AUTHOR QUERY FORM

<table>
<thead>
<tr>
<th>Location in article</th>
<th>Query / Remark: click on the Q link to go</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Please check and approve the insertion of country name in affiliation 'b'.</td>
</tr>
</tbody>
</table>

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof. Click on the 'Q' link to go to the location in the proof.

Thank you for your assistance.
The role of time on task performance in modifying the effects of gum chewing on attention

Lara Tucha a,*, William Simpson b

a Department of Clinical and Developmental Neuropsychology, Faculty of Behavioural and Social Sciences, University of Groningen, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands
b School of Psychology, University of Plymouth, Great Britain, United Kingdom

Short communication

The role of time on task performance in modifying the effects of gum chewing on attention

Lara Tucha a,*, William Simpson b

a Department of Clinical and Developmental Neuropsychology, Faculty of Behavioural and Social Sciences, University of Groningen, Grote Kruisstraat 2/1, 9712 TS Groningen, The Netherlands
b School of Psychology, University of Plymouth, Great Britain, United Kingdom

ARTICLE INFO

Article history:
Received 3 November 2010
Received in revised form 14 December 2010
Accepted 21 December 2010

Keywords:
Chewing gum
Vigilance
Attention
Time
Cognition

ABSTRACT

Recent research examined the effects of chewing gum on attention and reported a significant interaction of gum chewing with time. Using a crossover within-subject design, the present study examined the effect of gum chewing on sustained attention in healthy adults over a period of 30 min. The results revealed a significant main effect of time and a significant interaction between gum chewing and time. The findings suggest that gum chewing differentially affects attention performance. While gum chewing has detrimental effects on sustained attention in earlier stages of the task, beneficial effects on sustained attention were observed at later stages.

© 2010 Published by Elsevier Ltd.

Introduction

It has been observed that the chewing of a piece of ordinary chewing gum can facilitate cognition (Baker, Bezance, Zellaby, & Aggleton, 2004; Houcan & Li, 2007; Johnson & Miles, 2008; Stephens & Tunney, 2004b; Wilkinson, Scholey, & Wesnes, 2002). With regard to attentional functioning, beneficial effects of gum chewing have been found on alertness, selective attention, language-based attention and sustained attention (Scholey et al., 2009; Smith, 2009b, 2010; Stephens & Tunney, 2004b; Tucha, Mecklinger, Maier, Hammerl, & Lange, 2004). This facilitation of cognitive functioning by gum chewing has been ascribed to a chewing-related increase of regional cerebral blood flow, in particular in fronto-temporal brain regions, and an enhanced release of insulin. However, several studies failed to replicate these findings or demonstrated that gum chewing may even adversely affect attentional functioning (Kohler, Pavy, & Van Den Heuvel, 2006; Rost, Wirthwein, Frey, & Becker, 2010; Smith, 2009a; Tucha, Mecklinger, Maier, et al., 2004; Wilkinson et al., 2002).

The difficulties in replicating the results of studies have been attributed to methodological differences between studies. Comparisons between studies revealed that studies differed in regard to statistical power, the test procedures applied, the brands of chewing gums used, the participants’ familiarity with chewing gum (because of their different nationalities), the experimental designs (within- versus between-subjects design, lack of baseline assessments), the statistical analyses performed (parametric versus non-parametric analysis) and possible changes in gum consistency and flavor during the course of the examination (Scholey, 2004a, 2004b; Stephens & Tunney, 2004a; Tucha, Mecklinger, Hammerl, & Lange, 2004).

Although the studies differed in all of these aspects, it appears that no single factor or combination of factors can explain the disagreement of results of available studies.

In a recent study a new idea was put forward that might explain why some studies found beneficial and others detrimental effects of gum chewing on cognition (Tänzer, von Fintel, & Eikermann, 2009). This idea focuses on time as an important factor in the psychodynamics of gum chewing. In their study, Tänzer et al. (2009) examined concentration performance in 8–9 year-old children by using a cancellation task for a period of 16 min. Children who chewed a piece of chewing gum throughout the test session performed more poorly than the children who did not chew gum. However, this difference was only present during the first part of the task. After the twelfth minute, children who chewed a piece of gum outperformed the children of the no-gum-condition. Statistical analysis revealed that the interaction between conditions (gum chewing versus no gum chewing) and test period (earlier parts versus later parts of the task) was significant. In their discussion, Tänzer et al. (2009) mentioned that the poorer concentration performance of children chewing gum...
might have resulted from a biased selection of children with regard to their concentration performance. However, since no baseline assessment of concentration performance of groups has been performed, this is only one possible speculation. On the basis of the available literature, one could also assume that gum chewing might have detrimental or no effects on performance at earlier stages of tasks and beneficial effects at later stages. This explanation receives some support by a closer inspection of the sequence and timing of tests as applied in available studies. While some studies reporting beneficial effects of gum chewing on cognition observed the effects in tests that were performed during later stages of assessment (e.g. Smith, 2009b; Tucha, Mecklinger, Maier, et al., 2004; Wilkinson et al., 2002), studies that failed to replicate these effects performed similar measures at the beginning of assessment (e.g. Johnson & Miles, 2007; Tucha, Mecklinger, Maier, et al., 2004). However, the evidence provided by an inspection of the test sequences as used in published studies is not clear-cut because there is a lack of detail in publications concerning the exact timing and duration of tasks. Furthermore, positive effects of gum chewing on cognition were also observed at early stages of assessment (Smith, 2009a; Wilkinson et al., 2002). Therefore, it remains unclear whether time represents a mediating factor in the effects of gum chewing on cognition.

The aim of the present study was to examine the impact of gum chewing on cognitive performance over a prolonged period of time. Using a computerized task that has been shown to be sensitive to measures of sustained attention (Zimmermann & Fimm, 1993). The test was 30 min. The participants were requested to press a key on the computer screen. One square was situated on top of the other. A computerized attention test was performed for the measure-ment of sustained attention (Zimmermann & Fimm, 1993). The test was presented on a computer screen. Instructions were given orally. Participants were instructed to perform the computerized test as quickly as possible but to maintain a high level of accuracy. A brief sequence of practice trials preceded the test in order to familiarize the participants with the task. In the attention test, a structure consisting of two squares was presented in the centre of the computer screen. One square was situated on top of the other. These squares were alternately filled with a pattern (stimulus) for 500 ms with an interstimulus interval of 1000 ms. The duration of the test was 30 min. The participants were requested to press a button when no change of the pattern location occurred. The target rate (i.e. no change of pattern location) was about one target stimulus per minute. The time intervals between target stimuli were irregular. Reaction time for correct responses was recorded.

To measure the effect of time on task performance, the whole task was divided into six consecutive time blocks of 5 min (1st time block: 1st to 5th minute; 2nd time block: 6th to 10th minute; 3rd time block: 11th to 15th minute; 4th time block: 16th to 20th minute; 5th time block: 21st to 25th minute; 6th time block: 26th to 30th minute).

Statistical analysis was performed using a $2 \times 6$ MANOVA (condition by time block). Normal distribution of data was analyzed using Kolmogorov–Smirnov tests. For statistical analysis an alpha level of $p < .05$ was applied. All analyses were carried out using SPSS 16.0 for Windows. Furthermore, the index $r^2$ (eta squared) was calculated. According to Cohen (1988) a small effect size corresponds to an $r^2 = .0099$, a medium effect size to an $r^2 = .0588$ and a large effect size to an $r^2 = .1379$. Post hoc analysis was performed using paired t-tests. A determination of the required sample size in this type of studies with multiple within-subject factors is in general very complicated, in particular because available research did not provide sufficient information concerning the magnitude of the effects of gum chewing on cognition over a prolonged period of time. Tänzer et al. (2009) who found that time is a mediating factor in the psychodynamics of gum chewing unfortunately reported only mean scores but not standard deviations. This makes an analysis of effect sizes impossible. Tucha, Mecklinger, Hammerl, et al. (2004) and Tucha, Mecklinger, Maier, et al. (2004) also considered the effect of time on attention performance in a previous study by calculating ipsative mean scores of participants’ performance. From these data a medium effect size (i.e. effect sizes between $.5$ and $.6$ SD) can be estimated. Considering this range of effect sizes and setting power at $.80$ and the significance criterion at $.05$, sample sizes between 35 and 50 per cell appear to be sufficient (Cohen, 1988). With sample sizes of 42 per cell, this criterion was achieved in the present study.

**Results**

There was no evidence to reject the assumption of normal distribution of reaction time data. Because of a violation of the sphericity assumption, the Greenhouse–Geisser correction was employed. Multivariate analysis of variance (MANOVA) revealed a significant main effect of time block ($F(4, 46, 205) = 17.13, p < .001$, Greenhouse–Geisser corrected). The effect size for this difference in reaction time was large ($r^2 = .295$). Subsequent post hoc analysis using paired t-tests (Bonferroni adjusted) indicated that the...
reaction times shown during the first two 5 min blocks (1st to 10th minute of task) differed significantly (p < .001) from the reaction times during the remaining 5 min blocks (11th to 30th minute). The remaining pairwise comparisons did not reach significance (p > .05). Furthermore, there was a significant condition by time block interaction (F(3.73, 205) = 5.22, p = .001, Greenhouse–Geisser corrected) indicating a medium effect (η² = .113). The difference between conditions was not significant (F(1, 41) = .61, p = .439) and represented only a small effect (η² = .015). Test performances of participants are presented in Fig. 1. An additional analysis in which the order of gum condition was included as an additional factor. This analysis revealed no significant effect regarding the order of gum condition (results not shown).

Discussion

In the present study, the effect of gum chewing on attentional functioning over a prolonged period of time was examined. Attentional functioning was assessed by performing a computerized sustained attention task. Reaction time was measured for each of six consecutive time blocks of 5 min so that changes in test performance over time could be analyzed. An analysis of the number of omission and commission errors was not included in the present study, because errors in healthy participants have been shown to be a rare phenomenon (Tucha et al., 2009) in particular when analyzing time periods of only 5 min (number of omission and commission errors < 1). Moreover, the reliability of examinations based on the observation of short test scales and rare events is usually very small (Kline, 2000).

The present results suggest that there is a significant main effect of time denoting an increase of reaction times with task duration. This time-on-task effect is not surprising considering that the whole concept of sustained attention is based on the robust finding that human performance deteriorates over time (Cohen, 1993). The condition by time block interaction also reached significance. Similar to the findings of Tänzer et al. (2009) the performance of participants in the gum-condition was poorer during the first part of the task (first 10 min) than in the no-gum-condition. One may argue that the findings of Tänzer et al. (2009) might have resulted from a biased selection and group allocation of participants to conditions (as assumed by the authors themselves). The present study, however, applied a crossover within-subject design. Half of the participants were tested first with chewing gum and then without chewing gum. Furthermore, conditions of assessment were kept constant over the course of the study. Therefore, the present findings provide evidence that gum chewing can adversely affect attention performance during the early phases of an attention task. This result is also consistent with the findings of previous studies reporting detrimental effects of gum chewing on attentional performance (Kohler et al., 2006; Rost et al., 2010; Tucha, Mecklinger, Maier, et al., 2004; Tucha et al., 2010).

Since different attention tests have been applied in these studies the deficits observed appear not to be task dependent. The present study also found a beneficial effect of gum chewing on performance at later stages of an attention task. In the gum-condition, participants’ reaction time increased less with task duration than in the no-gum-condition (in particular in the period from the 20th to the 30th minute). Therefore, time-on-task appears to be a crucial mediating factor in the effects of gum chewing on attention. This assumption is supported by studies measuring the effects of repetitive movements and exercise on cognition. Recent overviews and meta-analyses of this research (e.g. Brisswalter, Collardeau, & Arcelin, 2002; Lambourne & Tomporowski, 2010) revealed that cognitive performance is reduced during the earlier phases (initial 10–20 min) but facilitated during the later phases of exercise (after 20 min). Furthermore, it has been shown that these effects depend on the type of exercise and the type of cognitive task performed. It is assumed that cognitive functioning is compromised in the initial phases by a dual-task interference (Lambourne & Tomporowski, 2010).

The consideration of the interaction between time and effect of gum chewing might considerably contribute to the discussion why some groups found positive and other negative effects of gum chewing on cognition. It is difficult to explain why there are different time-dependent effects of gum chewing on cognition. One might speculate that participants might be distracted by gum chewing during early stages of cognitive tasks or that certain biological processes (e.g. increase of regional cerebral blood flow) have to add up or reach a certain threshold to facilitate cognitive processing. The examination of the underlying factors of the time course of effects and the exact time course for different cognitive tasks or functions could be the aim of future studies. The present findings confirm our previous conclusions (Tucha, Mecklinger, Maier, et al., 2004) that gum chewing differentially affects attention and that claims stating that gum chewing improves cognition should be viewed with caution.

References