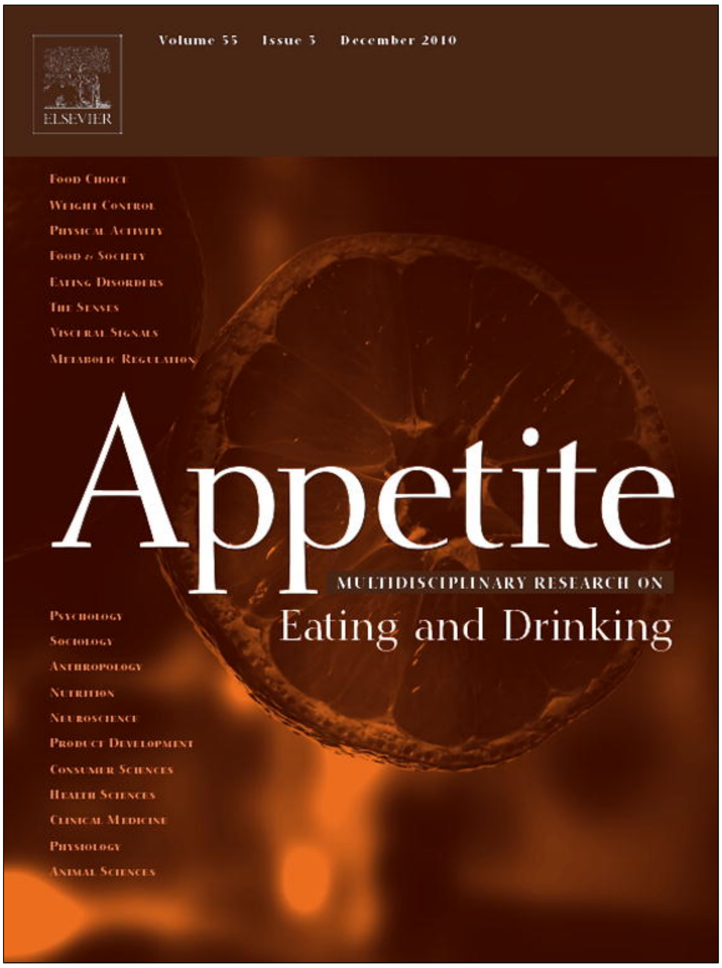
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Research report

Detrimental effects of gum chewing on vigilance in children with attention deficit hyperactivity disorder

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ABSTRACT

Impairments of attention are cardinal features of attention deficit hyperactivity disorder (ADHD) and can seriously affect the daily life of children with ADHD. Despite effective treatment strategies, there is a need of further treatment options that can be added to available and well established treatments. Further treatment options are needed since available treatments are often time consuming, expensive and limited regarding their external validity. Recent research demonstrated that gum chewing has beneficial effects on cognition including certain aspects of attention. Therefore, gum chewing may benefit children with ADHD in situations requiring particular cognitive efforts. In a crossover study, attentional functioning of 32 children with ADHD and 32 children without the condition was examined. All participants were assessed with chewing gum and without chewing gum. A computerized test was used for the assessment of vigilance and sustained attention. The findings of the present study suggest that gum chewing during task execution has detrimental effects on vigilance of both healthy children and children with ADHD. Sustained attention was not affected by gum chewing. Chewing gum, therefore, appears not to improve attentional performance in children with ADHD.

Introduction

Children with attention deficit hyperactivity disorder (ADHD) frequently experience difficulty paying attention in class and often experience social interaction problems, peer rejection, and academic failure or under-achievement (Barkley, 1998; Hoza & Pelham, 1993; Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997). These problems have detrimental effects on the children's development and their inclusion into society. Residual symptoms of ADHD adversely affect the occupational and social life of adolescents and adults with ADHD (Kovner et al., 1998). In view of the far-reaching consequences of ADHD in terms of its disruptive symptoms and its persistence into adulthood, there is a clear need for an effective treatment of patients suffering from the disorder. Treatment of ADHD encompasses various aspects including educational, behavioural, psychological and pharmacological intervention (Anastopoulos, Smith, & Wien, 1998; DuPaul, Barkley, & Connor, 1998; Ramirez, Desantis, & Opler, 2001; Robin, 1998; Sohlberg & Mateer, 2001; Spencer, Biederman, & Wilens, 1998). The common pharmacological treatment of ADHD is stimulant drug therapy using methylphenidate. This drug, which is considered to be the most effective treatment for ADHD (Hoza & Pelham, 1993; Peeples, Searls, & Wellingham-Jones, 1995; Solanto, 1998), has been shown to have beneficial effects on cognition, behaviour and both social and academic skills (DuPaul et al., 1998; Tucha, Prell, et al., 2006). Research data clearly indicate that pharmacological treatment is effective alone and appears to be the most effective part of a comprehensive multimodal treatment (Abikoff, Hechtman, Klein, Gallagher, et al., 2004; Abikoff, Hechtman, Klein, Weiss, et al., 2004; Greenhill, 1992; Pelham et al., 1992; Wilens & Biederman, 1992). However, drugs used for pharmacological treatment of children with ADHD are associated with some disadvantages. For example, not all children with ADHD respond to pharmacological treatment. Approximately 30% of children and 22–75% of adults with ADHD do not respond satisfactorily to treatment with stimulant medication (Wigal et al., 1999; Wilens, Spencer, & Biederman, 2002). Furthermore, side-effects of medication necessitate the discontinuation of pharmacological therapy in some children. The most common side effects of methylphenidate therapy occur even at low doses and include headache,

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stomach-ache, insomnia, decreased appetite and dizziness (Ahmann et al., 1993; Shaywitz, Fletcher, & Shaywitz, 1997). Moreover, the effects of stimulants are limited to the period in which the medication is physiologically active and even in drug responders stimulant therapy is not sufficient to bring children with ADHD into a normal range of cognitive, academic and social functioning (Gualtieri & Johnson, 2008; Tucha, Prell, et al., 2006). There is also a consensus that a multimodal approach to the management of ADHD is desirable (Cantwell, 1996; Shaywitz et al., 1997) and that non-pharmacological treatment strategies are effective in certain areas such as family functioning or cognition (Anastopoulos et al., 1998; Kerns, Eso, & Thomson, 1999; Pisterman et al., 1992; Semrud-Clikeman et al., 1999). The main disadvantages of these strategies are that they are often time consuming and expensive and that the generalisation of skills and effects is very often very limited (e.g., Sheridan, Dee, Morgan, McCormick, & Walker, 1996). Therefore, there is a need of additional treatments (1) that can be given in addition to the effective medication (no interactions with pharmacological treatments), (2) that are time and cost effective, (3) that have no detrimental side effects, (4) that can be taken flexibly, for example in situations in which an improved functioning is required, such as exams at school, and (5) that are effective on symptoms that are most detrimental to the patients' functioning, such as inattention.

In recent years, a small number of studies has examined the effects of gum chewing on cognitive functioning. It has repeatedly been found that chewing a piece of sugar-free chewing gum significantly improves memory and attention functions in healthy children and adults (e.g., Baker, Bezance, Zellaby, & Aggleton, 2004; Houcan & Li, 2007; Scholey et al., 2009; Stephens & Tunney, 2004b; Tucha, Mecklinger, Maier, Hammerl, & Lange, 2004; Wilkinson, Scholey, & Wesnes, 2002). The observed improvement of cognitive functioning has been discussed in terms of a chewing-related increase of regional cerebral blood flow and an enhanced release of insulin (Hirano et al., 2008; Stephens & Tunney, 2004b; Wilkinson et al., 2002). However, there is some controversy regarding the facilitative effect of gum chewing on cognition (Scholey, 2004; Stephens & Tunney, 2004a; Tucha, Mecklinger, Hammerl, & Lange, 2004), because some studies found no effects or even detrimental effects of gum chewing on some aspects of memory and attention (e.g., Johnson & Miles, 2007; Tucha, Mecklinger, Maier, et al., 2004; Wilkinson et al., 2002).

Since disturbances of vigilance are considered to be the most prominent disturbance of attention in children with ADHD and since a positive effect of gum chewing on cognition has been found in healthy adults (Tucha, Mecklinger, Maier, et al., 2004), it might be expected that chewing gum would improve performance on attention tasks in children with ADHD. In the present study, we will test whether in fact chewing gum improves vigilance and sustained attention in children with ADHD as compared to a control group of children with no attention deficits. To the best of our knowledge, the present study is the first examination in which chewing gum is used in a clinical sample to improve cognitive deficits.

Methods

Participants

Thirty-two children with a diagnosed ADHD (Diagnostic and Statistical Manual of Mental Disorders, DSM-IV) participated in the present study (8 girls, 24 boys; mean age = 10.8 years, SEM = 0.4 years). The diagnosis was based on clinical assessment (DSM-IV) including observations, questionnaires and/or interviews with parents and children. Interviews and assessments were performed by experienced clinicians (e.g., child psychiatrists). At the time of the study, all children with ADHD were being treated with clinically appropriate doses of stimulants. Furthermore, 32 healthy children participated in the present study (8 girls, 24 boys; mean age = 10.6 years, SEM = 0.4 years). The groups did not differ in gender or age (Mann–Whitney *U*-test: $Z = -0.64$, $p = .524$). Inclusion criteria were: diagnosis of ADHD (only in the patient group), age 6–16 at time of assessment, normal or corrected to normal vision and willingness to participate. Exclusion criteria included: the presence of any major medical problem such as major psychiatric or neurological conditions (e.g., epilepsy), disorders relating to food or glucose (such as diabetes) and any food allergies. However, no child met these exclusion criteria. Children were recruited from local schools or responded to public announcements. The study was approved by the ethics committee of the University of Plymouth, UK. Written informed consent was obtained from parents of all participating children.

Procedure

The study used a crossover design in which all participants were assessed both with chewing gum (gum-condition) and without chewing gum (no-gum-condition). In the gum-condition, participants were instructed to chew naturally and constantly a piece of spearmint flavoured sugar-free chewing gum throughout the whole test session. Fourteen children of each group were tested first without chewing gum and then with chewing gum, while the remaining children were examined in the reverse order. Participants were randomly assigned to the starting condition. The time period between testing and retesting was seven days.

Measure

All participants were assessed with a computerized attention test measuring aspects of vigilance and sustained attention (Zimmermann & Fimm, 2002). The test was of low complexity and therefore well suited for the assessment of children. Previous research already demonstrated that the test is a sensitive measure for alterations of attention in children with ADHD (Tucha, Walitza, et al., 2006; Tucha et al., 2009) as well as for the effects of chewing gum (Tucha, Mecklinger, Maier, et al., 2004). The test procedure 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 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 (each about 2.0 cm $\times$ 2.0 cm) was presented in the center 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 15 min. A total of 600 stimuli (changes of pattern location) was presented. 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. Median reaction time for correct responses, the number of omission errors (lack of response to target stimuli) and the number of commission errors (responses to non-target stimuli) were calculated. Median reaction times were used since medians are less sensitive to extreme scores (outliers) than means. The attention test used in the present study measures both vigilance and sustained attention. Vigilance is the ability to maintain attention over a period during which infrequent response-demanding events occur. The ability to sustain attention enables an individual to direct attention to sources of information over a relatively long and unbroken period of time. Consequently, disturbances of sustained attention are

Table 1
Test performance of healthy children and children with ADHD (means ± SEM).

	No-gum-condition		Gum-condition	
	Healthy children	Children with ADHD	Healthy children	Children with ADHD
Analysis of vigilance (test duration of 15 min)				
Reaction time (in ms)	686.6 ± 27.5	740.3 ± 33.7	743.4 ± 25.5[c]	826.9 ± 34.5[d]
Commission errors	4.6 ± 0.8	13.1 ± 3.2[A]	4.3 ± 0.5	17.7 ± 5.4[b]
Omission errors	2.0 ± 0.3	5.4 ± 0.7[A]	2.3 ± 0.3	6.9 ± 0.6[B,d]
Analysis of sustained attention (ipsative scores)				
Reaction time (in ms)	−63.8 ± 36.4	−14.3 ± 36.0	−63.6 ± 29.3	−91.4 ± 51.6
Commission errors	−0.7 ± 0.4	−1.0 ± 0.8	0.0 ± 0.4	−0.9 ± 1.0
Omission errors	0.1 ± 0.2	−0.2 ± 0.5	−0.3 ± 0.2	0.1 ± 0.6

Note. [A] $p \leq .01$ compared with healthy children in the no-gum-condition (Mann–Whitney *U*-test); [B] $p \leq .01$ compared with healthy children in the gum-condition (Mann–Whitney *U*-test); [b] $p \leq .05$ compared with healthy children in the gum-condition (Mann–Whitney *U*-test); [c] $p \leq .05$ compared with healthy children in the no-gum-condition (Wilcoxon test); [d] $p \leq .05$ compared with children with ADHD in the no-gum-condition (Wilcoxon test).

indicated by a decline of performance over time (time-on-task effects). Since this decline is normal for healthy well functioning individuals, impairments of sustained attention (e.g., of children with ADHD) would be indicated by an increased decrement of test performance over time (Cohen, 1993). To measure the effect of time on task performance, the whole task was divided into two consecutive time blocks.

Data analysis

Statistical analysis was performed using nonparametric tests. While comparisons between groups (children with ADHD versus healthy children) were performed using Mann–Whitney *U*-test, Wilcoxon tests were performed to compare conditions (gum-condition versus no-gum-condition). In order to compare the performance decrement over time between groups (i.e. interaction between group membership and time block), ipsative scores were calculated (for both conditions) by subtracting the participants' performance during the second half of the task (2nd time block) from their performance during the first half of the task (1st time block). These ipsative scores represent the change of performance over time and are therefore a measure of sustained attention (Tucha et al., 2009). These ipsative scores were also used to analyse the interaction between condition and time block in each group. Furthermore, Wilcoxon tests were used to analyse whether learning effects occurred during the execution of the attention task. This was accomplished by comparing the participants' performances during the first half of the task with their performances during the second half. This analysis was done for both conditions. Finally, Wilcoxon tests were calculated to analyse whether carryover effects from the first test session to the second test session affected participants' task performance independent from the treatment (gum-condition versus no-gum-condition). Learning and carryover effects were analysed separately for each group, since deficits of learning have repeatedly been reported in children with ADHD (Muir-Broaddus, Rosenstein, Medina, & Soderberg, 2002; Rhodes, Coghill, & Matthews, 2005). For statistical analysis an alpha level of $p \leq .05$ was applied. All statistical analyses were carried out using SPSS 16.0 for Windows.

Results

Differences between groups (healthy children versus children with ADHD)

Statistical comparison using the Mann–Whitney *U*-test revealed that children with ADHD made significantly more commission errors ($Z = -2.64$, $p = .008$) and omission errors ($Z = -3.27$, $p = .001$) in the no-gum-condition than healthy children. No difference was found between groups in reaction time ($Z = -0.91$, $p = .364$). The same pattern of differences between groups was found in the gum-condition (number of commission errors: $Z = -2.18$, $p = .029$; number of omission errors: $Z = -5.39$, $p < .001$; reaction time: $Z = -0.57$, $p = .568$). The analysis of ipsative scores revealed neither a significant difference between groups in the no-gum-condition (number of commission errors: $Z = -0.29$, $p = .769$; number of omission errors: $Z = -1.23$, $p = .221$; reaction time: $Z = -0.74$, $p = .458$) nor in the gum-condition (number of commission errors: $Z = -0.35$, $p = .730$; number of omission errors: $Z = -0.54$, $p = .591$; reaction time: $Z = -0.05$, $p = .958$) indicating no interaction effects between group membership and time block. Test performances of groups are presented in Table 1.

Differences between conditions (gum-condition versus no-gum-condition)

Comparison between participants' performances in the gum-condition and the no-gum-condition showed significant differences. Both healthy children ($Z = -1.97$, $p = .049$) and children with ADHD ($Z = -2.00$, $p = .046$) displayed an increased reaction time in the gum-condition. Furthermore, children with ADHD made significantly more omission errors when chewing gum during task execution ($Z = -1.99$, $p = .047$). No significant effects of gum chewing were found on the number of commission errors (healthy children: $Z = -0.30$, $p = .765$; children with ADHD: $Z = -0.58$, $p = .565$) and on the number of omission errors made by healthy children ($Z = -1.25$, $p = .212$). Finally, the analysis of the interaction between condition and time block revealed no significant differences neither for healthy children (reaction time: $Z = -0.56$, $p = .576$; number of commission errors: $Z = -0.82$, $p = .413$; number of omission errors: $Z = -1.57$, $p = .116$) nor children with ADHD (reaction time: $Z = -0.34$, $p = .737$; number of commission errors: $Z = -0.26$, $p = .793$; number of omission errors: $Z = -0.17$, $p = .862$).

The analysis of interactions regarding reaction time for correct responses are of limited value since the measurement of reaction time requires participants to respond to target stimuli which occur only infrequently in vigilance tasks such as the test used in the present study. Therefore, an assessment of reaction time is not possible if participants do not respond to any of the target stimuli. In the sample of ADHD children in the present study, 9 children failed to respond to any of the target stimuli within at least one time block of one of the two conditions. However, all children suffering from ADHD and healthy children responded correctly at least once within each condition, so that reaction times were available of all participants for the analysis of vigilance performance (test duration of 15 min).

Analysis of learning and carryover effects

Statistical comparisons of participants' performances during the first and second half of the task revealed no significant differences in both healthy children and children with ADHD, neither in the gum-condition nor in the no-gum-condition (data not shown). Furthermore, the data analysis showed no significant carryover effects in either of the groups (children with ADHD and healthy children; data not shown).

Discussion

In the present study, attentional functioning of children diagnosed with ADHD and healthy children was assessed. Children with ADHD were on stimulant medication during assessment, since the primary interest of the study was to examine whether gum chewing has an additional beneficial effect on the attention deficit of children with ADHD. Recent studies already demonstrated that cognitive impairments such as attention deficits persist in children with ADHD despite optimal pharmacological treatment (Gualtieri & Johnson, 2008; Tucha, Prell, et al., 2006). Therefore, treatment strategies that can be added to the pharmacological treatment are of particular importance in the field of ADHD.

The impaired performance of children with ADHD found in the no-gum-condition of the present study accords with findings in the existing literature. Several studies have demonstrated that patients with ADHD suffer from a considerable impairment of vigilance but not from disturbances of sustained attention (Epstein, Johnson, Varia, & Conners, 2001; Prior, Sanson, Freethy, & Geffen, 1985; Schachar, Logan, Wachsmuth, & Chajczyk, 1988; Stins et al., 2005; Tucha et al., 2009). When children with ADHD were asked to chew gum during task execution, their vigilance performance markedly deteriorated as indicated by an increase of both reaction times and the number of omission errors. Chewing gum, therefore, appears not to be a suitable and viable strategy in supporting children with ADHD with regard to their attention deficits. This conclusion is restricted to vigilance and sustained attention, since other attention functions known to be impaired in both children and adults suffering from ADHD, such as mental shifting, selective and divided attention (Tucha, Walitza, et al., 2006; Tucha et al., 2008), have not been examined. These functions may be differentially and possibly positively affected by gum chewing as already shown in a previous study on healthy adults (Tucha, Mecklinger, Maier, et al., 2004). Therefore, the aim of future studies could be to examine the effect of gum chewing on other measures of attention in children and adults with ADHD.

The results of the present study further suggest that chewing a piece of sugar-free chewing gum has also detrimental effects on the vigilance of healthy children, as shown in significantly increased reaction times. Therefore, the present results confirm studies reporting negative effects of gum chewing on attentional functioning. Tucha, Mecklinger, Maier, et al. (2004) performed two experiments to assess the impact of gum chewing on various measures of attention in healthy young adults. The authors observed that chewing gum differentially affects attentional functioning. While alertness and flexibility were adversely affected by gum chewing, beneficial effects have been found on aspects of sustained attention. Detrimental effects of chewing (a piece of Parafilm) on attention have also been observed in healthy young adults during sleep deprivation (Kohler, Pavy, & Van Den Heuvel, 2006). Following sleep deprivation for one night, reaction times and the frequency of lapses of attention in a vigilance task were significantly increased in the chewing-condition when compared to a no-gum-condition (capsules containing lactose). Finally, a recent study on 8–9 year-olds has shown that children who chew gum performed more poorly on a sustained attention task than children who did not chew gum (Taenzer, von Fintel, & Eikermann, 2009). This effect, however, was only observed for the first 12 min of the task. During the remaining test duration (4 min) children in the gum-condition performed better than children in the no-gum-condition. Unfortunately, it is not clear whether these differences were statistically significant. Nevertheless, the interaction between gum chewing and test period was significant. The analysis of the interaction between condition and time block in the present study revealed only a non-significant difference. However, it has to be considered that Taenzer et al. (2009) observed a beneficial effect of gum chewing only after the 12th minute of the task. The task used in the present study lasted only for 15 min and might therefore simply be not long enough to detect the positive effects of gum chewing. This assumption is supported by the results of a previous experiment on healthy young adults (Tucha, Mecklinger, Maier, et al., 2004). In this experiment the same attention test as used in the present study was applied, however, for a period of 40 min. A comparison of participants' ipsative scores calculated by subtracting their performance during the last 5 min of the task from their performance during the first 5 min indicated a beneficial effect of chewing gum on sustained attention. The participants in a gum-condition (sugar-free, spearmint flavored gum) displayed a smaller increase in reaction time over time during the task than participants in the no-gum-condition. These findings might indicate that time is an important factor in the psychodynamics of gum chewing.

On the basis of the available research one may speculate that gum chewing has detrimental effects at early stages but beneficial effects in late stages of cognitive tasks. However, our current knowledge is still very limited so that further studies are desirable. Consideration of time as a mediating factor of the effects of gum chewing may also help to understand why some studies found effects of gum chewing, either benign or detrimental, while others failed to find effects. This inconsistency might be the result of variations between studies concerning the designs and procedures used, in particular with regard to the sequence and timing of test application. For example, Wilkinson et al. (2002) who performed presumably the first controlled study in this field found positive effects of gum chewing on measures of memory. In this study, participants underwent a whole test battery assessing various aspects of cognition. The functions in which improvements of gum chewing were found, were primarily assessed during the second part of the test battery that lasted approximately 30 min. Subsequent studies that tried to replicate these findings failed to find beneficial effects or even found detrimental effects of gum chewing (Johnson & Miles, 2007; Tucha, Mecklinger, Maier, et al., 2004). In these studies, however, the critical functions that have been found to be improved in the study by Wilkinson et al. (2002) were assessed right at the beginning. Although this might indicate a strong effect of time, these considerations have to be viewed with caution, since other studies failed to replicate prior findings despite being similar with regard to timing and design (e.g., Baker et al., 2004; Johnson & Miles, 2007). Furthermore, positive effects of gum chewing on memory were not only observed at late stages of assessments, but also at early stages (Wilkinson et al., 2002).

On the basis of previous research and the present data, the assumption by Baker et al. (2004) that vigilance measures may not be appropriate to assess the effects of gum chewing on cognition (e.g., because of a lack of sensitivity) cannot be supported. Impairments of vigilance have repeatedly been observed in both children and adults when asked to chew gum or Parafilm during task execution (Kohler et al., 2006; Taenzer et al., 2009). Since the measures of vigilance applied in these studies varied in various dimensions (e.g., computerized tasks versus a paper-pencil task, test durations between 10 and 16 min, simple reaction time tasks versus a cancellation task) it can be concluded that the deficits observed are not task dependent. Therefore, vigilance measures appear to be sensitive to effects of gum chewing and possibly even, as discussed above, with regard to the dynamics of these effects over time (Taenzer et al., 2009; Tucha, Mecklinger, Maier, et al., 2004).

In summary, despite the fact that gum chewing has been found to have positive effects on cognition in healthy adults, the present study showed that both healthy children and children with ADHD are adversely affected by gum chewing when given a vigilance task. Gum chewing had no impact on sustained attention. Differences between both groups (children with ADHD versus healthy children) and conditions (gum-condition versus no-gum-condition) due to learning or carryover effects could be excluded since statistical analysis revealed no indication of the presence of such effects. The influence of age and gender could also be excluded since the groups did not differ in these variables.

Since the main interest of the present study was to investigate whether gum chewing can add a beneficial effect to the effects of stimulant drug treatment on attention, children with ADHD were on stimulant medication at the time of assessment. This approach might have masked true positive effects children with ADHD might have experienced if they would have been off their stimulant medication. Therefore, the lack of a group of children with ADHD off stimulant medication can be seen as a limitation of the present study. In particular, when considering that the effects reported in previous studies were relatively mild. However, in this context it has to be considered that detrimental effects of gum chewing have also been observed in healthy children. It, therefore, appears to be very unlikely that children with ADHD off medication would have gained a benefit. Nevertheless, the study design of the present examination would have been more complete if a group of children with ADHD off medication would have been included. The detrimental effects of gum chewing as observed in the present study are difficult to explain, since the biological correlates of gum chewing (including increases of cerebral blood flow and heart rate) have been associated with facilitation of cognitive functioning (e.g., Celsis, Agniel, Demonet, & Marc-Vergnes, 1991; Hansen, Johnsen, & Thayer, 2003; Herholz et al., 1987). However, one could speculate that in situations in which intense and continuous concentration is required from an individual, such as cognitive assessments, gum chewing can act as some form of distraction to an individual. Because of this distracting effect of gum chewing, participants might not be able to perform to their best or even show deficits. In studies examining the effects of gum chewing on cognition, participants are usually asked to chew a piece of chewing gum naturally but constantly throughout the whole experiment. This might not necessarily be what participants would normally do when performing cognitive tasks that are experienced as demanding. The instructions given in experiments appear reasonable to assure that participants of different groups or conditions are comparable with regard to the amount of mastication, however participants might perceive these situations as novel and artificial and therefore as very distracting. The suggestion of a distracting effect underlying the detrimental effect of gum chewing on cognition would also fit with the observation that time seems to be an important factor in the psychodynamics of gum chewing. Possibly, participants need some time to get habituated with the novel situation. After an initial habituation phase they might be able to cope with the unusual request to chew gum while performing demanding tests. Consequently, participants are able to perform in their normal range and, in case that there is a facilitating effect of gum chewing on cognition, even better than usual at later stages of assessment. However, at this point this is only speculation. Future research is necessary to clarify the mechanisms causing the detrimental effects of gum chewing on cognition.

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