The Effect of Chewing Gum on Physiological and Self-Rated Measures of Alertness and Daytime Sleepiness

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Abstract

The proposition that chewing gum can improve alertness was investigated via both physiological and self-rated measures. The Pupillographic Sleepiness Test (PST) provided a measure of pupillary unrest (PUI); a physiological index of daytime sleepiness. Chewing gum reduced the extent of sleepiness as measured by both PUI and self-rated sleepiness. Specifically, in comparison with sham chewing and no chewing controls, the chewing gum condition significantly limited the increase in pupillary unrest following the 11-minute PST within a darkened laboratory: a finding indicating moderation of the daytime sleepiness increase for the chewing gum condition. In addition, there was some evidence that chewing gum (relative to the no-chewing condition only) moderated the increase in a self-rated measure of sleepiness (Stanford Sleepiness Scale). However, there was no evidence that chewing gum moderated the decrease in self-rated alertness (Bond-Lader Visual Analogue Mood Scale). Although the precise mechanism underpinning the effect of chewing gum is unclear, the reduction in daytime sleepiness may be underpinned via heightened cerebral activity following the chewing of gum or the arousing effects of mint flavour.

Keywords: chewing gum; alertness; pupillography; sleepiness

1. Introduction

That chewing gum can act to both maintain and increase self-rated levels of alertness is now well established. For example, Scholey et al. [1] and Johnson et al. [2] reported increased levels of self-rated alertness following a cognitive-load multi-tasking stressor for those participants who chewed gum. Furthermore, following a social stressor (the Trier Social Stress Task, TSST, [3]), Sketchley-Kaye et al. [4] reported higher self-rated alertness for those participants who chewed gum. These effects are also found following completion of both memory and intelligence tasks [5]. There is additional evidence that these self-rated reports of alertness accentuation are mirrored physiologically. For instance, Smith [6] showed that, following administration of a noise-based stressor (75dB of office noise), participants who chewed gum revealed elevated levels of cortisol excretion: a finding interpreted as evidence of heightened alertness.

Scholey et al. [1] propose two mechanisms by which chewing gum may influence self-rated mood and alertness. The first proposal is that chewing gum increases both cerebral activity [7,8] and cerebral blood flow [9]. This increased cerebral activity coupled with enhanced delivery of both oxygen and glucose to neural regions [10] (see also [11]) may underpin elevated self-rated alertness. The second proposal is that chewing gum flavour is an important variable. For example, mint flavour has been associated with increased alertness. Norrish and Dwyer [12] employed the Pupillograpy Sleepiness Test (PST) and demonstrated that exposure to a peppermint odour can attenuate pupillary unrest (an inverse correlate of self-rated alertness [13]). Additionally, participants were able to detect more critical signals during a vigilance task when presented with peppermint, compared to the presentation of unscented air [14].

Notwithstanding, the precise conditions under which chewing gum elevates alertness is unknown. It is unclear to what extent the gum effects are predicated on participants being in a state of alertness degradation. In both Scholey et al. [1] and Smith [5], participants reported a decline in self-rated alertness following the tasks. However, this decline in alertness was reversed when participants were chewing gum. In contrast, the stress tasks used by Smith [6], Johnson et al. [2], and Sketchley-Kaye et

al. [4] did not affect alertness, yet chewing gum acted to elevate self-reported alertness.

The present study is designed to test directly the proposition that chewing gum has an effect on alertness when a participant is in a state of degraded alertness. We examine the effect of exposure to prolonged (11-minute) darkened conditions across three conditions: chewing gum, not chewing gum, and mimicking the motion of chewing (sham chewing). The latter condition is included to assess the extent to which the motion of chewing per se is sufficient to increase alertness and decrease daytime sleepiness. Sakamoto et al. [15] found that increased cerebral activity was found with chewing gum but not with the mimicry of gum chewing, indicating that the both texture and resistance of the gum may affect neural activity. The sham condition is an inexact control for gum chewing due to the potential differences in cognitive and motor demands. However, this condition does provide a rudimentary assessment with regard to the extent to which any effects are driven by mouth and jaw movements.

Physiological daytime sleepiness is measured using the PST. The PST measures fluctuations in the size of the pupil's diameter (pupillary oscillations), with darkness-induced changes in pupillary oscillations correlating significantly with self-rated alertness [13]. The pupillary oscillations in darkened conditions are determined by the inter-relation of sympathetic nervous activity matched with central parasympathetic inhibition (see [12,13,16] for reviews). Reductions in alertness are associated with decreases in both sympathetic nervous activity and central parasympathetic inhibition of the Edinger-Westphal nuclei; such reductions inhibit dilator and sphincter muscle control of the pupil diameter resulting in greater fluctuations of pupil size ([13]). This task provides both baseline and test pupillary unrest index (PUI) scores.

Self-rated measures of alertness are examined via the Bond Lader Visual Analogue Mood Scale (VAMS [17]) and the Stanford Sleepiness Scale (SSS [18]). Both scales are employed because chewing gum has been shown to reduce night-time sleepiness as indexed via the SSS [19] but not impact night-time alertness as indexed via the VAMS [20]. Self-rated measures are assessed both pre- and post-PST.

Previous studies ([12]) suggest that the 11-minute PST will result in a significant increase in daytime sleepiness as indexed via an increase in PUI. If chewing gum has

an effect on physiological daytime sleepiness, then chewing gum should limit the increase in PUI relative to both the sham chewing and no chewing controls. This should manifest statistically in an interaction between the time and gum conditions, such that baselines PUI measures will be similar for the chewing gum, sham chewing, and control conditions but PUI measures will be significantly lower PUI for the gum chewing condition following the test phase. Additionally, if chewing gum mediates the decline in self-rated alertness following the 11-minute PST, then analogous effects to the PST should be apparent. Specifically, pre-PST scores should be equivalent across the three conditions; in contrast, following the PST, self-rated alertness should be significantly higher in the chewing gum condition relative to both the no chewing and sham control conditions. The opposite trend should be apparent for the SSS; such that participants should report reduced sleepiness following the PST with gum compared to both the sham and no gum controls.

2. Material and Methods

2.1 Design

A 3x2 within-participants design was employed where the first factor represents experimental condition (chewing gum, sham chewing, and no chewing control) and the second factor represents the experimental stage (baseline or post PST). The order of experimental condition presentation was counterbalanced across participants (i.e. the six combinations of the three experimental conditions were employed and 5 participants were assigned at random to each). The dependent measures were self-rated sleepiness (as measured via the Stanford Sleepiness Scale), self-rated mood (as measured via the Bond-Lader Visual Analogue Mood Scale, which is partitioned into three separate measures for contentedness, calmness, and alertness), and pupillary unrest index (PUI: measured by the PST). PUI baseline and test-PUI comprise the first (0-82.5s) epoch and an average of the fourth to the last (247.5s – 660s) epoch, respectively.

2.2 Participants

Sample size calculations are complicated when multiple dependent variables are employed and these variables are examined at differing periods within the task (e.g.

PUI during the PST, mood and sleepiness before and after the PST). A simple assessment in respect to whether an effect of PST should be reported on PUI, revealed that a sample size of 27 would be sufficient at 0.8 power to significantly (one-tailed) report a medium effect size (d=0.5). Consequently, thirty (9 male, 21 female, mean age = 21 years 7 months) Coventry University Psychology undergraduates were selected as this enables perfect counterbalancing of experimental conditions. Volunteers participated in exchange for course credit. All participants were non-smokers who were requested to refrain from consuming caffeinated products on the days of testing. Participants were tested on three consecutive days and between 14:00 and 17:00 hours.

2.3 Physiological Measures

Pupillary oscillations were measured via a bench-mounted monocular (right-eye assessed) infrared video Pupillographic Sleepiness Test (PST: AmTech, Weinheim, Germany) that employed the software winPST version 2.0.3.720. The 11-minute PST provides the pupillary unrest index (PUI): a measure of pupillary fluctuation that comprises the distance travelled by the margin of the pupil over a 1-minute period.

A chin rest was used in order to position the participant's head in a stationary position whilst they viewed a static fixation point. Infrared goggles were used to block out any residual light whilst permitting perception of the fixation light. The goggles prevented light influences that might mirror sleepiness oscillations (for rationale for pupillography under darkened conditions see [21]).

The PST provided a pupillary unrest index (PUI) for each eighth of the 11-minute test (i.e. 82.5 s. epochs). The first eighth provided a baseline measure of PUI for each condition. PUI for eighths 4-8 (i.e. 247.5 s – 660 s) was measured to compute the mean test PUI score (see [12] for precedent where baseline was the first minute and test PUI was minutes 4-11). Peak PUI is both achieved and maintained from approximately minute 4 of the pupillography test [12,22].

2.4 Self-rated Measures

The Bond Lader Visual Analogue Mood Scale (VAMS) [17] comprises 16 mood questions, with mood antonyms anchoring at either end of a 100mm line. These 16 questions are factored into three distinct scores for alertness, contentedness, and calmness.

The Stanford Sleepiness Scale (SSS) has been used previously in conjunction with PUI measurements ([12]) and comprises a single item questionnaire. Participants select one of 7 options to identify their current level of sleepiness [18].

In the chewing gum condition participants received a single pellet of sugar free spearmint flavoured Wrigley's Extra chewing gum.

2.5 Procedure

Participants were tested individually in a well-ventilated, darkened laboratory (see, [21]) on each of three consecutive days. Testing occurred between 14:00 and 17:00 hours, with the requirement that participants were tested at the same time of day for each of the three testing sessions. Prior to the PST, participants completed both the Bond-Lader VAMS and Stanford Sleepiness Scale, the presentation order of which was counterbalanced. For the PST task, participants were required to sit with their head supported by a chinrest. Participants wore infrared goggles and were required to stare at an infrared light at a distance of approximately 0.65m. In the chewing gum condition participants were instructed to chew the gum throughout the 11-minute session. In the sham chewing condition, participants were instructed to mimic the motion of chewing gum throughout the 11-minute session. In the no chewing control condition participants were instructed not to chew throughout the 11-minute session. In addition, participants were instructed to stare at the infrared light for the 11-minute testing session whilst both remaining in the same position throughout and avoiding the closure of their eyes for extended periods.

Following the 11-minute PST participants were instructed to remove their gum or desist from sham chewing. Participants were then instructed to complete the Bond-Lader Visual Analogue Mood Scale (VAMS) and Stanford Sleepiness Scale (SSS)

with respect to how they were currently feeling. This procedure was repeated on testing days 2 and 3.

3. Results

3.1 Physiological Measures of Alertness

Figure 1 shows the change in PUI over the eight testing epochs as a function of the chewing gum, sham chewing, and control conditions. PUI increased as a function of time for each of the three experimental conditions. However, the increase is less marked for the chewing gum condition.

Insert Figure 1 about here please

Figure 2 demonstrates baseline and test PUI scores for the chewing gum, sham chewing and no chewing control conditions. The first epoch (0-82.5s) of the PST represents the baseline measure of alertness indexed via PUI. The mean of epochs 4-8 (247.5s-660s) was used as a measure of test daytime sleepiness for each condition indexed via PUI.

Insert Figure 2 about here please

The data demonstrated in Figure 2 was analysed via a three-way (2x3x6) mixed-design ANOVA where the first within-participants factor represents experimental stage (baseline and test PUI scores) and the second within-participants factor represents experimental condition (chewing gum, sham chewing, and no chewing control). The between-participants factor concerned the six different orders in which the gum conditions were presented. The ANOVA revealed no main effect of order (p=0.69), nor did order interact with the gum condition (p=0.77). A main effect of

experimental stage was found, $F(1,24)=34.63$, $MSe=3.18$, $p<0.001$, *partial* $\lambda^2 = 0.591$, demonstrating that PUI score was higher in the test phase (mean baseline PUI = 3.97, mean test PUI = 5.53). A main effect of experimental condition was found, $F(2,48)=4.11$, $MSe=2.78$, $p=0.023$, *partial* $\lambda^2 = 0.15$ (mean PUI score for the chewing gum condition = 4.26, mean PUI for the sham chewing condition = 5.08, mean PUI for the no chewing condition = 4.92). Post-hoc Bonferroni t-test comparisons (p=0.017) revealed that, as predicted, PUI scores for the chewing gum condition were significantly lower than the sham chewing condition ($t(29)=2.70$, $p=0.012$) and borderline significantly lower than the no chewing condition ($t(29)=2.44$, $p=0.021$). The difference between the sham and no chewing control conditions was non-significant ($t<1$). Importantly, the predicted interaction between experimental stage and gum condition was significant, $F(2,48)=4.40$, $MSe=1.55$, $p=0.018$, *partial* $\lambda^2 = 0.16$. Further planned comparisons revealed no significant differences between the three gum conditions at baseline, i.e. chewing gum and sham chewing ($t=1.25$), chewing gum and no gum ($t<1$), and sham chewing and no gum ($t=1.31$). In contrast, for the test measures, PUI score with chewing gum was significant lower than both the no gum ($t(29)=3.36$, $p=0.002$) and sham conditions ($t(29)=2.81$, $p=0.01$). There was no significant difference between the sham chewing and no gum condition (t<1).

3.2 Self-Rated Measures

Figure 3(a-d) demonstrates the pre- and post-PST scores for the self-rated measures of sleepiness, alertness, contentedness, and calmness.

Insert Figure 3(a-d) about here please

Each self-rated dependent variable (self-rated sleepiness, alertness, calmness, and contentedness) was analysed via a three-way (2x3x6) mixed-design ANOVA where the first within-participants factor represents experimental stage (pre- and post 11-minute PST) and the second within-participants factor represents experimental condition (chewing gum, sham chewing, and no chewing control). The between-

participants factor concerned the six different orders in which the gum conditions were presented. The main effect of order and interaction between order and gum condition was non-significant across the self-rated measures. The remaining results of these analyses are presented in Table 1.

Insert Table 1 about here please

The analysis demonstrated that the PST significantly increased self-rated sleepiness and calmness whilst significantly decreasing alertness and contentedness. There were no significant interactions between the chewing gum condition and experimental stage, suggesting that chewing gum did not moderate these PST-induced changes. However, closer inspection of Figure 3a suggests that the increase in self-rated sleepiness following the PST was reduced in the chewing gum condition. This proposition was examined via a series of preliminary investigative comparisons. Planned t-test comparisons revealed no significant differences at baseline between the chewing gum and sham chewing conditions (mean self-rated sleepiness = 1.90 and 2.27, respectively: $t(29)=1.55$, $p=0.13$), the chewing gum and no chewing conditions (mean self-rated sleepiness = 1.90 and 2.10, respectively: $t=1.00$), and the sham chewing and no gum conditions (mean self-rated sleepiness = 2.27 and 2.10, respectively: $t<1$). However, t-test comparisons revealed that post-test self-rated sleepiness was significantly lower for the chewing gum condition compared to the no gum condition (mean self-rated sleepiness = 2.60 and 3.23, respectively: $t(29)=2.73$, $p=0.01$). The differences between the chewing gum and sham conditions approached significance (mean self-rated sleepiness = 2.60 and 3.10, respectively: $t(29)=1.91$, $p=0.07$). There was no significant difference between the sham chewing and no gum conditions (mean self-rated sleepiness = 3.10 and 3.23, respectively: $t<1$). These comparisons provide preliminary evidence (as the interaction was non-significant) that chewing gum moderated the increase in self-rated sleepiness.

4. Discussion

The present study was designed specifically to examine the effect of chewing gum on both self-rated mood and physiological measures of daytime sleepiness following a passive 11-minute pupillography sleepiness test. Self-rated measures indicated that the task was successful in reducing participant alertness such that both self-rated alertness and sleepiness scores were lower post-task completion. This was mirrored by the physiological data such that pupillary unrest increased across the 11-minute period.

Chewing gum attenuated the darkness induced rise in PUI, suggesting that chewing gum can help reduce daytime sleepiness during a vigilance-type task. The facilitation following task induced degradation is consistent with Tucha and Simpson [23] who found gum benefitted attention but only following prolonged task exposure. The self-rated measures, however, produced mixed findings. Consistent with the physiological data, there was some preliminary evidence (via planned comparisons) that chewing gum limited the increase in self-rated sleepiness following the PST relative to the no gum condition only. In contrast, there was no evidence that chewing gum moderated the decline in self-rated alertness. In addition, there were no effects of gum condition on contentedness or calmness.

The effect of chewing gum on daytime sleepiness measures (both physiological and self-rated) reflects increments in self-rated alertness data found in other studies [1,2,4,5,6,19]. Furthermore, it is noteworthy that the effect on PUI was specific to the chewing gum condition, with no benefit found for sham chewing. This is consistent with previous data indicating that the motion of chewing per se is insufficient to induce either cognitive or neurological benefits [15, 24].

Notwithstanding the congruity with other studies who reported differential effects of chewing gum and sham chewing [15,24], the present study is, however, clearly limited by the motor differences between these conditions. Although the experimenter observed participants during the PST to ensure compliance with task demands, jaw and tongue movements may be qualitatively different for the two processes (indeed, as aforementioned, different neurological effects are observed [15]). Furthermore, one might speculate that different cognitive processes underpin chewing of material and

the mimicry of chewing. Consequently, these motor and cognitive differences may explain the differences between the PUI for sham and gum chewing conditions. Nevertheless, the clear value for inclusion of a sham chewing condition is threefold. First, beyond the pupillographic literature, sham chewing has precedent as a chewing gum control [15,24,25]. Second, although an imperfect control, it is unclear how an alternative superior treatment check might be achieved. Third, the PST data in the present study support other performance and neuro-imaging data in which chewing gum produced effects independent of sham chewing [15,24]. This further indicates that there is something unique about the act of chewing gum compared to the act of chewing motion per se.

It is plausible that our finding for PUI, that is, a decrease in daytime sleepiness, is related to the increases in both cerebral blood flow [9] and cerebral activity [7] linked to chewing gum. Alternatively, the mint flavour present in the chewing gum condition may have resulted in the reduced increase in PUI relative to the control conditions. Indeed, a previous study employing the PST [12] reported that exposure to peppermint oil odour during the pupillography test significantly moderated the increase in PUI relative to the no odour control (for other effects of mint see [14, 26-28]).

It is important to note that for the present study the self-rated data were less compelling than the physiological effects. There was some evidence that chewing gum moderated the increase in self-rated sleepiness relative to the no gum condition. However, the difference between the chewing gum and sham chewing conditions did not reach significance (p=0.07, indeed this borderline effect may be resultant from an underpowered design). This dissociation between the physiological pupillography measure and self-rated measures has precedence [12]; indeed, they [12] argue such incongruence is not uncommon. It is not entirely clear why such disparities are found; however, we propose three speculative explanations that require further investigation. First, this dissociation may relate to the physiological mechanisms underpinning PUI. It has been argued that pupillary fatigue oscillations are a result of decreases in sympathetic nervous system (SNS) activation of the Edinger Westphal nuclei and decreases in the parasympathetic nervous system (PSNS) inhibition of the Edinger Westphal nuclei [13]. Since both systems are part of the peripheral nervous system

(PNS), it is possible that gum chewing is only affecting PNS changes in arousal and not the central nervous system (CNS). Consequently, changes may be occurring at a subconscious level only. The second explanation is related to the first, in that, the length of task/chewing (11-minutes) may be insufficiently long to invoke changes in self-rated alertness (and, speculatively, induce changes in the CNS). Indeed, it should be noted that effects of gum on self-rated alertness have been reported following prolonged (20-90 minutes) chewing [1,2,4,6] but was not reported in our laboratory when chewing length was only 10-minutes in duration [29]. Alternatively, the longer tasks may have induced greater cognitive decrement/fatigue amongst participants; as a consequence of amplified decline, there was greater capacity for gum to benefit participants (see also [23]). The third explanation for the dissociation between physiological and subjective gum effects, relates to self-rated measures being taken in lightened conditions (compared to darkened conditions for the PST). This shift into light may qualitatively alter the state of the participants.

5. Conclusions

The present study contributes to the growing body of data reflecting facilitative effects of chewing gum on alertness [1,2,4,5,6]. We have shown that chewing gum limits the increase in daytime sleepiness (indexed via PUI and, to a lesser extent, self-rated sleepiness) following an 11-minutes period within a darkened laboratory; such a finding has clear practical applications. However, three further questions arise from this growing corpus of data: (1) since the effects of chewing gum on alertness are found intermittently [29], what are the precise conditions under which such benefits are reported, (2) are the effects driven by the act of chewing, the effects of flavour, or a combination of these factors, and (3) if such effects can be isolated, to what extent is the intervention of long-term benefit, i.e. what is the duration of such benefits and do individuals habituate to such facilitation following chronic exposure?

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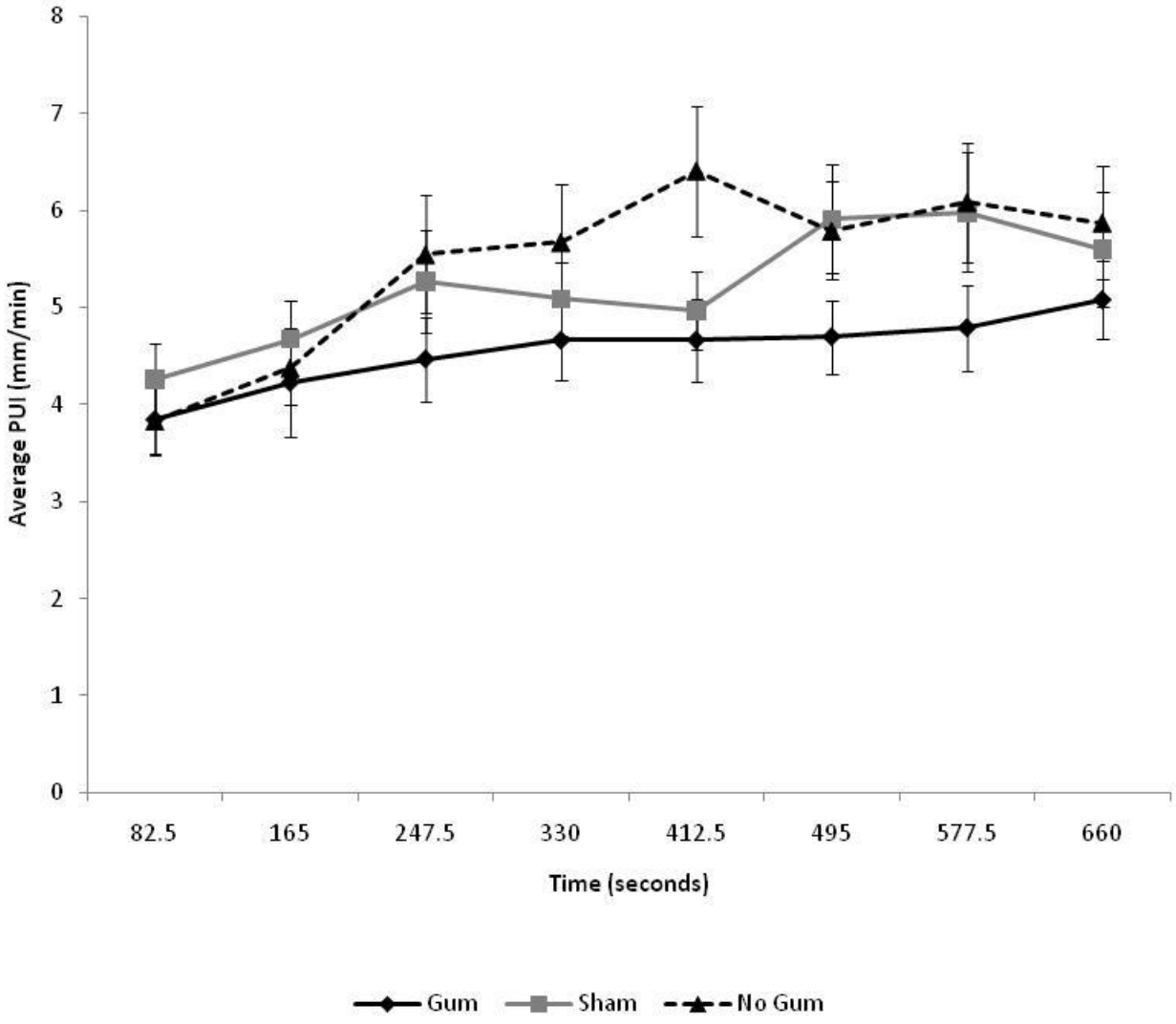

Figure 1: Mean PUI for each 82.5s epochs of the PST for the chewing gum, sham chewing and control conditions. Error bars denote the mean standard error.

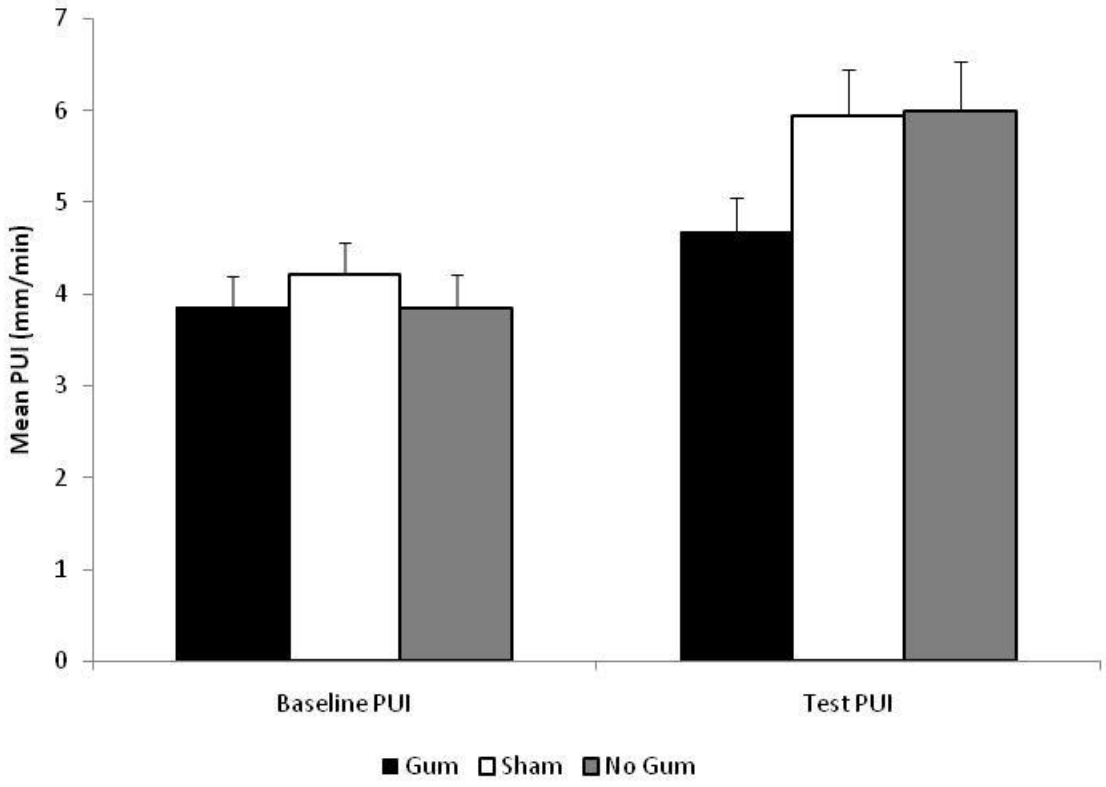

Figure 2: Mean baseline and test PUI for the chewing gum, sham chewing, and no chewing control conditions. Error bars denote the mean standard error.

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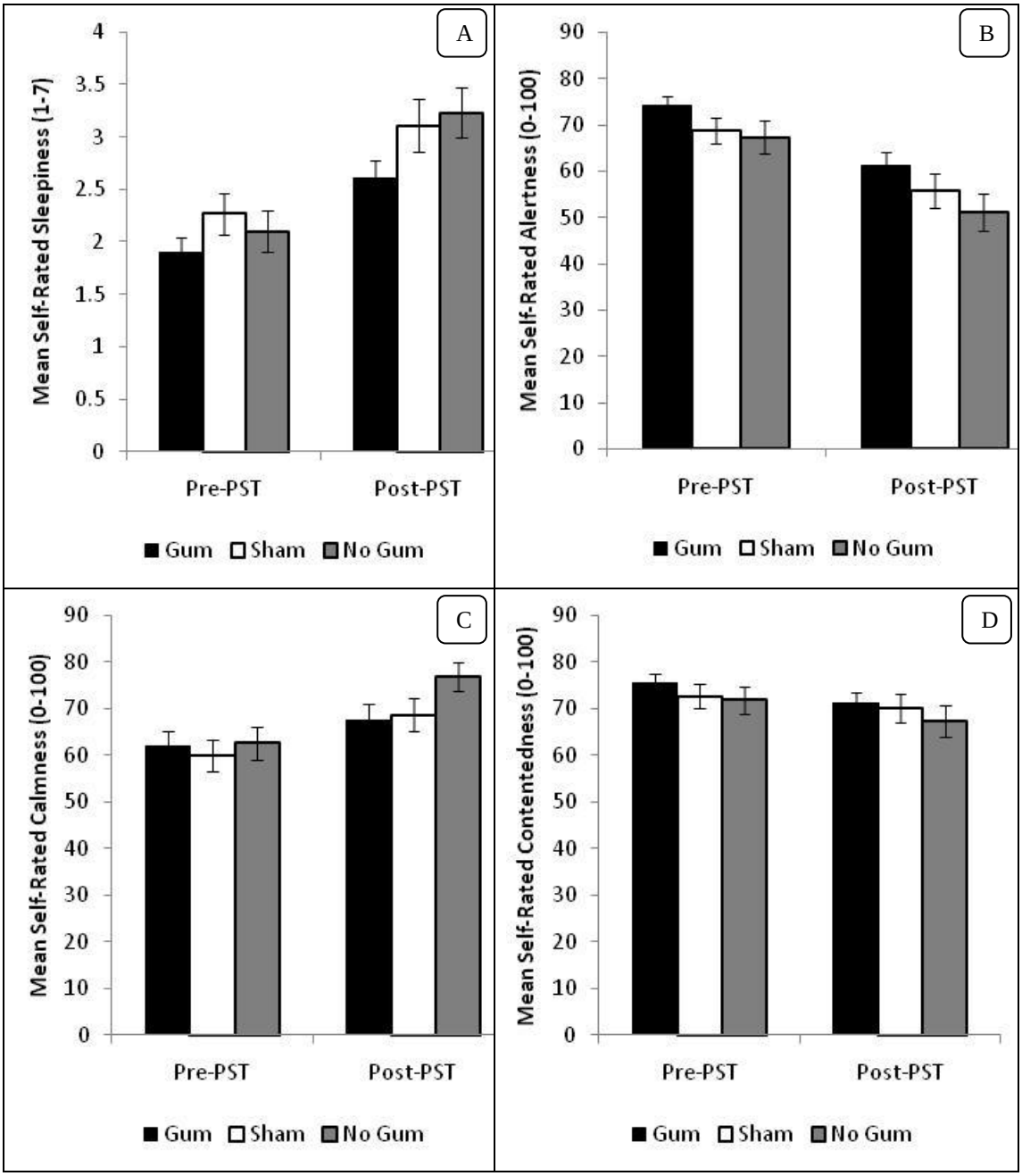

Figure 3(a-d): Mean pre and post PST self-rated scores for the chewing gum, sham chewing, and no chewing control conditions. The four variables measured are (a) self-rated sleepiness, (b) self-rated alertness, (c) self-rated calmness, and (d) self-rated alertness. Error bars denote the mean standard error.