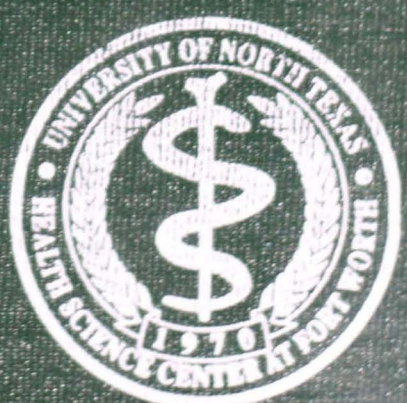
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The purpose of this randomized controlled trial is to determine what relationship, if any, exists between the act of chewing gum and the study subject's score on a standardized test for attention and concentration. To achieve this goal, a convenience sample of 201 graduate students were randomly assigned to one of three study groups (gum containing sugar, sugarless gum, and no gum control) before taking a standardized test which measured various aspects of attention and concentration.

There was no significant difference among subjects who chewed gum and those who did not chew gum with regard to the levels of attention and concentration measured by the standardized test taken during this study.

THE RELATIONSHIP BETWEEN CHEWING GUM, ATTENTION AND CONCENTRATION: A RANDOMIZED CONTROLLED TRIAL

Richard F. Virgilio, D.O.

APPROVED:

John Lucchesi DO
Major Professor

Committee Member

Kimberly Fulda, MPH
Committee Member

University Member

Elizabeth Palmuozzi DO
Chair, Department of Family Medicine

Dean, Graduate School of Biomedical Sciences

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Richard F. Virgilio, D.O.

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INTRODUCTION

The human memory and how it is best maximized is the focus of many research studies. An ideal technique to improve the function of one's memory would be inexpensive, readily available and easily performed. A controversial area of human memory research involves the use of chewing gum as an experimental intervention. A possible reason why chewing gum has been chosen as an experimental intervention by researchers is the fact that it is a commonly performed activity. Each year, 374 billion pieces of chewing gum, approximately 560,000 tons, are sold worldwide representing 5 billion U.S. dollars in sales.[1]

The act of chewing has been postulated to "increase neuronal activities in various regions of the human brain."[2] This nevertheless has been difficult to prove conclusively secondary to the difficulties inherent in examining the anatomic and physiologic areas associated with the act of chewing.[2] In an attempt to better understand the effects that the act of chewing may have on the brain and cognitive function, several studies, using various imaging techniques, have been performed in Japan, [2-11] Europe, [12-17] and collaboratively in Japan and Europe.[18] These imaging techniques included functional magnetic resonance imaging, positron emission tomography, xenon-enhanced computed tomography, and electroencephalogram tests.

Functional magnetic resonance imaging (MRI) is useful in functional brain mapping. During brain activation, "increases in regional blood flow lead to an increase in blood

oxygenation and a decrease in paramagnetic deoxygenated hemoglobin, causing an increase in the magnetic resonance signal intensity at the site of brain activation." [10] These are known as blood oxygenation level dependent signals.

Using positron emission tomography (PET) scans, the metabolism and blood flow to any area of the brain can be observed. To perform a PET scan, a small amount of a radioactive tracer is injected intravenously, and then it is absorbed by brain cells which are metabolically active. The PET scan shows the metabolic rate of the various areas of the brain using a color scale. More metabolically active areas appear red and less metabolically active areas appear blue.[19]

Xenon-enhanced computed tomography (CT) can determine the blood flow to any area of the brain. Inhaled xenon gas acts as a contrast agent because it is radiodense on CT scans. Inhaled xenon gas is non-radioactive and is rapidly removed from the body by the lungs.[20]

An electroencephalogram (EEG) is "a record of the electrical activity of the brain by measuring electric potentials using electrodes attached to the scalp." [21] The type of wave form present on the EEG indicates the level of mental activity ranging from being awake and alert to being asleep.

Studies regarding the relationship between chewing gum and cerebral blood flow

Onozuka and colleagues in two separate studies, using functional MRI showed that the act of chewing gum resulted in increased blood flow, represented by increases in blood

oxygenation level dependent signals, to several areas of the brain including the senorimotor cortex, supplementary motor area, insula, thalamus, and cerebellum.[2-3]

Takada and Miyamoto performed a study to evaluate the changes in brain activity during the process of chewing gum.[4] Using functional MRI, significant activation was seen in the frontal, prefrontal, and parietal areas of the brain of the subjects who were chewing gum as opposed to those not chewing gum.[4] They concluded that "a fronto-parietal network for mastication exists and may contribute to higher cognitive information processing."[4]

Watanabe and colleagues performed a study to investigate the areas of activation in the brain related to inhibitory control.[5] They used functional MRI "to observe changes in functional MRI signals of the entire brain during a GO/NO-GO task to identify the functional fields activated in relation to the NO-GO decision."[5] The study subjects were instructed to press a computer mouse when they were shown the GO signal, but were not to do anything when they were shown the NO-GO signal.[5] They concluded that proper performance of the NO-GO response consisted of neuronal activities involving the prefrontal, intraparietal, and occipitotemporal cortices of the brain.[5]

Using PET scans and MRI, Momose and colleagues showed that the act of chewing gum increased the blood flow to several different areas of the brain.[6] The cerebral blood flow images of study subjects at rest were subtracted from those taken while the study subject was chewing gum.[6] They concluded that chewing gum "activates widespread regions of the brain."[6]

In two separate studies, Masumoto and colleagues investigated what changes in arousal state were associated with the act of chewing gum.[7-8] In these studies, EEGs were performed on the same study subjects at rest and during gum chewing.[7-8] The results of these studies showed that the act of chewing gum led to higher levels of arousal on EEG testing than that shown on EEG before the gum chewing started.[7-8]

Morinushi and colleagues performed a study to investigate the effect that chewing gum with and without flavoring had on EEG results.[9] They concluded that the difference in the alpha, beta and theta bands on the EEGs when chewing flavored gum and unflavored gum, as opposed to the pre-stimulus control EEG record, "suggested that the flavor as well as chewing could induce concentration with a harmonious high arousal state in brain function."[9]

A study performed by Sesay and colleagues investigated the effects of chewing gum on cerebral blood flow using xenon-enhanced CT.[18] The images obtained at baseline while not chewing gum were subtracted from the images obtained while chewing gum, thus demonstrating the effect on cerebral blood flow that was due to chewing gum.[18] The results demonstrated "a significant regional cerebral blood flow increase in the fronto-temporal cortex, caudate nucleus, thalamus and a minor increase in the rolandic areas, insula, cingulate and cerebellum."[18]

Theoretically, increases in blood flow to an area could improve the function of that area. With increased blood flow comes increased delivery of nutrients and removal of waste products. Several examples of studies showing that the act of chewing gum can

lead to increases in cerebral blood flow have been given in this thesis.[2-9,18] This increased blood flow to the brain could lead to improved cognitive performance.

Studies regarding the relationship between chewing gum and memory function

Four studies have been published regarding what effect, if any, the act of chewing gum has on memory. The results of these studies were conflicting.

Wilkinson and colleagues studied the effects of chewing gum on memory using a cognitive assessment battery on three groups of study subjects.[12] One group chewed gum, one group pretended to chew gum, and one group did not chew gum while completing the tests.[12] The results showed that those who chewed gum had better immediate and delayed word recall than those who did not chew gum.[12]

Baker and colleagues attempted to discover if the act of chewing gum has context-dependent effects.[13] A second question was whether the act of sucking a piece of gum can produce the same effect on word recall as chewing it. This would test if memory effects are related to the taste of gum or from the action of chewing the gum. Each of four study groups was given a list of 15 words to remember. One group chewed gum at both learning and recall. One group chewed gum at learning but not recall. One group did not chew gum at learning but did chew gum at recall. One group did not chew gum at learning nor recall. The results showed that the group that chewed gum at both learning and recall had higher word recall scores than those that did not chew gum at learning nor recall. This demonstrated that chewing gum had context-dependent effects. To answer

whether sucking a piece of gum can produce the same effect on word recall as chewing it, each of four groups were given a list of 15 words to remember. One group chewed gum at both learning and recall. One group sucked a piece of gum at learning and recall. One group was not given any gum at learning but sucked gum at recall. One group was not given any gum at learning but chewed gum at recall. The results showed that the groups that chewed or sucked gum at both learning and recall had higher word recall scores than those in the no gum at learning – sucked gum at recall group. This demonstrated that sucking gum can have some of the same effect as chewing gum.[13]

Stephens and Tunney performed a study to test the hypothesis that "chewing gum leads to cognitive benefits through improved delivery of glucose to the brain, by comparing the cognitive performance effects of gum and glucose administered separately and together."[14] A 2 X 2 design was used with the two factors being chewing gum (sugarless gum versus sugar-free mint) and glucose (25 gram glucose drink versus water). The results showed that chewing gum along with glucose administration had beneficial effects on the neuropsychological tests measuring working memory, immediate episodic long term memory, processing speed and language based memory.[14]

Tucha and colleagues also studied the effect that chewing gum has on memory using four different groups, chewing a piece of spearmint flavored gum, chewing a piece of tasteless gum, pretending to chew a piece of gum, no gum chewing.[15] The study subjects in each group were given word recall, attention, visual scanning, and flexibility tests, to evaluate memory function. The results demonstrated improvement in sustained attention

in the group that chewed spearmint flavored gum, but cognitive flexibility and alertness were adversely affected in this group. [15]

Studies regarding the relationship between glucose administration and memory function

The relationship between glucose administration, heart rate, and cognitive performance was studied by Kennedy and Scholey.[16] Neuropsychological tests to evaluate memory function (Serial Sevens, Serial Threes, and Word Retrieval) were given twice to the same two groups under two different experimental conditions. One experimental condition was the administration of oral solution containing 25 grams of glucose, the other was administration of an oral solution containing 30 milligrams of saccharine. The results showed that both the test scores and heart rates were higher after administration of the oral solution containing glucose than the oral solution containing saccharine.[16]

Scholey and colleagues performed another study to examine what relationship neuropsychological tests of differing levels of cognitive demand have on peripheral blood glucose measurements.[17] Neuropsychological tests to evaluate memory function (Serial Sevens, Word Memory, and Word Retrieval) were given twice to the same two groups under two different experimental conditions. One experimental condition was the administration of an oral solution containing 25 grams of glucose, the other was the administration of an oral solution containing 30 milligrams of saccharine. Peripheral blood glucose levels were measured before consumption of the oral solution and performance of the neuropsychological tests, again 40 minutes after consuming the oral

solution, after performing the cognitively demanding test, and again after completing the minimally demanding cognitive test. The results showed there was a significant decrease in peripheral blood glucose in both oral solution groups after performing the cognitively demanding test compared with the minimally demanding test. They concluded that the more cognitively demanding a task is the more sensitive it would be to the performance enhancing effect of glucose.[17]

Attention and concentration are important mental activities of everyday life. One group in which these activities are paramount would be students. Because of their desire to obtain the best grades possible in their classes, students are always trying to develop study routines and activities that they believe will maximize their attention and concentration. If it can be proven that the act of chewing gum, which is inexpensive, readily available and easily performed, helps improve attention and concentration, students may be able to parlay this increase in attention and concentration into better grades.

How the present study compares to previously performed studies

This study is a variation of previously performed studies in that the experimental interventions of chewing gum and the administration of a glucose load to study subjects will occur to determine the relationship each of these experimental interventions has on attention and concentration. Previous studies investigating the effects of glucose on cognitive function used a dose of 25 grams of glucose, given as an oral solution.[14, 16-17]

No study has ever investigated whether chewing gum containing sugar would produce a similar improvement in cognitive function as was shown in the previous studies that used an oral solution containing 25 grams of glucose.[14, 16-17] This study will incorporate the use of a research instrument, the *d2 Test of Attention,*[22] to access the study subject's level of attention and concentration. A review of the literature shows that this particular research instrument has never been used in assessing the association between chewing gum and levels of attention and concentration.

Primary and secondary study hypotheses

The proposed research study will combine both gum chewing and administration of an oral glucose load in the form of chewing gum containing sugar, to test the following study hypotheses. The primary hypothesis is that the act of chewing gum will increase an individual's level of attention and concentration as shown by higher standardized test scores, compared with individuals who do not chew gum. A secondary hypothesis is with regard to the individuals who chew gum. Those who chew gum containing sugar will have higher scores on the standardized test for attention and concentration than those who chew sugarless gum.

METHODS

Sample size calculations

Sample size calculation was performed *a priori*. I hypothesized that there would be a 5 point difference, between the study groups, in the values of the mean standard scores of the outcome variables obtained from the standardized test. This represents an effect size of 0.5, which means that the experimental intervention (chewing gum) would have a moderate effect. To allow for the detection of a 5 point difference in the mean standard scores of the outcome variables obtained from the standardized test with 80% power and a standard deviation of 10, a sample size of at least 64 subjects per group was needed. The standard values for α and β, .05 and .20 respectively, were chosen. The standard deviation value of 10 was chosen because the standardized test manual reported that this was the value for the standard scores of the outcome variables of the *d2 Test of Attention.*[22]

Study population

To obtain the study population for the randomized controlled trial, a convenience sample of 201 students (67 per group), 18 years of age or older, who were currently enrolled in any of the four schools that comprise the University of North Texas Health Science Center at Fort Worth (Texas College of Osteopathic Medicine, Graduate School of

Biomedical Sciences, School of Public Health, School of Health Professions) was obtained by recruiting volunteers.

In order to recruit volunteers, advertisements were posted in various locations around the campus of the University of North Texas Health Science Center. Enrollment started on February 15, 2005 and ended on April 12, 2005. Enrollment was brisk initially. There were 120 study subjects enrolled within the first three weeks. The number of student volunteers quickly declined over the next five weeks, until the study population of 201 subjects was achieved on April 12, 2005.

Study randomization

The study subjects were randomly assigned to one of three groups. A block randomization process was performed, consisting of 14 total blocks, in an attempt to obtain three equal sized groups. Thirteen blocks consisted of 15 sealed envelopes containing a piece of paper on which the letter "N" (5 envelopes), "S" (5 envelopes), or "C" (5 envelopes) was written. One block consisted of 6 sealed envelopes containing a piece of paper on which the letter "N" (2 envelopes), "S" (2 envelopes), or "C" (2 envelopes) was written. The letter "N" meant the study subject was assigned to the "no gum control group". The letter "S" meant the study subject was assigned to the "sugarless gum chewing group". The letter "C" meant the study subject was assigned to the "gum containing sugar group". All study participants took the same standardized test, the *d2 Test of Attention,* [22] which measured their level of attention and concentration

using eight outcome variables. Those subjects assigned to either of the two gum chewing groups were asked to start chewing the gum given to them by the study investigator, after which the standardized test was administered. The sugarless gum used in this study was Wrigley's Extra Spearmint. The gum containing sugar used in this study was Wrigley's Spearmint. Both types of gum used in this study were manufactured by the Wm. Wrigley Jr. Company, Chicago, IL. Those in the gum chewing groups were asked to continue chewing their gum, as they would do normally, throughout the entire study period, namely until they completed the standardized test. Upon completion of the standardized test, the subject's participation in the study ended.

Description of the research instrument used in this study

(All information included in this subsection of the methods section of my thesis was taken from the 1998 U.S. edition of the *d2 Test of Attention* by Brickenkamp and Zillmer.)[22]

Brickenkamp and Zillmer's d2 Test of Attention was created at the Institute for Safety in Mining, Industry, and Transportation at the Technical Control Commission in Essen, Germany. The first edition of this test was published in 1962. Its original purpose was to measure driving proficiency, but over the past 43 years, it has been used in research in various fields of psychology including clinical psychology, applied psychology, educational psychology, psychometrics, and pharmacological psychology. Because of its wide use, it has become the mainstay of the assessment of attention in Europe.

Originally, it was only available in German, but in 1998, with the publication of the first U.S. edition, it was translated into English. The d2 test is a concise measure of selective attention (the capacity to focus on one or two important stimuli, while suppressing awareness of competing distractions) and mental concentration. Its name comes from the directions that are given to those individuals taking the test which is that they are to "cross out every letter 'd' that has '2' dashes".

The d2 Test of Attention is a standardized test that has 14 lines, each containing 47 characters. The characters are the letters "d" and "p" which have anywhere from one to four dashes placed above or below each individual letter. The individual taking the test is instructed to scan each line and cross out each test item consisting of the letter "d" with two dashes (d2's) while ignoring all of the other characters listed on each line (non-d2's). Test takers are given 20 seconds to complete each line. At the end of each 20 second period, the test taker is given a verbal signal to immediately stop working on the current line and instead start working on the next line. There are a total of 658 items per test that when analyzed yield information on various aspects of attention and concentration.

Scoring of the d2 Test of Attention is done manually by the study investigator, using two different answer keys provided with the test instruction manual. Both of these answer keys are transparencies with strategically placed black boxes printed on it, so that when placed on the completed test form obscure irrelevant characters, thus making it easier to assess the appropriate characters. One of the answer keys obscures all the characters that should have been crossed by the study subject and is used to determine the number of "non-d2's" that were crossed out. The other answer key obscures all the

characters that were not supposed to be crossed out by the study subject and is used to obtain all other scores except the number of characters that were crossed out inappropriately.

Using the test instruction manual and the answer keys, the tests are scored in the following manner. First, the number of items processed, correctly or incorrectly, on each line are counted and recorded. This is referred to as the total number of items processed. Next, the number of mistakes made is calculated in two steps. The number of "d2's" that were not crossed out on each line is counted and recorded. These mistakes are referred to as errors of omission. The number of "non-d2's" that were crossed out on each line are also counted and recorded. These mistakes are referred to as errors of commission. Next, the number of correctly crossed out "d2's" on each line is counted and recorded. The number of errors of commission on each line is subtracted from this number. This result is referred to as the concentration performance. Next, the individual line with the greatest number of items processed is subtracted from the line with the lowest number of items processed and is also recorded. This is referred to as the fluctuation rate. After every line is scored, the results are added together to compute a total score for each variable.

Outcome variable data are obtained directly from or derived from the various scores recorded on each test. The variable "total number of items processed" quantitatively measures the allocation of selective and sustained attention, processing speed, amount of work completed, and motivation. The variable "errors of omission" measures attentional control, rule compliance, accuracy of visual scanning and quality of performance. The

variable "errors of commission" measures inhibitory control, rule compliance, accuracy of visual screening, carefulness, and cognitive flexibility. Two other variables are derived from error scores. The variable "percentage of errors" is a qualitative measure of performance. It is calculated by multiplying the sum of both types of errors by 100 and dividing this amount by the total number of items processed. The smaller the percentage of errors, the better the subject's accuracy, quality of work, and degree of carefulness. The variable "total number of items scanned minus error scores" measures attentional control, inhibitory control, and the relationship of speed and accuracy of performance. This variable is derived from subtracting the total number of both types of errors from the total number of items processed. This variable could lead to an overestimation of total performance if the test taker indiscriminately crossed out characters without regard. The dichotomous variable "skipping syndrome" (present/absent) identifies those test takers who fall into this special category. In normal subjects, the skipping syndrome indicates superficial scanning and a disregard of the test instructions. The variable "concentration performance" provides an index of coordination of speed and accuracy of performance. Unlike the variable "total number of items scanned minus error scores," concentration performance is not affected by the skipping syndrome and is therefore a more reliable variable if the skipping syndrome is present. The variable "fluctuation rate" assesses the stability and consistency of performance across trials, which is a measure of temporal persistence. Tests with high fluctuation rate scores could be indicative of inconsistent work speed possibly secondary to poor motivation.

Data acquisition

All of the standardized tests were scored by the study investigator. Scoring of the test was a process that took approximately 20 minutes per test to complete, in order to properly analyze the 658 test items to obtain the values for the eight outcome variables. The study investigator created a database with this information.

Inter-rater reliability

In order to check the reliability of values of the eight outcome variables from the standardized tests scored by the study investigator, inter-rater reliability testing was performed using a second rater. The first twenty completed standardized test forms were independently scored by a second rater. The inter-rater reliability was quantified by calculating the Pearson's product moment correlation coefficient for each of the eight outcome variable pairs.

Testing for baseline differences between the study groups regarding covariates

Testing was also performed to determine if the three study groups differed significantly with regard to the covariates age, gender, and whether the study subjects were right handed or left handed (handedness). An analysis of variance (ANOVA) was performed

to determine if there was any significant difference between the three study groups with regard to the covariate age. Chi square (χ^2) testing was performed to determine if there was any significant difference between the three study groups with regard to the covariates gender and handedness.

Distribution of the study data

All data obtained from the standardized test forms were analyzed to determine if the data were normally distributed. Histograms plotting every data point of each of the eight outcome variables were plotted. Also, measures of central tendency (mean, median, and mode) were calculated for each of the eight outcome variables.

Study design

All statistical analyses were performed utilizing two different study designs (two group and three group). In the two group study design, the "gum containing sugar group" and the "sugarless gum group" were combined into one "gum chewing group" and was compared with the "no gum control group." This study design was used to test the primary hypothesis. In the three group study design, the "gum containing sugar group" and the "sugarless gum group" were compared with each other and with the "no gum control group." This study design was used to test the secondary hypothesis.

Any of the eight outcome variables that were normally distributed were analyzed using the parametric tests ANOVA and analysis of covariance (ANCOVA) to control for the covariates age, gender, and handedness. Any of the eight outcome variables that were not normally distributed were analyzed using the non-parametric test chi square.

Lastly, the raw scores for the outcome variables "total number of items processed" and "total number of items scanned minus error scores" were converted to standardized scores. An ANOVA and an ANCOVA, controlling for the covariates age, gender, and handedness, was performed on the mean standardized values of each of the outcome variables "total number of items processed" and "total number of items scanned minus error scores"

Statistical analyses of the data were performed using the Statistical Program for Social Sciences (SPSS) Version 11.5 for Windows.[23] A p value of less than or equal to .05 was considered to be a statistically significant result. If it was determined that statistically significant differences existed among any of the means of the three study groups, *post hoc* testing using Tukey's honestly significant difference test was performed. This randomized controlled trial protocol was approved by the Institutional Review Board at the University of North Texas Health Science Center at Fort Worth.

RESULTS

Distribution of the study data

Analysis of the histograms containing every data point of the eight outcome variables (total number of items processed, errors of omission, errors of commission, total number of errors, percentage of errors, total number of items scanned minus error scores, concentration performance, and fluctuation rate) and the calculated measures of central tendency (mean, median, and mode) revealed that the outcome variables "total number of items processed", "total number of items scanned minus error scores", "concentration performance", and "fluctuation rate" were normally distributed. The outcome variables "errors of omission", "errors of commission", "percentage of errors", and "total number of errors" were not normally distributed but rather were each positively skewed.

Inter-rater reliability

There was good inter-rater reliability between the values of the eight outcome variables from the standardized tests scored by the study investigator and those scored by the second rater. The Pearson product moment correlation coefficient for each of the eight outcome variable pairs is displayed in **Table 1**.

Testing for baseline differences between the study groups regarding covariates

The randomized controlled trial included 201 study subjects (3 groups of 67). The distribution of study subjects with regard to age, gender, and whether the subject was right handed or left handed (handedness) is displayed in **Table 2**. There were no significant differences between the three study groups (gum containing sugar, sugarless gum, and no gum control) with regard to the covariates age ($F = 0.69$; $p = 0.50$), gender ($\chi^2 = 0.77$; $p = 0.68$), or handedness ($\chi^2 = 3.91$; $p = 0.42$).

Also displayed in **Table 2** are the values for the outcome variable "skipping syndrome". Since the "skipping syndrome" was only present in a total of 7 of the 201 total study subjects (3 subjects in the "gum containing sugar group", 1 subject in the "sugarless gum group", and 3 in the "no gum control group"), no analytical statistics were performed. Instead, descriptive statistics were performed.

Testing the primary hypothesis

An ANOVA was performed to compare the mean values of each of the normally distributed outcome variables (total number of items processed, total number of items scanned minus error scores, concentration performance, and fluctuation rate) of the two study groups (gum chewing and no gum control). The ANOVA results are displayed in

Table 3. No statistically significant differences were demonstrated among the two study groups with regard to these four outcome variables.

Chi square testing was performed to compare the mean values of each of the non-normally distributed outcome variables (errors of omission, errors of commission, total number of errors, and percentage of errors) of the two study groups (gum chewing and no gum control). The chi square results are displayed in **Table 4**. No statistically significant differences were shown among the two groups with regard to these four outcome variables.

An ANCOVA was also performed to compare the mean values of each of the four normally distributed outcome variables (total number of items processed, total number of items scanned minus error scores, concentration performance, and fluctuation rate) of the two study groups (gum chewing and no gum control) after controlling the covariates age, gender, and handedness. The ANCOVA results are displayed in **Table 5**. No statistically significant differences were demonstrated among the two groups with regard to these four outcome variables.

Testing the secondary hypothesis

An ANOVA was performed to compare the mean values of each of the four normally distributed outcome variables (total number of items processed, total number of items scanned minus error scores, concentration performance, and fluctuation rate) of the three study groups (gum containing sugar, sugarless gum, and no gum control). The ANOVA

results are displayed in **Table 6**. No statistically significant differences were shown among the three groups with regard to these four outcome variables.

Chi square testing was performed to compare the mean values of each of the four non-normally distributed outcome variables (errors of omission, errors of commission, total number of errors, and percentage of errors) of the three study groups (gum containing sugar, sugarless gum, and no gum control). The chi square results are displayed in **Table 7**. No statistically significant differences were demonstrated among the three study groups with regard to these four outcome variables.

An ANCOVA was also performed to compare the mean values of each of the four normally distributed outcome variables (total number of items processed, total number of items scanned minus error scores, concentration performance, and fluctuation rate) of the three study groups (gum containing sugar, sugarless gum, and no gum control) after controlling for the covariates age, gender, and handedness. The ANCOVA results are displayed in **Table 8**. No statistically significant differences were shown among the three study groups with regard to these four outcome variables.

Standardized score data

An ANOVA was performed to compare the mean values of the standardized scores of each of the two outcome variables "total number of items processed" and "total number of items scanned minus error scores" of the two study groups (gum chewing and no gum control). The ANOVA results are displayed in **Table 9**. No statistically significant

differences were demonstrated among the two study groups with regard to these two outcome variables.

An ANCOVA was also performed to compare the mean standardized scores of each of the outcome variables "total number of items processed" and "total number of items scanned minus error scores" of the two study groups (gum chewing and no gum control) after controlling for the covariates age, gender and handedness. The ANCOVA results are displayed in **Table 10**. No statistically significant differences were shown among the two study groups with regard to these two outcome variables.

An ANOVA was performed to compare the mean standardized scores of each of the outcome variables "total number of items processed" and "total number of items scanned minus error scores" of the three study groups (gum containing sugar, sugarless gum, and no gum control). The ANOVA results are displayed in **Table 11**. No statistically significant differences were demonstrated among the three study groups with regard to these two outcome variables.

An ANCOVA was also performed to compare the mean standardized scores of each of the outcome variables "total number of items processed" and "total number of items scanned minus error scores" of the three study groups (gum containing sugar, sugarless gum, and no gum control) after controlling for the covariates age, gender, and handedness. The ANCOVA results are displayed in **Table 12**. No statistically significant differences were shown among the three study groups with regard to these two outcome variables.

DISCUSSION

The results of the present study were unable to put an end to the uncertainty over what effect, if any, the act of chewing gum has on attention and concentration. The mean scores of each of the outcome variables (total number of items processed, total number of items scanned minus error scores, concentration performance, fluctuation rate, errors of omission, errors of commission, total number of errors, and percentage of errors) for the study subjects in the "gum chewing group" were generally better than those of the subjects in the "no gum control group." The highest mean scores were generally from the "gum containing sugar group", followed by the "sugarless gum group", followed by the "no gum control group." All of these results were not statistically significant and therefore could have occurred by chance alone.

Study limitations

There were several limitations to the present study. Since a convenience sample was used, the possibility of selection bias cannot be excluded. There may have been systematic differences between those eligible students who volunteered to be in the study and those students who did not volunteer, with regard to their level of attention and concentration. Also, it is difficult to determine if a representative sample of the student

population at the University of North Texas Health Science Center at Fort Worth was obtained.

There is also the possibility that any differences in the scores of the standardized test among the three study groups already existed at baseline and were not reflective of the study intervention. The use of randomized assignment of study subjects was performed in an attempt to prevent the latter situation. Through randomization, those study subjects with a higher baseline level of attention and concentration had an equal chance to be assigned to each of the three study groups.

The results of this study demonstrated that the effect size of the experimental intervention (chewing gum) was less than the value which it was hypothesized to be in the *a priori* sample size calculation. This caused the present study to be underpowered and a Type II error may have occurred. The effect size was hypothesized to be 0.5, which would represent that the study intervention (chewing gum) would have a moderate effect. The effect size for each of the two outcome variables converted to standardized scores (total number of items processed and total number of items scanned minus error scores) was calculated *post hoc*. The actual effect size for the outcome variable total number of items processed was 0.10 and the *post hoc* power was calculated to be 0.10 ($\beta = 0.90$). The actual effect size for the outcome variable total number of items scanned minus error scores was 0.15 and the *post hoc* power was calculated to be 0.17 ($\beta = 0.83$).

Another limitation of this study was related to the population from which the study sample was obtained. Because the present study recruited only graduate students, who by the fact that they had achieved acceptance into graduate school, had higher levels of

attention and concentration than the general population not in graduate school, a study intervention with a small effect size will not be as noticeable in someone with a higher baseline level of attention and concentration than in a person with a lower baseline level of attention and concentration. This is known as the ceiling effect.

Ways to increase statistical power

If the present study was to be repeated, there a few ways to possibly have greater statistical power, and therefore be more likely to demonstrate that a significant difference exists between two or more groups when in fact a difference does actually exist. First a greater number of study subjects could be enrolled because as sample size increases, so to does statistical power.

The study population sampled could be changed. Instead of just including graduate school students, a wide variety of people from the general population could be recruited. This could help reduce or eliminate the ceiling effect. Also by enrolling a wide range of people, the effects of the covariates included in the present study (age, gender, and handedness) could be better examined.

Another way to improve the power of the study would be to perform baseline testing of the levels of attention and concentration before any study intervention occurs and compare these values to those obtained after the study intervention. This is referred to as a pre-test / post-test design. This would eliminate the limitation of the present study, which was a post-test design, and would be able to document whether any differences

among the different study groups occurred as a result of the study intervention or was already present before the study intervention occurred.

The statistical power could also be improved if there was a greater level of standardization of the test taking techniques. Differences in the location and the environment in which the attention and concentration testing is given could effect the subjects performance. The mental and physical condition of the study subjects, as well as the time since the last meal, and whether or not gum was chewed immediately prior to taking the test for attention and concentration could affect the test performance results.

CONCLUSION

The results of the present study were unable to support the hypothesis that attention and concentration can be improved by the act of chewing gum. Instead of clearing the confusion regarding the effect that the act of chewing gum may or may not have on attention and concentration, the present study just adds to the current controversy. More studies are needed to further clarify this issue.

TABLE 1: INTER-RATER RELIABILITY

Outcome variable	**Pearson Correlation**	***p***
Total number of items processed	1.00	< 0.001
Errors of omission	1.00	< 0.001
Errors of commission	0.99	< 0.001
Total number of errors	1.00	< 0.001
Percentage of errors	1.00	< 0.001
Total number of items scanned minus error scores	1.00	< 0.001
Concentration performance	1.00	< 0.001
Fluctuation rate	0.99	< 0.001

TABLE 2: CHARACTERISTICS OF STUDY SUBJECTS

	STUDY GROUP			
	Gum containing sugar	Sugarless gum	Combined gum types	No gum control group
	(*N* = 61)	(*N* = 64)	(*N* = 125)	(*N* = 66)
AGE *	26.00 ± 4.79	25.58 ± 4.86	25.78 ± 4.81	24.91 ± 3.82
GENDER				
	(*N* = 67)	(*N* = 67)	(*N* = 134)	(*N* = 67)
Male	30 (44.8%)	29 (43.3%)	59 (44.0%)	26 (38.8%)
Female	35 (52.2%)	37 (55.2%)	72 (53.7%)	41 (61.2%)
Missing	2 (3.0%)	1 (1.5%)	3 (2.2%)	0 (0.0%)
HANDEDNESS				
	(*N* = 67)	(*N* = 67)	(*N* = 134)	(*N* = 67)
Right	55 (82.1%)	58 (86.6%)	113 (84.3%)	57 (85.1%)
Left	8 (11.9%)	6 (9.0%)	14 (10.4%)	6 (9.0%)
Both	0 (0.0%)	1 (1.5%)	1 (0.7%)	3 (4.5%)
Missing	4 (6.0%)	2 (3.0%)	6 (4.5%)	1 (1.5%)
SKIPPING SYNDROME				
	(*N* = 67)	(*N* = 67)	(*N* = 134)	(*N* = 67)
Present	3 (4.5%)	1 (1.5%)	4 (3%)	3 (4.5%)
Absent	64 (95.5%)	66 (98.5%)	130 (97%)	64 (95.5%)

* Age expressed as mean age in years ± standard deviation

TABLE 3: OUTCOMES FOR THE TWO GROUP STUDY DESIGN: NORMALLY DISTRIBUTED DATA

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Gum	520.63	74.96	6.48	0.63	0.43
	Control	511.69	76.97	9.40		
Total number of items scanned minus error scores	Gum	500.70	72.01	6.22	1.62	0.21
	Control	486.96	72.82	8.90		
Concentration performance	Gum	204.33	38.07	3.29	2.59	0.11
	Control	195.13	38.51	4.71		
Fluctuation rate	Gum	13.29	5.26	0.45	2.19	0.14
	Control	14.48	5.56	0.68		

* Gum = "combined gum chewing" group; Control = "no gum control" group
$N = 134$ for the "combined gum chewing" group
$N = 67$ for the "no gum control" group

TABLE 4: OUTCOMES FOR THE TWO GROUP STUDY DESIGN: NON – NORMALLY DISTRIBUTED DATA

Outcome Variable	Group *	Mean	S.D.	S.E.	$\chi 2$	p
Errors of omission	Gum	17.81	18.26	1.58	60.94	0.19
	Control	21.51	24.34	2.97		
Errors of commission	Gum	2.12	3.41	0.29	17.17	0.31
	Control	3.27	4.72	0.58		
Total number of errors	Gum	19.93	19.54	1.69	58.05	0.36
	Control	24.76	26.87	3.28		
Percentage of errors	Gum	3.77	3.47	0.30	174.75	0.47
	Control	4.70	4.62	0.56		

* Gum = "combined gum chewing" group; Control = "no gum control" group
$N = 134$ for the "combined gum chewing" group
$N = 67$ for the "no gum control" group

TABLE 5: OUTCOMES FOR THE TWO GROUP STUDY DESIGN CONTROLLING FOR AGE, GENDER, AND HANDEDNESS

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Gum	520.63	74.96	6.48	0.51	0.48
	Control	511.69	76.97	9.40		
Total number of items scanned minus error scores	Gum	500.70	72.01	6.22	1.71	0.19
	Control	486.96	72.82	8.90		
Concentration performance	Gum	204.33	38.07	3.29	2.71	0.10
	Control	195.13	38.51	4.71		
Fluctuation rate	Gum	13.29	5.26	0.45	1.80	0.18
	Control	14.48	5.56	0.68		

* Gum = " combined gum chewing" group; Control = "no gum control" group
$N = 134$ for the "combined gum chewing" group
$N = 67$ for the "no gum control" group

TABLE 6: OUTCOMES FOR THE THREE GROUP STUDY DESIGN: NORMALLY DISTRIBUTED DATA

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Sugar	524.55	80.76	9.87	0.49	0.61
	Sugarless	516.72	69.06	8.44		
	Control	511.69	76.97	9.40		
Total number of items scanned minus error scores	Sugar	504.82	80.55	9.84	1.02	0.36
	Sugarless	496.58	62.67	7.66		
	Control	486.96	72.82	8.90		
Concentration performance	Sugar	206.45	43.81	5.35	1.49	0.23
	Sugarless	202.21	31.51	3.85		
	Control	195.13	38.51	4.71		
Fluctuation rate	Sugar	13.07	5.75	0.70	1.20	0.30
	Sugarless	13.51	4.74	0.58		
	Control	14.48	5.56	0.68		

* Sugar = "gum containing sugar" group; Sugarless = "sugarless gum" group; Control = "no gum control" group
$N = 67$ in each of the three groups

TABLE 7: OUTCOMES FOR THE THREE GROUP STUDY DESIGN: NON – NORMALLY DISTRIBUTED DATA

Outcome Variable	Group *	Mean	S.D.	S.E.	$\chi 2$	p
Errors of omission	Sugar	17.43	19.01	2.33	100.90	0.57
	Sugarless	18.18	17.62	2.15		
	Control	21.51	24.34	2.97		
Errors of commission	Sugar	2.28	3.95	0.48	24.00	0.77
	Sugarless	1.96	2.78	0.34		
	Control	3.27	4.72	0.58		
Total number of errors	Sugar	19.72	20.57	2.51	98.54	0.78
	Sugarless	20.13	18.61	2.27		
	Control	24.76	26.87	3.28		
Percentage of errors	Sugar	3.77	3.87	0.47	350.00	0.46
	Sugarless	3.76	3.04	0.37		
	Control	4.70	4.62	0.56		

* Sugar = "gum containing sugar" group; Sugarless = "sugarless gum" group; Control = "no gum control" group
$N = 67$ in each of the three groups

TABLE 8: OUTCOMES FOR THE THREE GROUP STUDY DESIGN CONTROLLING FOR AGE, GENDER, AND HANDEDNESS

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Sugar	524.55	80.76	9.87	0.69	0.50
	Sugarless	516.72	69.06	8.44		
	Control	511.69	76.97	9.40		
Total number of items scanned minus error scores	Sugar	504.82	80.55	9.84	1.48	0.23
	Sugarless	496.58	62.67	7.66		
	Control	486.96	72.82	8.90		
Concentration performance	Sugar	206.45	43.81	5.35	2.01	0.14
	Sugarless	202.21	31.51	3.85		
	Control	195.13	38.51	4.71		
Fluctuation rate	Sugar	13.07	5.75	0.70	1.04	0.35
	Sugarless	13.51	4.74	0.58		
	Control	14.48	5.56	0.68		

* Sugar = "gum containing sugar" group; Sugarless = "sugarless gum" group; Control = "no gum control" group
N = 67 in each of the three groups

TABLE 9: OUTCOMES FOR THE TWO GROUP DESIGN USING STANDARDIZED SCORES

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Gum	118.31	9.43	0.82	0.49	0.49
	Control	117.30	10.04	1.23		
Total number of items scanned minus error scores	Gum	119.34	9.11	0.79	1.18	0.28
	Control	117.82	9.86	1.20		

* Gum = "combined gum chewing" group; Control = "no gum control" group
N = 134 for the "combined gum chewing" group
N = 67 for the "no gum control" group

TABLE 10: OUTCOMES FOR THE TWO GROUP STUDY DESIGN CONTROLLING FOR AGE, GENDER, AND HANDEDNESS USING THE STANDARDIZED SCORES

Outcome Variable	Group	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Gum	118.31	9.43	0.82	0.46	0.50
	Control	117.30	10.04	1.23		
Total number of items scanned minus error scores	Gum	119.34	9.11	0.79	1.40	0.24
	Control	117.82	9.86	1.20		

* Gum = "combined gum chewing" group; Control = "no gum control" group
N = 134 for the "combined gum chewing" group
N = 67 for the "no gum control" group

TABLE 11: OUTCOMES FOR THE THREE GROUP STUDY DESIGN USING STANDARDIZED SCORES

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Sugar	118.72	10.20	1.25	0.36	0.70
	Sugarless	117.90	8.65	1.06		
	Control	117.30	10.04	1.23		
Total number of items scanned minus error scores	Sugar	119.55	10.08	1.23	0.62	0.54
	Sugarless	119.13	8.09	0.99		
	Control	117.82	9.86	1.20		

* Sugar = "gum containing sugar" group; Sugarless = "sugarless gum" group; Control = "no gum control" group
N = 67 in each of the three groups

TABLE12: OUTCOMES FOR THE THREE GROUP STUDY DESIGN CONTROLLING FOR AGE, GENDER, AND HANDEDNESS USING STANDARDIZED SCORES

Outcome Variable	Group *	Mean	S.D.	S.E.	*F*	*p*
Total number of items processed	Sugar	118.72	10.20	1.25	0.55	0.58
	Sugarless	117.90	8.65	1.06		
	Control	117.30	10.04	1.23		
Total number of items scanned minus error scores	Sugar	119.55	10.08	1.23	0.93	0.40
	Sugarless	119.13	8.09	0.99		
	Control	117.82	9.86	1.20		

* Sugar = "gum containing sugar" group; Sugarless = "sugarless gum" group; Control = "no gum control" group
$N = 67$ in each of the three groups

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