effects of gum on cognitive recall. It has been shown that increased stress leads to impaired cognitive recall. Therefore, it is reasonable to postulate that, if gum was able to attenuate stress, it could also indirectly enhance cognitive recall even without a direct relationship to cognitive performance.

Thus, this study sought to determine whether chewing gum, beginning either prior to or after an induced cognitive stressor, directly attenuates the stress response. In addition, it attempted to elucidate how chewing gum may indirectly affect cognitive recall ability. Given existing interpersonal variability in stress levels, individual baseline measures of heart rate, blood pressure and brain activity were taken and served as a negative control. Due to inherent variability in individuals' response to stressors, it is necessary to ensure that the desired physiological stress response is veritably and consistently elicited via well-established positive controls. Accordingly, this study utilized paired auditory and cognitive task stressors known to

induce physiological stress responses in experimental subjects, further detailed in methods, as positive controls. Expected responses to the stressors included an increase in heart rate, blood pressure, and brain wave activity. Each subject therefore effectively served as his or her own positive and negative control throughout the course of the experiment.

It is hypothesized that chewing gum will directly attenuate the elicited stress response and indirectly enhance cognitive performance. Additionally, because it is predicted that chewing gum will attenuate physiological stress responses, it is hypothesized that the participants receiving gum prior to the stressor being induced will exhibit significantly reduced measureable stress responses as compared to the participants receiving gum after the stressor.

Materials

Heart rate (HR), blood pressure (BP), and brain wave activity were the three physiological responses measured in the study. Heart rate and brain wave activity were measured continuously with exact measurements being recorded at specific time points with BioPac software. Heart rate was monitored using ECG with an electrode lead set (SS2L, BioPac Systems Inc., Goleta, CA, USA) to measure beats per minute (BPM). Brain wave activity was measured via EEG using an electrode lead set (SS2L, BioPac Systems Inc., Goleta, CA, USA). Both ECG and EEG leads were connected to 3 disposable electrodes (EL503, BioPac System Inc., Goleta, CA, USA). These electrodes were pre-gelled but a drop of gel (sigma gel, Physio-Control) was added as the electrodes were often dry following removal from packaging. Electrodes for the EEG measurements were secured using a self-adherent bandage wrap (3M Coban™). Blood pressure was measured by using an automated blood pressure monitor with a cuff (BP742N, Omron Healthcare Inc., Lake Forest, IL, USA). Data recording was completed using BioPac Student Lab System (BSL 4 software, MP36), with reference to equipment setup and data

collection methods published in the BioPac Systems, Inc. Student Manual (BioPac Systems Inc. ISO 9001:2008). Microsoft Office Excel and Vassar Stats were used for data analysis. To test the effect of gum on the stress response, all participants also received a piece of sugar-free, mint flavored gum (Extra brand flavored spearmint).

Methods

Procedure

Participants for this study (n = 24, with 12 females and 12 males) were recruited from students enrolled at the University of Wisconsin Madison for the 2018 spring semester. Participants were assigned to one of two experimental groups, A and B, in the order they volunteered, with an equal distribution of males and female participants between groups (n=12 per group). Group A received the gum after the stressors and word search task, while group B received the gum before the stressors and word search task. Once a participant received gum they were instructed to chew the gum for the remainder of the study. Two groups were used in order to see the direct effect of gum on stress as well as the effect of giving gum before or after inducing stress, through measured physiological stress response deviations from baseline. Group A tested the effectiveness of gum on decreasing physiological stress response after stress had already been induced, while Group B tested the effectiveness of gum on attenuating physiological stress response levels before stress had been induced. These results could then be applied to see how the attenuated stress affected cognitive recall. Thus, the direct effect of gum on stress could be used to identify the indirect effects of gum on cognitive recall.

The study design involved a two-part task, completion of a word search of 12 words, followed by a subsequent cognitive recall test using the words from the word search. The word search was administered in a paper format (see appendix). The subjects were given a blank sheet

of paper for the word recall task (see Appendix). To evoke a stress response all participants were exposed to two stressors, a verbal and auditory stressor, that were both intended to induce cognitive stress. The specific details of the stressors are outlined in the methods section. Subjects were directed to begin chewing at established experimental time points, detailed in the methods section below. The verbal stressor induced competition and put pressure on the participants by promising a reward for the best performer in the study. The stressor consisted of informing the participant that they had the ability to win a gift card ($50) on behalf of Dr. Lokuta's research fund based on their results. The auditory stressor (see appendix) used was a distractive song played on repeat for consistency between participants. A MacBook Pro played the auditory stressor in the room, set directly above the test computer, set at maximum volume in order to maximize cognitive interference and evoke a stress response. Participants had their heart rate, blood pressure, and brain wave activity measured using the BioPac equipment throughout the course of the study to measure stress response. The experimental design is explained in detail below and can be seen in Figure 1.

Group A was instructed to chew gum in a break between the word search and recall tasks to limit interference that could affect the subjects' performances. The setup of the study requires removal of the word search before giving the subject a blank sheet for the recall. This allows for the distribution of gum during an intended break in the study, thus eliminating a major change in the study timeline between groups. Subjects from Group B experienced the same break at this time point, just without the addition of gum, to prevent any advantages over Group A from occurring. Group B was given gum before the stressors were induced.

Protocol

Before starting the study, all participants signed a consent form and were given a subject number to protect confidentiality. The BioPac equipment was then attached to the participants, including the automatic blood pressure monitor, ECG leads and EEG leads. Blood pressure was measured only at the specific time points in the course of the experiment. The data points taken for heart rate and brain wave activity were matched to the specific time points in which blood pressure was taken. For EEG, the electrode placements for a 3-lead system follow selected frontal lobe (Fp1, Fp2) and midline grounding (Fz) positions outlined in the international standard 10-20 EEG system (Khazi et al., 2012). The negative lead was attached to an electrode on the front left side of the frontal lobe (FP1), while the positive lead was attached to an electrode on the right side of the prefrontal cortex (FP2) (Figure 2). These placements were selected in order to measure frontal lobe brain activity and to ensure a better reading due to increased electrode adhesion.

For ECG, the negative lead was attached to an electrode placed on the medial, ventral side of the subject's right forearm. The positive lead was attached to an electrode placed on the inside of the left leg directly above the subject's ankle. The grounding cable was attached to an electrode placed on the inside of the right leg directly above the subject's ankle. An automatic blood pressure cuff was attached to all participants' non-dominant arms. The non-dominant arm was chosen to reduce interference with the word search and word recall tasks.

Group A

Instructions for both the word search and recall task were given to all participants. Baseline measurements for brain wave activity, heart rate, and blood pressure were then taken 30 seconds into the study for Group A. Group A was then exposed to both the verbal and auditory

stressors and prompted to start the word search. The auditory stressor was administered for the entirety of the word search. Participants were given 3 minutes to complete the search with blood pressure measurements being taken at the 2 minute point of the task. The heart rate and brain wave activity measurements ran continuously, but a data point for each was taken at the 2 minute point of the task. After the word search, participants were given a piece of sugar-free gum to chew. The gum would be chewed for the remainder of the experiment. After chewing the gum for 30 seconds, blood pressure, brain wave activity, and heart rate measurements and/or data-points were taken to measure any initial deviations due to the gum.

Group A then engaged in the cognitive recall task for 1 minute, during which blood pressure, brain wave activity, and heart rate measurements and/or data-points were taken again. 30 seconds after completion of the recall task, final post-experiment blood pressure, brain wave activity, and heart rate measurements and/or data-points were taken. The number of words recalled for each participant were recorded after completion of the cognitive recall task.

Group B

Instructions for both the word search and recall task were given to all participants. Baseline measurements and/or data-points of blood pressure, brain wave activity , and heart rate were then taken 30 seconds into the study. Participants were then given a piece of sugar-free gum to chew, with blood pressure, brain wave activity, and heart rate measurements and/or data-points taken after 30 seconds to examine any initial deviations from baseline the gum may have caused. Participants were required to chew the gum throughout the course of the experiment, following the point in time when gum was given. All participants in Group B were then exposed to the verbal stressor and auditory stressor and prompted to start the word search. The auditory stressor was continually administered for the entirety of the word search. Participants were given

3 minutes to complete the word search, with blood pressure, brain wave activity, and heart rate measurements and/or data-points being taken at 2 minutes into the task. A small break followed the word search, in order to replace the word search with the blank paper for the cognitive recall. This allowed for consistency between groups, as this break matched the time needed for group A to receive gum. Group B was then tasked with the cognitive recall for 1 minute, during which blood pressure, brain wave activity, and heart rate measurements were taken again. 30 seconds later, final post-experiment blood pressure, brain wave activity, and heart rate measurements were taken. The number of words recalled for each participant were recorded after completion of the cognitive recall task. The entire experiment encompassed a duration of approximately 15 minutes per individual.

Data Analysis

After all of the data was collected, percent changes from baseline for each physiological measure were calculated at the time points described in the study timeline: 2 minutes into the word search task, 30 seconds after gum, 30 seconds into the recall task, and post-measurements (Figure 1). The method of data collection for all variables and their calculations of percent change and standard error were identical. An example of data collection and method of translation to figures can be observed in a table in the appendix. (see Appendix). The average words recalled for each group were calculated as well as standard error. The standard errors of the percent changes were calculated using a one-way ANOVA test. Standard error was considered since the true population mean and variance were unknown, as this study used a very small sample as a representative subset of the greater college student population. Statistical differences between Groups A and B were tested for all variables using a two sample two-tailed

t-test. A p-value of 0.05 was used to determine statistical significance. (See appendix for a list of t-test values)

Positive Control

Positive controls for this study were measured through a series of pilot studies. These trials verified that, when paired verbal and auditory stressors were introduced for a subject, a corresponding and measurable change was obtained through physiological responses. The subject was exposed to the stressors and measurements were taken both prior to and after exposure. The pilot data verified that the stimuli produced a measurable change in physiological stress (see Results).

Negative Control

The negative control is reflected in the experimental design of the study. The baseline of each individual, measured prior to introduction of stressors, effectively serves as a negative control for pre-existing interpersonal variation in stress levels. Due to a lack of stressors during baseline measurement, as expected, no physiological stress response occurs. As a result of this set-up, each participant effectively serves as their own negative control.

Results

Study Characteristics

This experiment set out to test the hypothesis that chewing gum would attenuate physiological stress responses from applied stressors. Blood pressure, heart rate, and brain wave activity were the three physiological measurements and compared to baseline measurements for each subject in order to determine deviations for each measurement throughout the stud. The average percent change and standard error for all three physiological measurements are depicted

in Figures 3-5. Additionally, the number of words recalled for Group A and B were averaged and standard error was calculated (Figure 6).

Pilot Study

The pilot studies indicated an increase in heart rate, as measured using BioPac with ECG, from 86.21 to 96.93 BPM. Brain wave activity was measured using EEG, with resultant readings of 2.10 mV before to 16.70 mV following the induced stressor. Lastly, the subject's blood pressure increased from 90/62 to 104/70 following the induced stressors. The pilot study was conducted using a single participant to verify that the BioPac equipment would effectively measure the physiological measurements used in the study. The pilot study used a separate stressor than the study itself. The stressor used in the pilot was a verified physiological stressor, which was requiring the subject to watch a scary video clip. This study was done to validate the positive and negative controls in the study before committing to the full study. It also validated that heart rate using ECG, brain wave activity using EEG, and blood pressure could be measured appropriately using BioPac equipment and the automatic blood pressure cuff.

Blood Pressure

Figure 3 depicts blood pressure percent change throughout the experiment compared to baseline levels. Increased systolic blood pressure during the recall task was the only significant result between groups (p=0.039; 95% CI).

Measurements taken when chewing gum resulted in a larger deviation from baseline for both systolic and diastolic blood pressure for Group A that was approximately five times greater than that of Group B. though, this finding was insignificant (p=0.053; 95% CI). During the stress-inducing cognitive word search task, both groups had a similar percent increase in diastolic blood pressure. However, Group B experienced an increase that was twice that of

Group A for systolic measurements. During the recall task portion of the experiment Group B, who received their chewing gum before any stressor was given, had a larger deviation from baseline for both systolic and diastolic when compared to Group A. Despite Group B's larger deviation during the recall portion of the experiment, the participants' post experimental measurements were at or below baseline. Post-measurement levels near baseline were not seen in Group A.

Heart Rate

Figure 4 depicts the percent change from baseline for heart rate for each time an experimental data point was taken. No measurements were statistically significant. The greatest difference between groups was observed during the word search task, following the administration of both stressors. Group B had a more than double percent change increase from baseline compared to Group A (p=0.13; 95% CI). Group A had a lower post measurement percent change than did Group B. Both groups had similar percent changes for the gum and recall task measurements.

Brain Wave Activity (EEG)

Figure 5 depicts the percent change from baseline for brain wave activity, as measured by EEG, for each time an experimental data point was taken. There were no statistically significant differences between the groups for any of the data points, even in comparing the addition of the stressor to baseline between groups (p=0.47; 95% CI). Based upon observing the data, it does not seem that chewing gum reduces brain wave activity in either group or that stress significantly alters it. As indicated by the error bars reflecting standard error in Figure 5, large individual variation from the group mean contributed to high p-values when comparing groups.

Cognitive Recall

Group A word recall average was only slightly higher than that of Group B - 4.75 words and 5.25 words, respectively (p=0.47; 95% CI).

Discussion

Upon analysis of physiological data, it was concluded that the majority of the study findings were insignificant and disproved the hypothesis that chewing gum will directly attenuate the elicited stress response and indirectly enhance cognitive performance. Within each group there were deviations from baseline for the physiological data. However, based on the majority of p-values being greater than 0.05, the results are most likely due to chance.

Blood Pressure

The majority of blood pressure p-values were considered to be insignificant but there was one exception. The systolic blood pressure during the recall task had a p-value of 0.039. That being said, because the majority of the other p-values calculated were insignificant, this value may be the result of a Type I error.

Heart Rate (ECG)

Overall, heart rate gave insignificant results based on the observed p-value of 0.13. However, there are noticeable differences in percent change between the two groups shown in Figure 4. For instance, during the stressed induced task the large difference between the two groups may be explained by the fact that only group B had received gum by this point in the experiment. The chewing gum may have increased attentional allocation to the word search by increasing heart rate. In addition, this could explain why both groups had similar percent changes during the gum and recall task measurements, as both groups would have been chewing gum during these measurements.

Brain Wave Activity (EEG)

The insignificant p-values for brain wave activity may be attributed to the equipment that was used in the course of the experiment. Most EEG studies use equipment and software that is outfitted specifically for use in measuring brain wave activity across the cerebral cortex, with the capacity to distinguish between alpha, beta, delta, and theta waves across different lobes and regions of the brain. Equipment available for this study did not have these functions. Furthermore, there was considerable difficulty in the adherence and placement of the electrodes, given their poor adhesion where hair is present. This may have affected the ground electrode, which was placed on participants' heads, and as a result was often insecure. The positive and negative lead placements used in this study, Fp1 and Fp2, respectively, while largely avoiding adherence issues, appeared to record motion from the temporomandibular joint when the participant was chewing gum. Thus, it is inferred that the EEG results at least partially reflect mastication, instead of frontal lobe activity.

Additionally, large subject variation may have played a role in the lack of significant findings for brain wave activity. The percent changes varied drastically between individuals within both groups throughout the course of the study. Thus, the variance of individuals from their respective groups' means were extremely high. With such extreme differences, the t-test produced extremely insignificant p-values that reflected the individual variation rather than any overall discernible change in brain wave activity.

Cognitive Recall

There was no statistically significant difference in word recall ability between the two groups, with a p-value of 0.26 being calculated after doing a two-tailed t-test. Given this similarity in the level of recall, it was concluded that recall was unaffected by the timing of gum

chewing with respect to the stressors. This could be attributed to the fact that there was no statistically significant impact of gum on stress for either group, and thus no indirect effect on cognitive recall ability through stress attenuation.

Comparison to Previous Studies

Previous studies found chewing gum reduced stress levels, like blood pressure, at work (Smith et al., 2013). Our study only found one significant value for blood pressure, but this could possibly be attributed to a type I error. This could be due to the extensive limitations of our study discussed below and the use of varying populations of study.

Previous studies also found an inverse correlation between stress and cognitive recall ability (Publishing Harvard Health, n.d.; The Physiology of Stress, 2011). Our study found no significant effect of stress on cognitive recall ability, which may be attributable to the extensive limitations of our study discussed below. This agrees with Tucha et al's study finding inconclusive effects of chewing gum on cognitive recall (2012). Our study also adds the additional finding that regardless of what time point gum is introduced, there is no significant effect on cognitive recall ability or stress.

Limitations

Various limitations were present throughout the course of this study. The efficacy of the available equipment represented a major limitation. The previously discussed issues with EEG equipment created difficulties with obtaining accurate measurements of brain activity. The equipment was unable to isolate individual brain waves, so a comparison to EEG measurements in previous papers in The Journal of Advanced Student Science (JASS) prompted us to use an average millivolt difference over a two second period. The issues with electrode adherence and sensitivity described with EEG, were also present with ECG. Electrodes on subjects' wrists were

not secure due to lack of proper adhesive. This problem was further heightened with the movement required for the subjects to complete the written tasks.

There were also difficulties encountered with the blood pressure cuff. On several occasions, the cuff reported an error message, resulting in the readings having to be taken again, past the desired time point. This occurred to such an extent in one Group A subject, that measurements could not be taken and the subject had to be excluded from the statistical analyses. Cuff error could be attributed to multiple causes, such as subjects subconsciously moving their arm during the study, crossing their legs, or cuff size.

The study design itself also represented a limitation faced. The short timeframe available to complete the study, led to constraints on the number of subjects available for recruitment and the number of trials conducted. The resultant small population may have hindered the ability to discern any overall changes in physiological responses among subjects, as individual differences would have had a larger effect. The small population also led to subjects being systematically assigned to group A or B in an effort to make the groups equal in size and gender distribution. This non-random appointment meant that any differences between the groups could not be definitively labeled as a result of the different study timelines, i.e., when gum was given. Instead, some systematic differences and bias could have existed between the groups prior to the start of the study.

Additionally, the possible contradictory effects of the stressors used to evoke a stress response may have affected the study results. The auditory stressor aimed to increase stress levels in all subjects, however the prompt to win a $50 gift card may have motivated some participants to perform at levels above that of the intended induced stress levels. Thus, the

measured stress levels in such subjects could have been lower due to competing types of stressors, and thus skewing the results.

The limited timeframe to complete the study also led to the effects of some possible confounding variables being ignored, such as caffeine, drug, or alcohol use by participants. Caffeine and other CNS stimulants can cause an increased heart rate and vasoconstriction of blood vessels, resulting in higher blood pressure readings. Any participants who regularly consume large amounts of alcohol or other depressants may have displayed higher blood pressure readings and lower heart rates. Without such participants being screened from the study, any possible resultant outliers could not be attributed to these confounding variables. Additionally, the variable regularity of gum chewing between participants could not be taken into account with the limited time frame. Participants who regularly chew gum may not have experienced as large of an effect on stress levels in response to gum as those who do not.

Another possible limitation arose because this study was not masked. Many of the participants were from Physiology 435 and thus had a basic understanding of the intended purpose to measure physiological changes in response to a stressor. While it was not specifically stated that the effects of gum were being measured, it is likely many came to that conclusion. In instances where this was not the case, or the participants were from outside the class, those running the study may have either consciously or subconsciously imparted insights regarding study purpose and design to participants. As a result, participants' cognitive performance may have been enhanced by the biased knowledge imparted to them that gum could enhance their cognitive ability.

Future Studies

Future studies are likely to benefit from upgrades in both equipment and study design as well as types of measurements used. Based upon the data, blood pressure and heart rate seem to be more effective at measuring stress than brain wave activity, as can be seen in inconsistencies in EEG measurements and other problems associated with it. Thus, in future studies, brain activity could possibly be replaced with another measure of stress such as dermal activity.

Upgrades in the study design would include a massive increase in sample size, cross-sectional, random assignment, and controls for caffeine/stimulant consumption and drug or alcohol use. In addition, it would be beneficial for more trials to be administered per subject to ensure that findings are not due to chance. An upgrade for EEG equipment would be the use of an electrode cap and equipment that can reliably detect and measure different brain waves across the cerebral cortex. Electrodes with better adhesive should be used for any ECG measurements as well. A fully automated BP cuff that operates more reliably would be extremely beneficial. Another consideration for future studies would be to take measurements based on individual stabilization and variation for each physiological measurement after introducing each study component, even if that required different time scales for each participant. This would differ from the experiment design in this study where data points were taken at the same time for each subject regardless of the fluctuation or stabilization for that measurement at that point in time. Lastly, looking at variability in subjects might be beneficial, such as trying to account for and minimize individual variability through more rigid gum chewing instructions rather than 'free chewing' like what was done in this experiment.

Acknowledgments
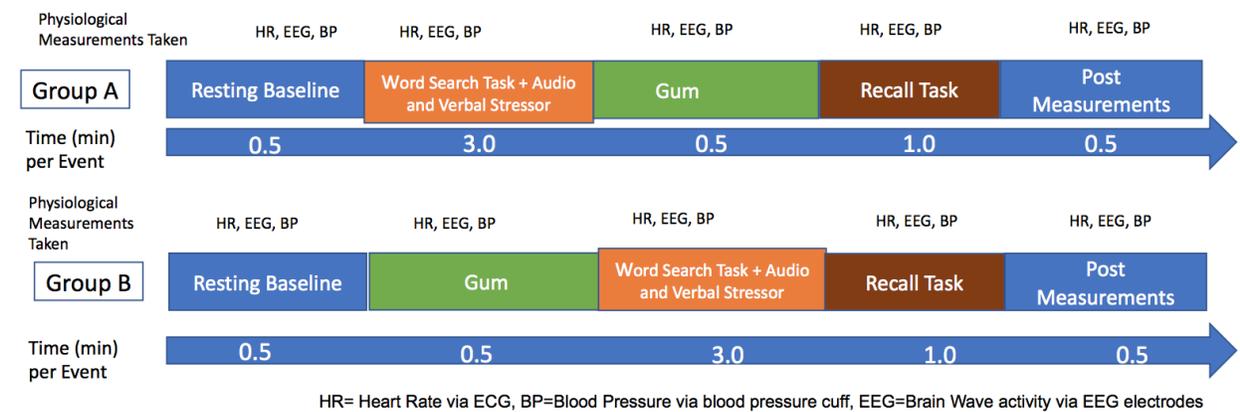
Figures

Figure 1: Timeline and procedure for Group A and B for recording data.
Heart rate and brain wave activity were measured continuously, while blood pressure was taken at specific points throughout the study. For heart rate and brain wave activity, data points were taken at indicated intervals. EEG reflects measurement of brain wave activity and ECG measures heart rate activity, electrical activity, and cardiac cycle length of the heart.
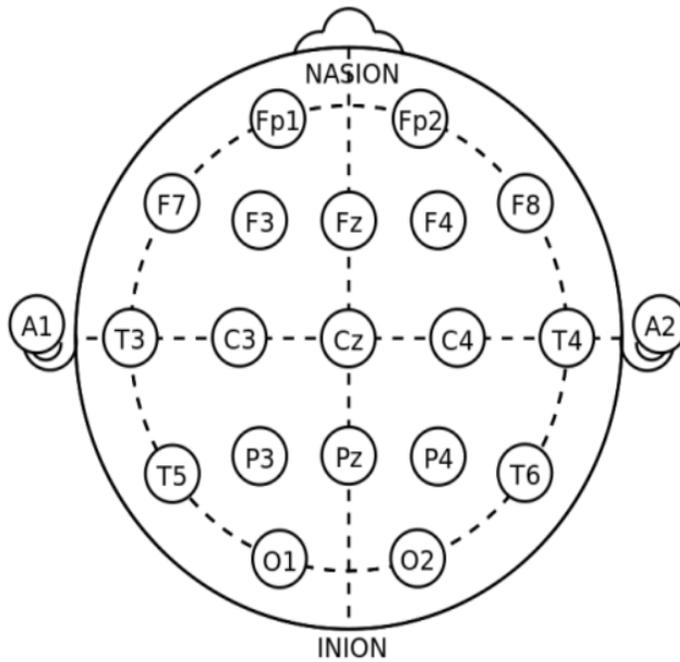
Figure 2: **A schematic diagram depicting a dorsal view of the human skull**
There is placement of the 21-electrode tracing system, based on the International 10–20 EEG system (Khazi et al. 2012). To assess brain wave activity in the frontal lobe, we utilized the Fp1 and Fp2 placements for negative and positive leads, respectively, with the grounding electrode positioned at the Fz midline.
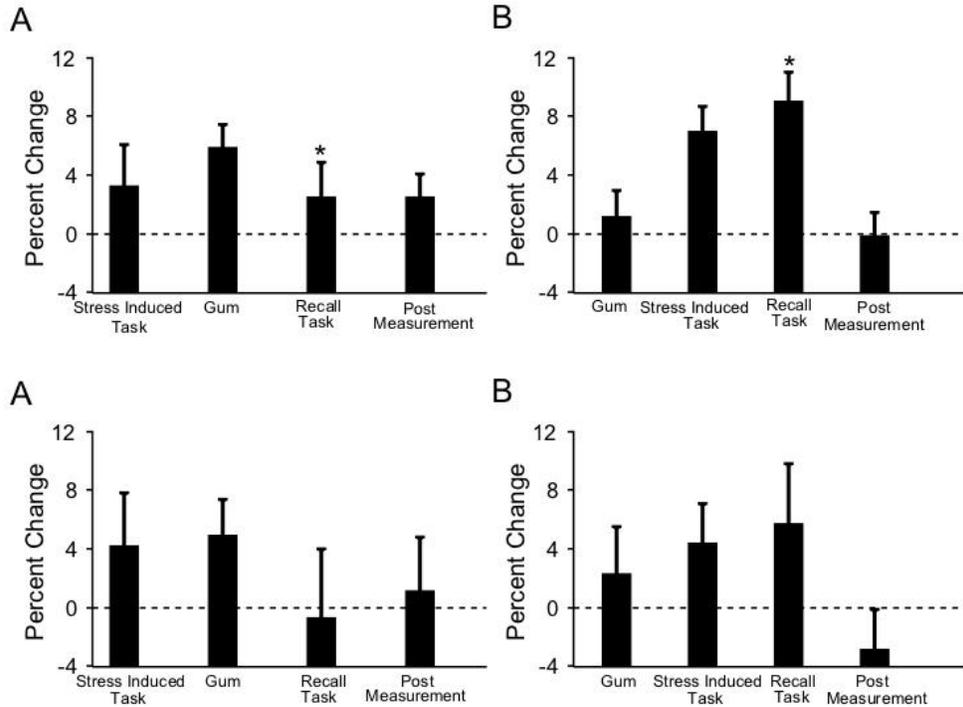
Figure 3: Blood pressure deviation from baseline.
All values are percent change from baseline measurements. Top panels represent systolic blood pressure, bottom panels are diastolic blood pressure. Values for Group A (panel A) are a group mean, n=11. Values for Group B (panel B) are a group mean, n=12. Group A consists of 11 participants due equipment failure during one of the measurements. Stress induced task represents a data point taken during the word search task after the audio and verbal stressor had been given. Note the different ordering of experimental components between groups. Error bars represent standard errors. * represents a p value of < 0.05.
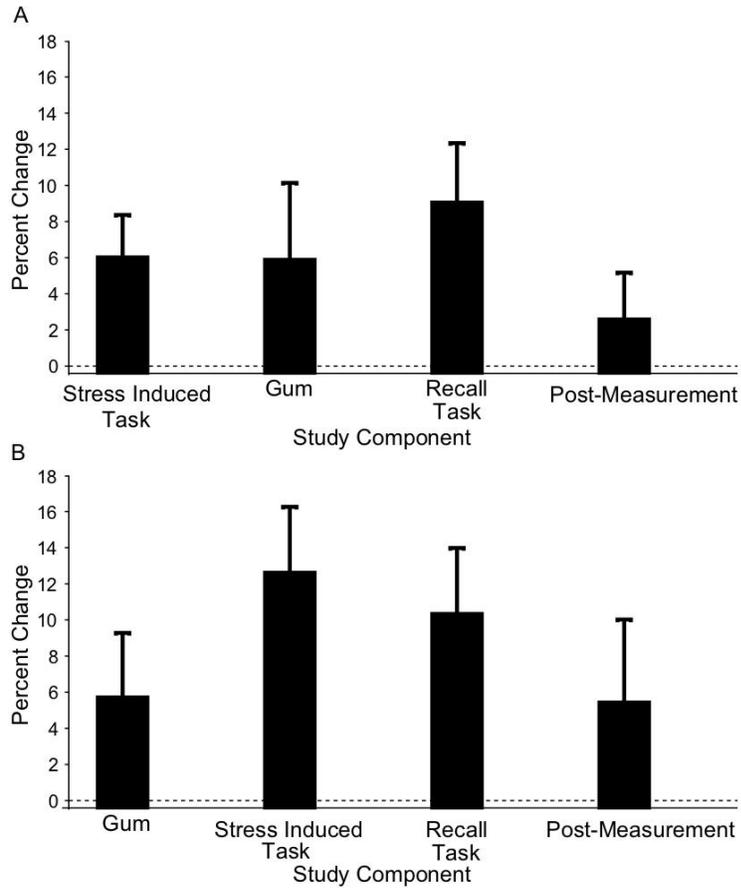
Figure 4: Heart Rate deviation from baseline.
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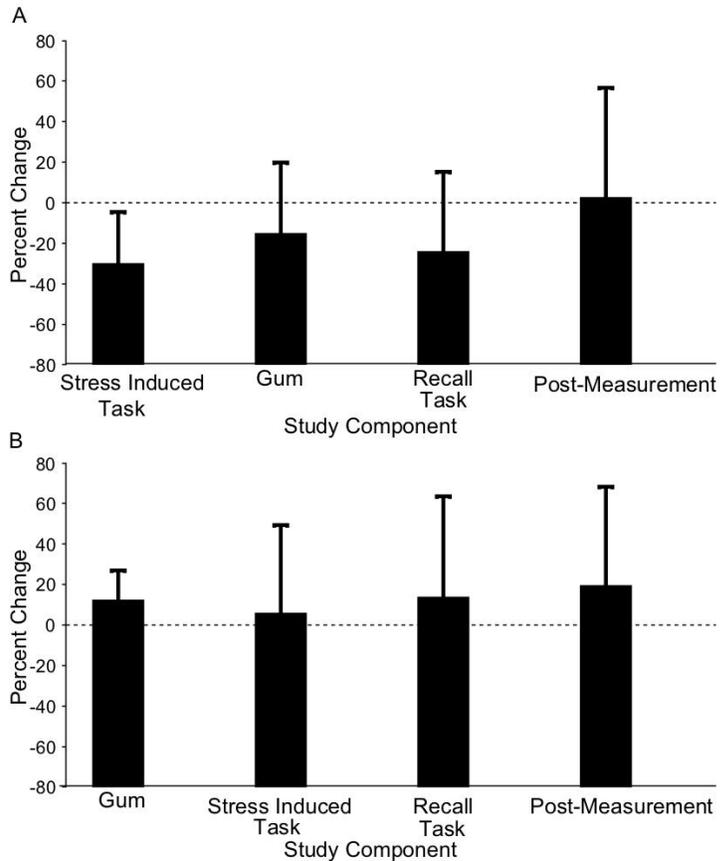
Figure 5: Brain wave activity deviation from baseline.
All values represent percent change from baseline measurements. Values for Group A (panel A) are a group mean, n=12. Values for Group B are a group mean, n=11. Group B (panel B) consists of 11 participants due to removal of an outlier. Stress induced task represents a data point taken during the word search task after the audio and verbal stressor had been given. Note the different ordering of experimental components between groups. Error bars represent standard errors.
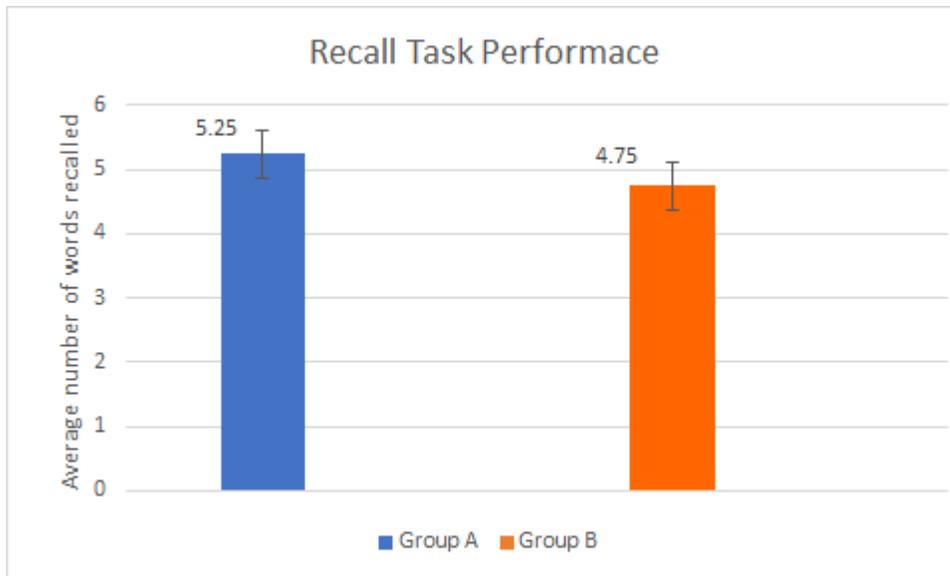
Figure 6: Cognitive Recall Ability
The performance on the cognitive recall task resulted with an average of 5.25 words (SE=.3718) for Group A and an average of 4.75 words (SE=.5222) for Group B. Values for Group A are a group mean, n=12. Values for Group B are a group mean, n=12. The values are group means +/- standard error.

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Appendix

Directions: Complete the word search to help recall the words for the following task.

```
C R I F A E X Q P H A B E R M
I A W S X U L Y Q Y E F E N U
N B T C R L D Z Y R F T J A N
Z L O E U A R I U Z S Q I B I
C D T L R M O D T A G R K P T
L I J B S P D N S O P J B Y A
X S R K K S I I A O R J E A L
U C A K O H D L R B G Y P T P
P O R T R A I T L C R A G C S
R V B A B D V R L A R U L C W
E E K T K E L O U T R U B T F
F R S P C N H W M P K W V U Y
N O Z I R O H E W Y G Y N L S
T Q Y A Q L N P Y K P T X J N
W H Q V W T K C A B H S A L F
```

AIRPORT
APARTMENT
AUDITORY
CATERPILLAR
DISASTER
DISCOVER
FLASHBACK
HORIZON
LAMPSHADE
PLATINUM
PORTRAIT
SUBURBAN

Recall Task

Directions: Write out the 12 words that were in the word bank of the word search you just completed.

Auditory Stressor Link:
https://www.youtube.com/watch?v=gT9u2VK0Ivo

Statistical Analysis - T-test Results

Two-tailed t-test between groups A and B	Systolic Blood Pressure	Diastolic Blood Pressure	Heart Rate	Brain Wave Activity
Stress Inducing Word Search Task	p=0.25	p=0.97	p=0.13	p=0.47
Gum	p=0.053	p=0.52	p=0.98	p=0.49
Recall Task	p=0.039	p=0.31	p=0.79	p=0.55
Post-Measurement	p=0.23	p=0.38	p=0.58	p=82

Raw data Collection example of Heart Rate (ECG) from group A (plotted in figure 4, panel A)

ECG (BPM)	Baseline	2 min into stress task	30 sec after Gum	30 sec into recall task	post-measurement
1A	71.8	74.6	81.9	86.2	78.1
2A	70.3	77.1	65.4	67.03	68.4
3A	80	78.6	84	85.7	75.1
4A	56	63.6	62.9	61.2	63.7
5A	85.23	88.5	86.2	89.2	84.6
6A	105.7	96.9	79.4	101.4	88
7A	71.86	76.82	72.55	97.72	77.62
8A	62.96	69.2	81.5	71.4	67.11
9A	63.56	75	67.1	71.77	70.34
10A	68.1	73.8	70.26	73.8	71.01
11A	60.2	68.1	76.4	63.7	59.2
12A	64.86	62.96	68.26	65.54	70.18
Average	71.7141667	75.4316667	74.6558333	77.88833333	72.78

% Change from baseline Levels	% change Stress induced cognitive task	% change Gum	% change Recall task	% change Post measurement
1A	3.9	14.06	20.05	8.77
2A	9.67	-6.97	-4.65	-2.7
3A	-1.75	5	7.125	-6.125
4A	13.57	12.3	9.29	13.75
5A	3.84	1.14	4.66	-0.74
6A	-9.08	-24.88	-4.07	-16.75
7A	6.9	0.96	35.98	8.01
8A	9.91	29.44	13.4	6.59
9A	18	5.57	12.91	10.67
10A	8.37	3.17	8.37	4.27
11A	13.1	26.9	5.81	-1.66
12A	-2.93	5.24	1.05	8.2
Average	6.125	5.99416667	9.16041667	2.690416667
Standard Deviation	7.7636	14.3701	11.0277	8.606
Standard Error	2.2411	4.1483	3.1834	2.4843