

Chewing gum moderates the vigilance decrement

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Abstract

We examine the impact of chewing gum on a Bakan-type vigilance task that requires the continual updating of short-term order memory. Forty participants completed a 30-minute auditory Bakan-task either with, or without, the requirement to chew gum. Self-rated measures of mood were taken both pre- and post-task. As expected, the vigilance task produced a time dependent performance decrement indexed via decreases in target detections and lengthened correct reaction times (RTs) and a reduction in post-task self-rated alertness scores. The declines in both performance and subjective alertness were attenuated in the chewing chewing-gum group. In particular, correct RTs were significantly shorter following the chewing of gum in the latter stages of the task. Additionally, the gradients of decline for target detection and incline for correct RTs were both attenuated for the chewing-gum group. These findings are consistent with the data of Tucha and Simpson (2011), who showed beneficial effects of chewing gum in the latter stages of a 30 min. visual attention task, and extend their data to a task that necessitates the continuous updating of order memory. It is noteworthy that our data contradict the claim (Kozlov, Hughes, & Jones', 2012) that chewing gum negatively impacts short-term memory task performance.

Introduction

Vigilance can be regarded as a state of alertness such that the participant is able to both detect and respond to, pre-determined, small, and randomly occurring changes (or targets) in the external environment. A participant's level of vigilance may be indexed via their ability to detect these targets, and the extent to which that ability alters with task duration (e.g., Mackworth, 1957; Bakan, 1959). To the extent that the vigilance decrement reflects a general decrease in the participant's level of alertness, it follows that if alertness is maintained then the normally observed decrement should be attenuated. It is now well established that chewing gum can act to both maintain (e.g. Johnson, Muneem, & Miles, in press; Scholey, Haskell, Robeson, Kennedy, Milne, & Wetherell, 2009; Smith, 2009a,b) and increase (e.g. Johnson, Jenks, Miles, Albert, & Cox, 2011; Sketchley-Kaye, Jenks, Miles, & Johnson, 2011; Smith, 2010), self-rated levels of alertness. Such changes in alertness levels have been associated with both increased cerebral blood flow (e.g. Sesay, Tanaka, Ueno, Lecaroz., & De Beaufort, 2000) and increased cerebral activity (Fang et al., 2008).

To the extent that chewing-gum benefits self-rated alertness, the present study builds upon earlier work (Tucha & Simpson, 2011) showing beneficial effects of chewing-gum in the latter stages of a 30 min. visual attention task. The Tucha and Simpson (2011) task comprised the presentation of a vertical structure comprising two squares. The squares were rapidly and alternately filled with a pattern. Targets were defined as no change of pattern location on two successive presentations and appeared approximately once every minute. Upon perception of a target, participants were instructed to respond, via a button press, as quickly and accurately as possible. Compared to the no-gum condition, chewing-gum was associated with, initially, lengthened correct RTs, and markedly shortened correct RTs across the final 10 mins. of the task. That is, the vigilance decrement, as reflected by lengthened correct RTs was attenuated by the chewing of gum, especially for the latter stages of the task (see also, Allen & Smith, 2012). These findings clearly illustrate the benefit of chewing-gum on sustained attention or vigilance (particularly as time-on-task increases) and we might, with caution, infer that the benefit is mediated via the effect of chewing-gum on alertness.

The present study is designed to extend Tucha and Simpson's (2011) work by examining the effects of chewing-gum on a 30 min. auditory Bakan-type (Bakan, 1961; Jones, Smith, & Broadbent, 1979; Miles, Auburn, & Jones, 1984) vigilance task. The Bakan task comprises the continuous and random presentation of the digits 1-9, and participants are required to detect target sequences comprising odd-even-odd digits, e.g., 5-2-9. The unique feature of this task is that, unlike the Tucha and Simpson (2011) task, which required a

relatively passive vigil on the part of the participant, the Bakan task requires active cognitive engagement on the part of the participant. Detection of target sequences demands deployment of working memory (e.g., Baddeley, & Hitch, 1974) by virtue of the fact that such detection requires the participant to both maintain the order of, and continuously update, a minimum sequence of 3 digits e.g., 5-1-2, 1-2-8, 2-8-3 etc. and, additionally, to categorise each digit as either 'even' or 'odd'. The requirement to continuously update the content of short-term memory, whilst simultaneously maintaining the order of the individual digits comprising that content, is important to the extent that chewing-gum can negatively influence the immediate ordered recall for letter sequences. This negative influence is evidenced by Kozlov, Hughes, and Jones (2012) who, for the first time, demonstrated impaired immediate serial recall for 7-letter sequences, presented either visually (Experiment 1) or auditorially (Experiment 2), whilst chewing-gum throughout both the encoding and recall phases of the task. Indeed, Kozlov et al.'s (2012) data contradict earlier studies reporting a benefit to numeric working memory whilst chewing-gum (Wilkinson, Scholey, & Wesnes, 2002; Stephens, & Tunney, 2004).

The findings of Tucha and Simpson (2011) and those of Kozlov et al. (2012) thus lead to opposing predictions for the current study. On the basis of Tucha and Simpson's (2011) data, we predict that chewing-gum will attenuate the vigilance decrement, as assessed by both number of target detections and their associated correct RTs. Specifically, the decline in target detection and the lengthening of correct RTs, both associated with the time-dependent vigilance decrement, should be attenuated in the chewing-gum group. In contrast, on the basis of Kozlov et al.'s (2012) findings, we predict that chewing-gum will reduce the number of target detections, and, as a corollary, lengthen correct RTs, independently of time-on-task. The current study builds further upon the work of Tucha and Simpson (2011) via the assessment of changes between pre- and post-task self-rated alertness scores. Such assessment permits analysis of the extent to which changes in self-rated alertness scores are associated with time-dependent changes in task performance. There is now abundant published data showing that chewing-gum can act to increase subjective measures of alertness, both in the absence of a task-induced decline (see, Smith, 2010; Johnson et al., 2011; Sketchley-Kaye et al. 2011), and in the presence of a task-induced decline (see, Smith, 2009; Scholey et al., 2009; Johnson et al., in press). Thus, we predict a benefit to post-task alertness for the chewing-gum group.

The extent to which time dependent changes in the rate of target detection and correct RTs might be associated with changes in subjective alertness are less certain. For example,

Johnson, Miles, Haddrell, Harrison, Osborne, Wilson, & Jenks (2012) showed that, although chewing-gum attenuated the rise in the Pupillary Unrest Index (a physiological measure of daytime sleepiness), this finding was not reflected in self-rated measures of alertness. In contrast, Johnson et al. (in press) found that the effects of chewing-gum on sustained attention were positively associated with self-rated alertness. With respect to possible effects of chewing-gum on calmness and contentedness, a recent sustained attention task (Johnson et al., in press) showed beneficial effects of chewing-gum on both contentedness and calmness. However, past studies examining daytime sleepiness (Johnson et al., 2012) and stress (e.g. Scholey et al., 2009; Johnson et al., 2011; Sketchley-Kaye et al., 2011), failed to report mediating effects of chewing-gum on either contentedness or calmness.

Method

Participants

Forty (38 female, 2 male; mean age 19 yrs. 8 months; age range 18 yrs. 3 months-22 years 6 months) Cardiff University volunteer Psychology undergraduates participated in exchange for course credit. Participants were assigned at random and in equal numbers to one of two groups; no-gum (control) and chewing-gum. Participants were tested between the hours of 9am and 5pm, depending upon their availability. No information regarding food consumption prior to the experimental session was collected. The study obtained ethical approval from Cardiff University School of Psychology Ethics Committee.

Design

A 2-factor (2x6) mixed design was adopted with experimental group (no-gum versus gum) as the between-participants factor and task epoch (six 300 s epochs) as the within-participants factor. There were two dependent measures for the Bakan task: number of targets detected and correct RTs (ms). For the subjective mood measures, a 2-factor (2x2) mixed design was adopted with experimental group (no-gum versus gum) as the between-participants factor and task stage (pre- versus post-) as the within-participants factor. There were three dependent measures for the subjective mood measures: alertness, contentedness, and calmness.

Apparatus

The Bakan Vigilance Task: A 30 min. modified version of the Bakan task (Bakan, 1959) was employed. The digits 1-9 were presented by a digitised male voice at a rate of 1 per s., each with a sound envelope of 500 ms. and an inter-stimulus-interval of 500 ms. The digits

were presented randomly and continuously over headphones at a comfortable listening level. Targets were defined as odd-even-odd digit sequences (e.g. 7-2-1) and were presented at a rate of 1 per min. Targets were presented at random within the mid-20 sec. period of each task min., thus a minimum period of 40 s. elapsed between successive target presentations. Participants responded to targets by depressing the space bar on a laptop (Toshiba Satellite P770) computer as quickly as possible upon their detection. The computer screen remained blank throughout the task. Both the number of target detections and their associated correct RTs (msec.) were recorded online. No performance feedback was provided.

Subjective Mood Measures: A paper and pencil version of the 16-item Bond-Lader Visual Analogue Mood Scale (VAMS: Bond, & Lader, 1974) was employed to measure subjective mood. For each item, participants mark an antonym anchored at either end of a 100 mm line indicating their current mood (e.g. alert-drowsy). The 16-items measure the three independent factors of alertness, contentedness, and calmness.

Procedure

The experimenter was not blind to the experimental testing conditions. Participants were tested in groups of 2-3 in a soundproofed laboratory. Upon entering the laboratory participants were provided with written instructions in which the Bakan Task was described. Participants in the chewing-gum condition were additionally informed that they were required to chew a single-pellet of gum at a 'natural' rate for the duration of the experiment. They were given no information regarding the possible performance effects of gum-chewing. Participants then completed the pre-test Bond-Lader VAMS where they indicated their current mood. A 1 min. practice session for the Bakan task, in which one target occurred in the mid-20 s period, followed. For all participants, the practice session was completed without the requirement to chew gum.

For the experiment proper, participants in the chewing-chewing-gum group chewed a single pellet of Wrigley's sugar-free Spearmint gum continuously and at a 'natural' rate throughout the 30 min. task. To start the experiment, participants were required to depress the space bar on their individual laptops upon instruction from the experimenter. Participants in the chewing-gum group were required to simultaneously commence chewing. Upon task completion participants removed their chewing-gum and immediately completed the post-test Bond-Lader VAMS test. The experiment took approximately 45 mins. to complete.

Results

Bakan Task

Target Detection

An error response was defined as any response occurring more than 2 s. after a signal. Error responses accounted for fewer than 3% of the total corpus of responses, and, therefore, were not analysed. Figure 1 shows the mean target detections for the no-gum and -chewing-gum groups as a function of the six 300 s. task epochs. A 2-factor (2x6) mixed ANOVA was computed comprising the between-participants factor experimental group (no-gum versus chewing-gum) and the within-participants factor task epoch (1-6). The ANOVA revealed a main effect of task epoch, reflecting the expected vigilance decrement, $F(5,190)=10.71$, $p < .001$, *partial* $\eta^2 = .22$. Post-hoc Bonferroni-corrected comparisons ($\alpha = .003$) revealed that target detection at epoch 1 was significantly higher than that at epochs 3-6, and that target detection at epoch 2 was significantly higher than that at epochs 3 and 6. The main effect of experimental group was non-significant, $F(1,38) = .41$, $p = .53$, *partial* $\eta^2 = .01$. However, the experimental group by task epoch interaction was significant, $F(5,190)=4.36$, $p = .001$, *partial* $\eta^2 = .10$. Non-orthogonal planned comparisons revealed a borderline significantly greater number of target detections for the no-gum group at epoch 1, ($t(38) = 2.02$, $p = .051$: mean target detections = 4.45 and 4.00, for the no-gum and chewing-gum groups, respectively) and a significantly greater number of target detections for the no-gum group at epoch 2, ($t(31.75) = 2.29$, $p = .03$: mean target detections = 4.35 and 3.70, for the no-gum and chewing-gum groups, respectively). At epoch 5 the greater number of target detections for the chewing-gum group approached significance ($t(38) = 1.80$, $p = .08$: mean target detections = 3.25 and 3.85, for the no-gum and chewing-gum groups, respectively). No other comparisons achieved significance.

Figure 1 about here please

Gradients of Decline

To the extent that chewing-gum attenuates the time-on-task induced vigilance decrement, the rate of deterioration in target detection (i.e. gradient of decline) should be greater for the no-gum group when compared to the chewing-gum group. To assess the veridicality of this proposition, we computed an analysis more typically used to assess the rate of learning for the Hebb repetition paradigm (see, Parmentier, Maybery Huitson, & Jones, 2008; Johnson, Cauchi, & Miles, in press). Specifically, independent regression

analysis for each participant in the no-gum and chewing-gum groups provides an estimate for their gradients of vigilance decline across epochs. The proposition is supported if the gradient of decline for the no-gum group is significantly steeper than that for the chewing-gum group. The computed gradients of decline (see Figure 2) were compared via an independent samples t-test and, consistent with the proposition, the gradient of decline for the no-gum group exceeded that for the chewing-gum group, ($t(38)=3.99$, $p < .001$: regression means = -0.32 and -0.06, for the no-gum and chewing-gum group, respectively).

Figure 2 about here please

Correct Reaction Times

Figure 3 shows the mean correct RTs for the no-gum and chewing-gum groups as a function of the six 300 s. task epochs. The same model ANOVA as described above revealed a significant main effect of task epoch, $F(5,190)=18.33$, $p < .001$, *partial* $\eta^2 = .33$. Post-hoc Bonferroni-corrected comparisons ($\alpha = .003$) revealed that the mean correct RT for epoch 1 was significantly shorter than those for epochs 2-6, mean correct RTs for epochs 2 and 3 were significantly shorter than those for epochs 5 and 6. The main effect of experimental group was non-significant, $F(1,38)=2.03$, $p = .16$, *partial* $\eta^2 = .05$. Importantly, the main effects were modified by their interaction, $F(5,190)=3.83$, $p = .003$, *partial* $\eta^2 = .09$. Non-orthogonal planned comparisons revealed no differences in mean correct RTs between the groups at epochs 1-4. Consistent with theory, planned comparisons revealed significantly shorter mean correct RTs for the chewing-gum group at epoch 5, $t(38) = 2.88$, $p = .007$. However, this difference failed to maintain for epoch 6, $t(38) = 1.45$, $p = .16$.

Figure 3 about here please

Gradients of Incline

To the extent that chewing-gum attenuates the increase in mean correct RTs, the gradient of incline for the no-gum group should be steeper than that for the chewing-gum group. As described above, the gradients were calculated (see Figure 4) and compared via an independent samples t-test and, again, consistent with the proposition above, the gradient of incline was significantly steeper for the no-gum group, ($t(38)=3.34$, $p = .002$: regression means = 72.80 and 34.84, for the no-gum and chewing-gum groups, respectively).

Figure 4 about here please

Self-Rated Mood Evaluations

Complete self-rated data sets were available for 35 participants (no-gum= 15 and chewing-gum = 20). For each of the three mood measures (alertness, contentedness, and calmness) a single-factor (no-gum versus chewing-gum) between-participants ANCOVA was conducted with the pre-task score as the covariable, and the post-task score as the dependent measure. For all three measures the covariable was independent of the experimental manipulation and the assumption of homogeneity of regression slopes was met.

Alertness: Figure 5 shows pre- and post-task mean self-rated alertness scores as a function of experimental group. The main effect of experimental group was significant, $F(1,32)=14.25$, $p=0.001$, *partial* $\eta^2=0.31$, indicating higher post-task alertness scores for the chewing-gum group (mean alertness scores = 30.96 and 47.29, for the no-gum and chewing-gum group, respectively).

Figure 5 about here please

Contentedness: Figure 6 shows pre- and post-task mean self-rated contentedness scores as a function of experimental group. The main effect of experimental group was significant, $F(1,32)=5.48$, $p=0.03$, *partial* $\eta^2=0.15$, indicating higher post-task contentedness scores for the chewing-gum group (mean contentedness scores = 56.71 and 67.05, for the no-gum and chewing-gum group, respectively).

Figure 6 about here please

Calmness: Figure 7 shows pre- and post-task mean self-rated calmness scores as a function of experimental group. The main effect of experimental group was non-significant after controlling for baseline calmness, $F(1,32)=2.97$, $p=0.10$, $partial \eta^2=0.08$.

Figure 7 about here please

Vigilance-Alertness Correlation: To assess commonality of function for the effects of chewing-gum on both vigilance performance and self-rated alertness, we computed for the chewing-gum group, (Pearson's) correlations between (1) the proportional change in mean target detection between epochs 1 and 6 (for example, if the mean target detection at epoch 1 = 4 and at epoch 2 = 2, then the proportional change score=.5), and the proportional change in alertness pre- and post-Bakan task and, (2) the proportional change in mean correct RTs between epochs 1 and 6 and the percentage change in alertness pre- and post-Bakan task. Both correlations were non-significant, $r=.019$, $p=.94$ for 1, and $r=-.05$, $p=.84$ for 2, suggesting that the effect of chewing-gum on vigilance performance reflects the action of a mechanism independent of that underpinning the effect on self-rated alertness.

Discussion

The current study examined the impact of chewing-gum on an auditory Bakan-type vigilance task, and contrasted opposing predictions derived from the work of Tucha and Simpson (2011) and Kozlov et al. (2012). By the Tucha and Simpson (2011) account, chewing-gum should act to attenuate the typical vigilance decrement, particularly in the latter stages of task performance. For our study, therefore, both the decrease in target detection and the lengthening of correct RTs should be attenuated whilst chewing-gum. In contrast, by the Kozlov et al. (2012) account, target detection across all task epochs should be impaired whilst chewing-gum. The pattern of data here is consistent with the Tucha and Simpson position: the impairment to both target detection and correct RTs was attenuated whilst chewing-gum. This finding is consistent with earlier suppositions (e.g. Mackworth, 1957) that under 'normal' conditions the vigilance decrement reflects a time dependent decrease in the participant's alertness level. It is tempting to suppose further, therefore, that chewing-gum acted to maintain alertness, as indicated by the higher post-task self-rated alertness score for

the chewing-gum group, and that in turn, this measure of alertness positively influenced the participant's vigil. However, such a supposition is unfounded: for the chewing-gum group, there was no meaningful statistical association between time-dependent changes in self-rated alertness and either measure (target detections and correct RTs) of vigilance performance. Our data suggest, therefore, that those cognitions associated with chewing-gum induced attenuation of the vigilance decrement are independent of those underpinning changes in self-rated alertness.

Inconsistent with the position of Kozlov et al. (2012), chewing-gum did not consistently impair the maintenance of serial order (although reduced target detection for the chewing-gum group was observed at epochs 1 and 2). Clearly, the current task demands differed to those associated with traditional serial recall. Although participants were required to continually update the contents of the phonological loop component of short-term memory, it was not necessary to retain more than 3-items within the loop. This contrasts with the Kozlov et al. (2012) requirement to retain 8-items for serial recall. Notwithstanding this methodological difference, the present data clearly contradict their claim that 'chewing has an overall negative impact on STM tasks, both serial and non-serial' (pg. 509).

It is worth noting that target detection was significantly impaired for the chewing-gum group during the first two task epochs. This finding of impairment in vigilance performance confined to early stages is inconsistent with the predictions of Kozlov et al. (2012): by their account, chewing-gum induced interference with phonological processing should persist throughout the task. However, this early vigilance performance decrement whilst chewing-gum does have precedence in the work of both Tucha and Simpson (2011) in their perceptual vigilance task, and Allen and Smith (2012), and is consistent with the (post-hoc) speculation that the effect is due to division of resources between the tasks of chewing-gum and auditory monitoring (Onyper, Carr, Fararr., & Floyd, 2011). Presumably, such speculation is premised on the assumption that participants habituate to the demands of resource division, and thus the effect is temporary. In the absence of this caveat, the speculation fails to accommodate the evidence for improved task performance in the latter task stages.

The present study compared the attention degradation gradient for the no-gum and chewing-gum groups. Vigilance performance for the no-gum group was characterised by both significantly steeper decrements and increments for the number of target detections and correct RTs. We interpret this pattern of findings as reflecting a genuine time-dependent impairment in vigilance performance for the no-gum group in comparison to the chewing-gum group. Some readers may object to our interpretation, arguing that since the number of

target detections was significantly higher in the no-gum group at epoch 1, there was greater scope for this group's performance to deteriorate across the vigil. In support, they may also cite the correct RT data, whose pattern, although non-significant, mirrors that for target detections. We reject this alternative interpretation for two reasons. First, visual inspection of both Figures 1 and 3 shows that for the second half of the task, performance continued to deteriorate at a greater rate for the no-gum group compared to the chewing-gum group. This was apparent despite the abolishment of the initial performance advantage for the no-gum group. Second, exploratory t-test comparisons between the experimental groups at epochs 1 and 2 and at epochs 5 and 6, showed the following: for target detections, the no-gum group's performance exceeded that of the chewing-gum group for epochs 1 and 2, $t(38)=2.61$, $p=.01$, but this pattern was reversed for epochs 5 and 6, $t(38)=2.04$, $p=.048$; for mean correct RTs, the no-gum group's performance did not differ to that for the chewing-gum group for epochs 1 and 2, $t(38)=1.22$, $p=.23$, but the chewing-gum groups RTs were significantly shorter at epoch 5 and 6, $t(38)=2.92$, $p=.01$. Taken together, this pattern of data suggests that chewing-gum acted to sustain vigilance performance in the latter task stages.

The current data further emphasise the increasingly robust observation that chewing-gum can influence self-perceptions of alertness. In the present study, and consistent with a range of other studies (Johnson et al., in press; Scholey et al., 2009; Smith, 2009a,b), chewing-gum reliably attenuates the decline in post-task alertness. This shows that under conditions of task-induced decline, chewing-gum can act to both maintain vigilance performance and perceptions of alertness.

In summary, the present data both support and extend the findings of Tucha and Simpson (2011) by confirming that chewing-gum can act to attenuate the vigilance decrement in a task requiring continuous monitoring, and updating of order memory. Extending previous work we show that the decrement attenuation is mirrored by changes in self-rated alertness. However, the absence of a relationship between task performance and self-rated alertness indicates that these changes are underpinned via independent processes.

In conclusion, that chewing-gum can benefit some components of cognition is now well established (e.g., Wilkinson, Scholey, & Wesnes, 2002; Baker, Bezance, Zellaby, & Aggleton, 2004; Stephens, & Turney, 2004; Houcan, & Li, 2007; and Miles, Charig, & Eva, 2008). This benefit has been interpreted as reflecting the action of increased neurological activity (Onozuka, et al., 2002; Momose, et al., 1997) and the fluctuations in nervous system activation via adrenal arousal (Smith, 2010) observed in gum-chewing participants. In addition, that gum-chewing increases blood flow to the frontal-temporal brain regions has

been demonstrated by positron emission tomography (PET) (Onozuka et al., 2002; Momose et al, 1997), and by that research employing functional magnetic resonance imaging (fMRI), showing increases in cerebral blood flow when gum-chewing (Sesay et al, 2000; Onozuka et al, 2002; and Houcan, & Li, 2007). Likewise, Onozuka et al. (2002) found that chewing-gum resulted in a bilateral increase in blood oxygen level dependence (BOLD) signals to a number of brain regions including the sensory motor cortex, supplementary motor area, insula, thalamus and the cerebellum. It is theoretically plausible, therefore, that such neurological activity acts to maintain performance alertness independently of participants' subjective ratings of alertness.

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Figure 1

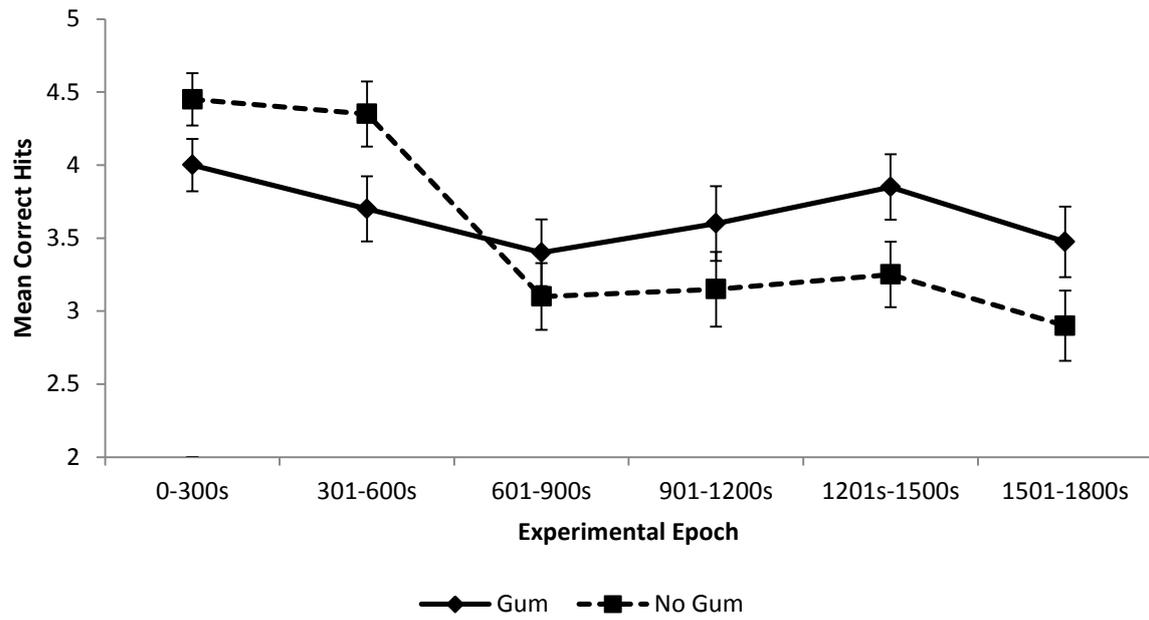


Figure 1: Mean correct responses for the gum and no-gum groups as a function of the six 300s epochs of the vigilance task. Errors bars denote +/- SEM.

Figure 2

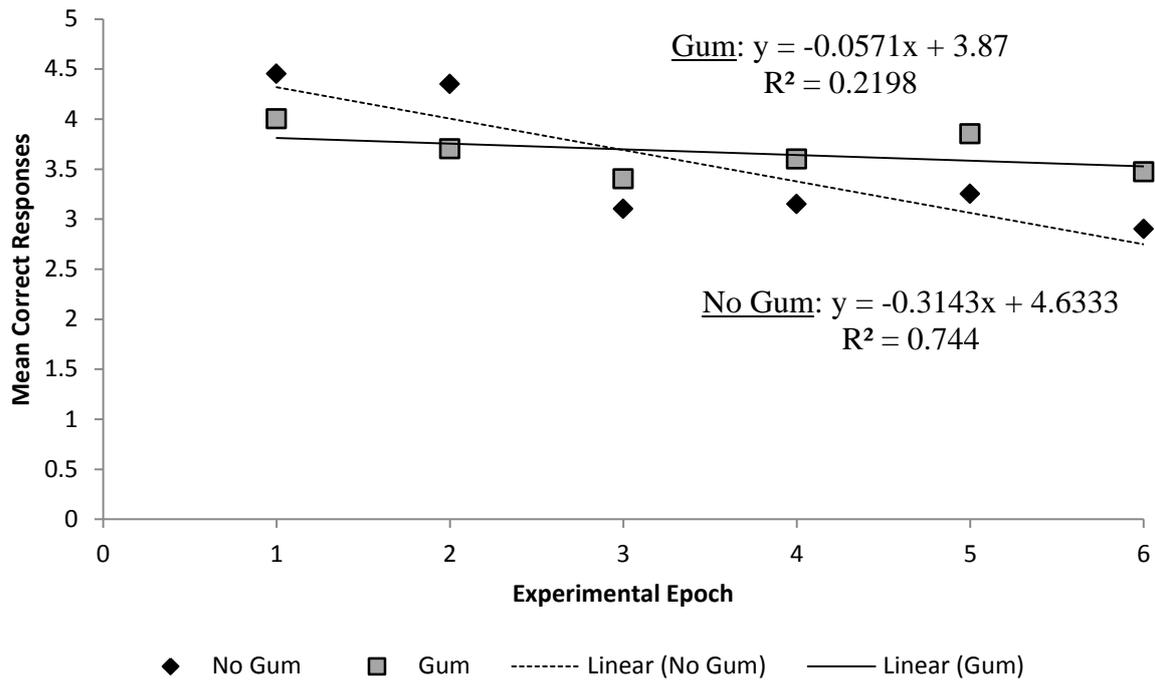


Figure 2: Mean correct responses for the gum and no-gum as a function of the six 300s epochs of the vigilance task. Line of best fit depicts the gradient of decline for each gum condition.

Figure 3

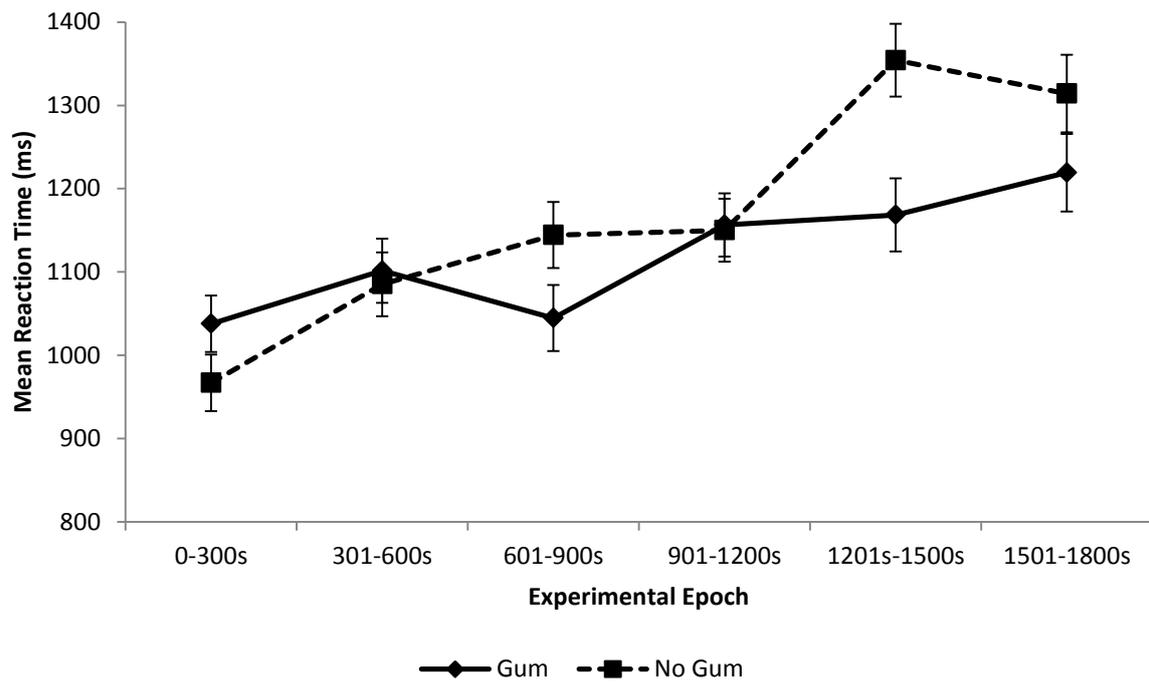


Figure 3: Mean correct RTs for gum and no-gum as a function of the six 300s epochs of the vigilance task. Errors bars denote +/- SEM.

Figure 4

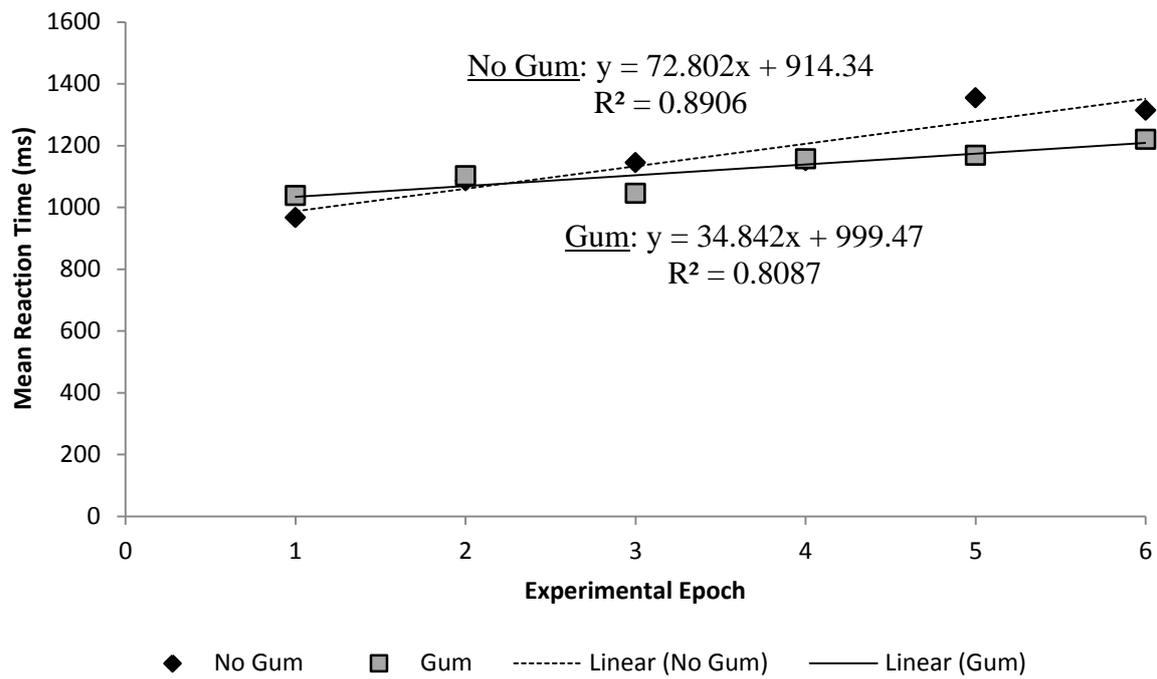


Figure 4: Mean correct RTs for the gum and no-gum as a function of the six 300s epochs of the vigilance task. Line of best fit depicts the gradient of decline for each gum condition.

Figure 5

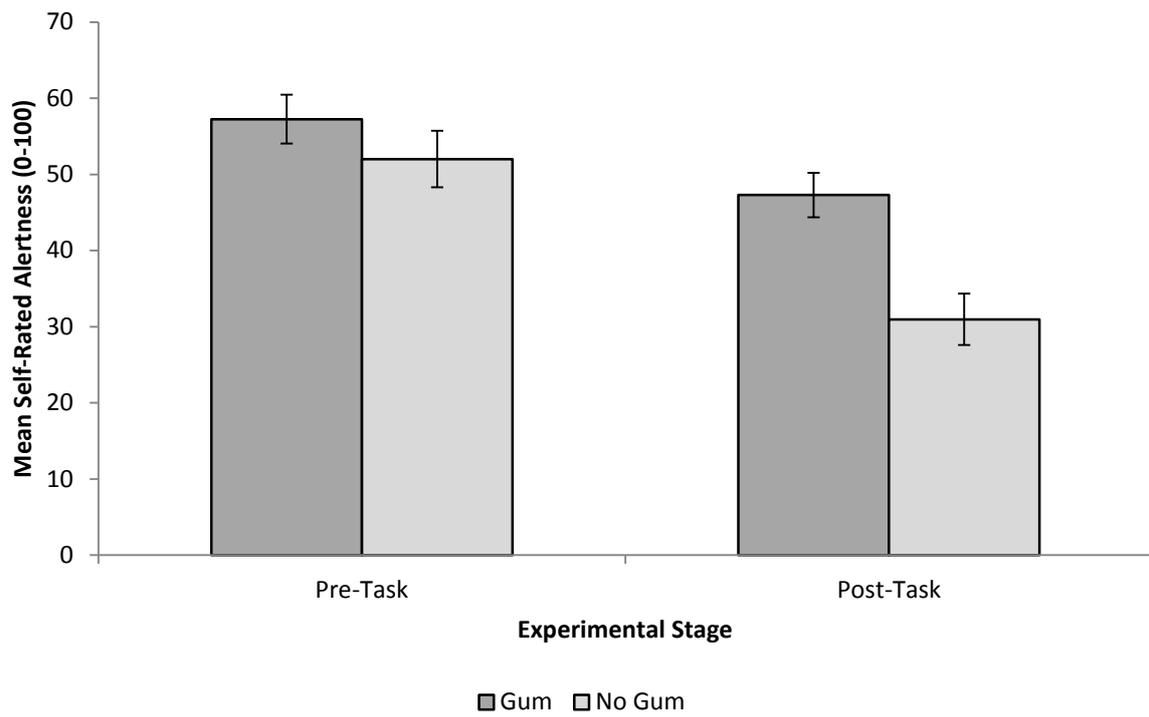


Figure 5: Mean self-rated alertness scores for the gum and no-gum conditions pre- and post-task. Errors bars denote +/- SEM.

Figure 6

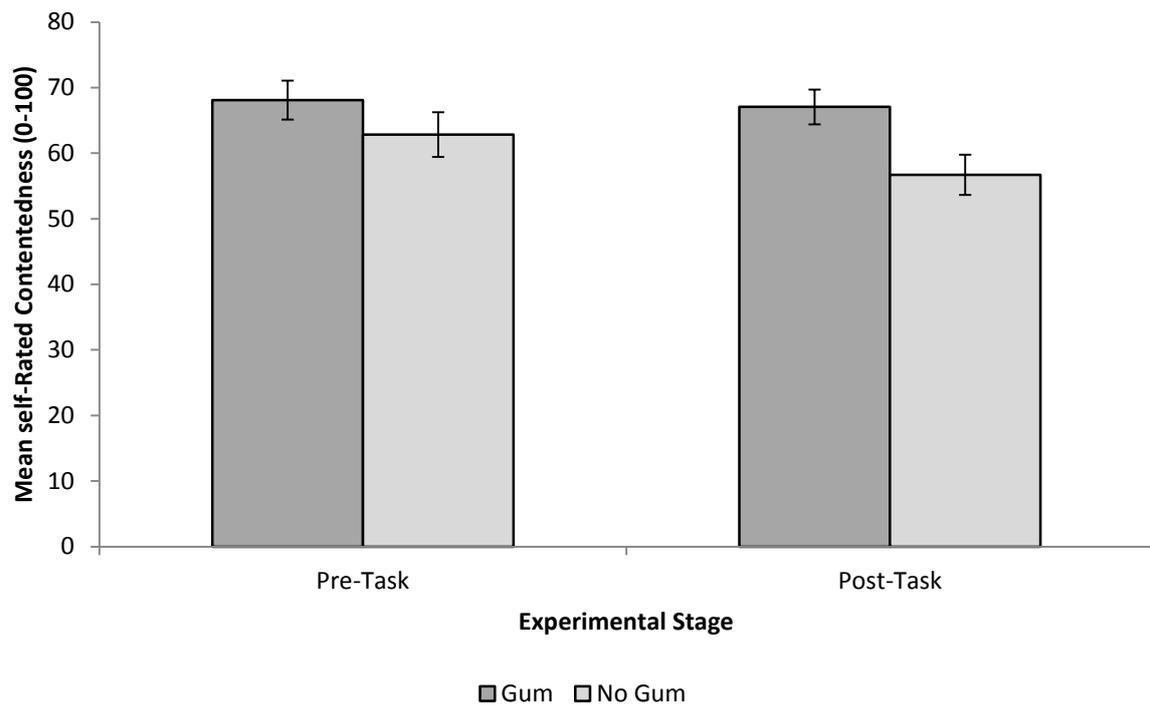


Figure 6: Mean self-rated contentedness scores for the gum and no-gum conditions pre- and post-task. Errors bars denote +/- SEM.

Figure 7

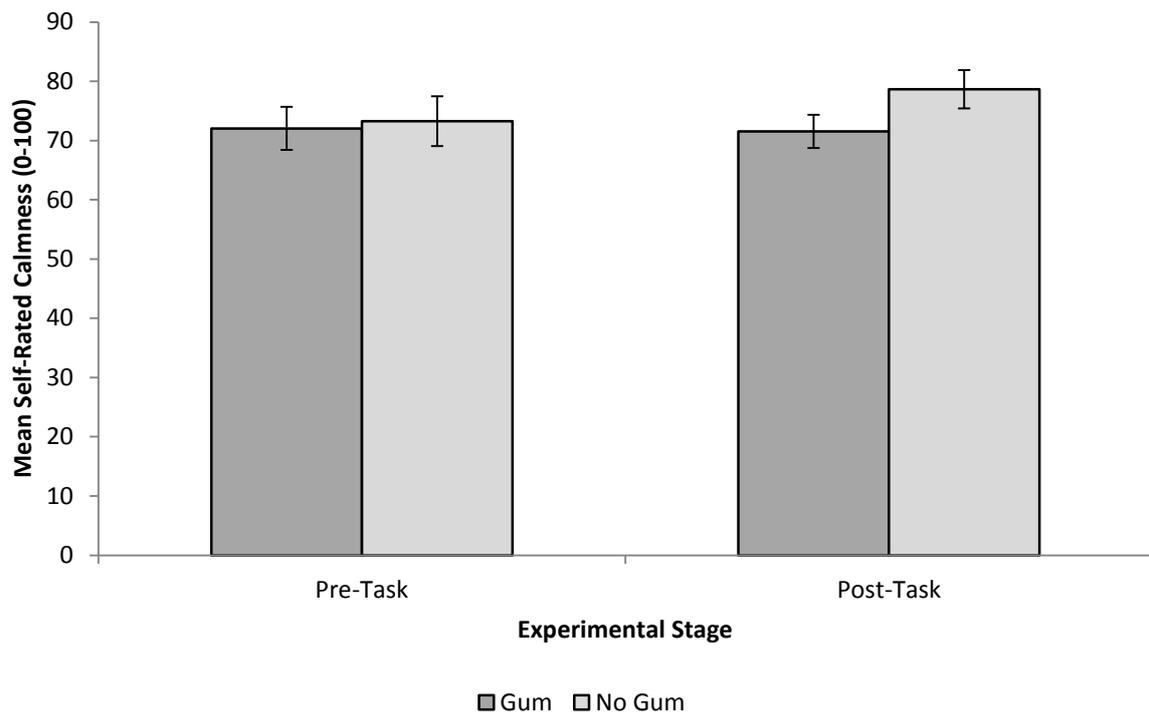


Figure 7: Mean self-rated calmness scores for the gum and no-gum conditions pre- and post-task. Errors bars denote +/- SEM.