Chewing gum’s effects on alertness, performance and stress

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Finally, thank you to my teachers.

Declaration

This work has not been submitted in substance for any other degree or award at this or any other university or place of learning, nor is being submitted concurrently in candidature for any degree or other award.

Signed .... (candidate) Date: 29th May 2013

STATEMENT 1

This thesis is being submitted in partial fulfillment of the requirements for the degree of PhD

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This thesis is the result of my own independent work/investigation, except where otherwise stated.
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Contents

List of Tables

List of Figures

Summary

Chewing gum has previously been found to reduce chronic stress and enhance alertness, but effects on attention have been less reliable. The aim of this thesis was to investigate possible mechanisms for such effects, and to study the reliability and timing of effects in greater detail.

Two surveys provided detailed information about habitual gum consumption. Two intervention studies involved chewing gum during a workday and reporting well-being and performance at work; the second intervention also assessed physiological variables. Six experiments studied the timing of and mechanisms for acute chewing gum effects. Two of these experiments studied the prevalence of time-on-task trends in gum effects on attention and mood. A further experiment studied the effects of gum on mood in the absence of attention tasks. The final three experiments examined possible mechanisms for consistent effects of gum on alertness and variable effects on attention: the first concerned psychophysiology, the second concerned demand characteristics, and the third concerned rate of chewing and task order.

The results of this thesis suggest that chewing gum can reliably maintain alertness and enhance reported performance at work. Chewing gum also moderated decrements in vigilance, although the direction of this effect depended on length of prior performance. A reduction of stress and anxiety was observed in some cases, but this finding was less reliable. Under experimental conditions, heart rate increased while chewing gum and began to slow following chewing, suggesting a physiological mechanism for both enhanced alertness and reduced stress. However, heart rate did not differ over the course of a workday. Salivary cortisol was higher during the morning when chewing gum, suggesting an endocrine response associated with higher alertness. Demand characteristics moderated reported alertness, but did not explain any effects on attention. Neither rate of chewing nor task order moderated chewing gum effects.

Chapter 1 Introduction

1.1 General introduction

In a survey of American undergraduate students, nearly 87% reported chewing gum at least occasionally (Britt, Collins, & Cohen, 1999), and 61% of respondents in a survey of full-time workers in the UK indicated that they were gum chewers (Smith, 2009a). Despite its popularity, chewing gum is in some ways an unusual act; it involves the feeding behaviour of chewing without the associated act of digestion. People may chew gum in the belief that it will reduce stress, or that it will aid concentration; in a survey of students by Princeton Review and Wrigley (2005), 41% of those who chewed gum reported doing so to alleviate stress, and 23% did so to improve focus and concentration. Given how widespread chewing gum consumption is, it is worthwhile establishing if these beliefs are well-founded. Positive results would suggest the possible application of chewing gum as a means of reducing stress or enhancing attention.

Chewing gum seems to be associated with reduced chronic stress, but the research on acute stress has been equivocal. A relatively robust effect on acute reported alertness has been found. However, there have been contradictory findings from different studies investigating chewing gum's effects on attention. There are a number of possible mechanisms through which chewing gum may affect stress, alertness and attention, such as brain activity, increased heart rate or demand characteristics. In addition, the length over which gum is chewed may moderate any effects. A more complete understanding of what the psychological effects of chewing gum are, as well as when and why such effects may occur, is thus an interesting topic.

1.2 Objectives of thesis

<u>Objective 1</u>: To review the literature on chewing gum consumption and its effects on stress, alertness and attention.

The first task undertaken was a review of previous research on chewing gum consumption and what effects this might have on stress, alertness and attention. A review of past research allows for estimation of which tasks may be sensitive to effects of chewing gum, but it is necessary to build on existing findings rather than simply attempting to replicate them. For example, although mechanisms for chewing gum effects have been suggested, they have rarely been empirically investigated in past research.

Objective 2: To investigate people's general consumption of chewing gum and its correlates.

Research that manipulates chewing gum (e.g. experimental work) has to be put in the context of the nature of gum consumption in everyday life, to ensure that gum manipulations have external validity. In addition to reviewing previous survey research, original survey data were collected using both students and workers as respondents. If chewing gum affects chronic stress, associated problems such as anxiety and depression may be related habitual consumption of chewing gum, so these factors were also measured.

Objective 3: To observe what effects chewing gum may have over the workday.

The acute effects of constantly chewing for a short period of time may differ from regular chewing, with breaks, over the course of the day. Consequently, intervention research is needed to investigate if gum chewing affects stress and performance in an everyday (e.g. occupational) context. Although this has already been examined for interventions lasting from three days to two weeks, it is of interest if a shorter intervention can show comparable effects.

Objective 4: To test the acute effects of chewing gum on attention, anxiety and alertness.

Given that some of the experimental findings on the effect of gum on attention and anxiety have been fragile, further investigation could shed light on the robustness of such effects. Although an effect of gum on alertness has been repeatedly observed following cognitive performance, the robustness of an alerting effect can be probed by testing alertness without cognitive performance, as well as testing if an alerting effect persists for long after chewing has ceased.

Objective 5: To find what mechanisms might enable chewing gum to have such observed effects.

Any account of the effects of chewing gum would be incomplete without an explanation for how such effects are brought about. For example, there are a number of possible ways in which chewing gum could affect reported alertness and attention, such as physiological arousal or demand characteristics. Furthermore, enhanced alertness could explain positive effects on attention.

Research manipulating demand characteristics can ascertain if they have a strong effect on reported mood and performance on attention tasks. The assessment of psychophysiology could establish if factors such as increased heart rate are associated with enhancement of attention and alertness. The rate of chewing may also influence the presence of effects, although the nature of tasks being performed may also affect the rate of chewing. The plausibility of these mechanisms is put to the test in the research described in this thesis.

Objective 6: To ascertain if the effects of chewing gum vary over time.

Some previous studies have suggested that chewing gum may only affect alertness, stress and aspects of attention after a certain amount of time chewing. It is of interest if this effect applies for other attention tasks. Where time-on-task trends do exist, it may also be the case that they interact with the mechanisms which lead chewing gum to alter stress, alertness and attention. For example, gum chewing may lead to an increase in heart rate which in turn attenuates a fall in vigilance, but only over time.

1.3 Outline of thesis

Chapter 2 reviews previous research on the effects of chewing gum, alertness, cognitive performance and stress. Plausible mechanisms for effects and the possibility of time-on-task trends in effects are discussed.

Chapter 3 reports surveys investigating habitual patterns of chewing gum consumption and associated well-being in both student and worker samples.

Chapter 4 concerns interventions with chewing gum to assess the effects of gum chewing over a workday on worker performance and well-being, as well as associated physiology.

Chapter 5 opens the discussion of experimental research with two experiments assessing the prevalence of time-on-task trends in chewing gum effects on attention and mood.

Chapter 6 concerns a study assessing the effect of chewing gum on mood in the absence of concurrent cognitive performance tasks.

Chapter 7 is the first chapter studying mechanisms for chewing gum effects, with a report on an experiment into the effects of chewing gum during vigilance performance on underlying physiological factors (heart rate and EEG) that could explain self-reported and behavioural effects of gum.

Chapter 8 outlines an experimental study which manipulated demand characteristics and assessed attitudes towards the effects of chewing gum.

Chapter 9 describes an experiment assessing the rate of gum chewing, in order to ascertain if this may explain individual differences in chewing effects. This experiment also manipulated the order in which attention tasks were presented.

Chapter 10 is a general discussion of the empirical work outlined in the main body of the thesis: how it compares to previous research, what are its strengths and shortcomings, and how future research may expand on the findings outlined in the course of this work.

1.4 A note on ethical approval

All research described in this thesis received approval from Cardiff University’s School of Psychology Ethics Committee.

Chapter 2 Previous research and possible mechanisms[1]

In order to address the objectives described in the previous chapter, it is important to first place the research questions in context by reviewing previous literature. In light of past research, mechanisms for effects of chewing gum on mood, attention and stress are suggested.

2.1 Search methodology for review of relevant literature

ScienceDirect, PubMed and Google Scholar were used as search engines. The search term "chewing gum" was used along with "stress", "anxiety", "alertness", "cognition", "attention", "reaction time" and "vigilance". References within papers were checked for useful research. In addition, papers which had previously been made available to the author were reviewed.

Papers reviewed in this chapter described original research concerning the effects of chewing gum on cognition, stress, and mood. Papers that examined factors which could contribute to gum effects on cognition, stress and mood without examining such effects directly were excluded. Review articles which did not describe original research were excluded, as was research which primarily concerned nicotine chewing gum, given the psychopharmacological effects of nicotine. Number of papers excluded and included are summarise in Figure 2.1. Many of the papers excluded from the main review are referred to in this thesis.

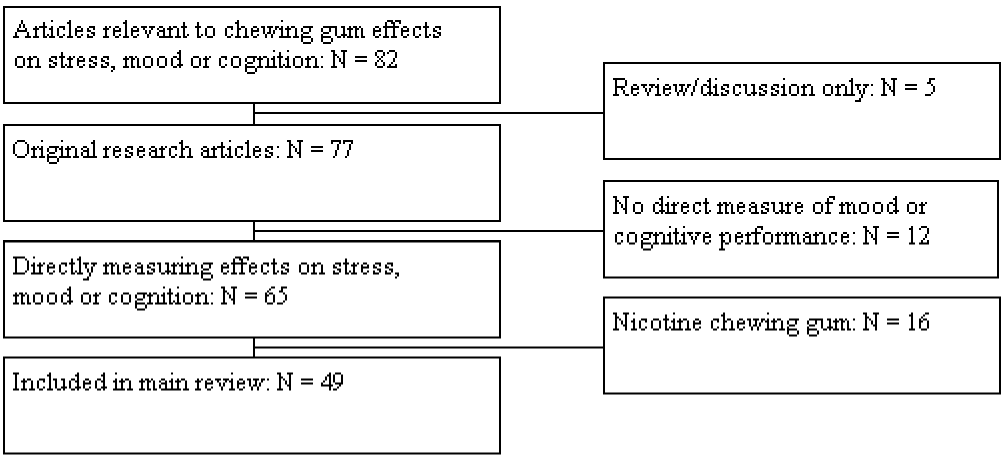

Figure 2-1: Flow chart of inclusion/exclusion of paper for main body of literature review

[1] This chapter is an extended version of Allen, A.P. & Smith, A.P. (2011). A review of the evidence that chewing gum affects stress, alertness and cognition. *Journal of Behavioral and Neuroscience Research 9*(1), 7-23

2.2 Chewing gum and alertness

Although Torney, Johnson and Miles (2009), Sketchley-Kaye, Jenks, Miles and Johnson (2011) and Gray, Miles, Wilson, Jens, Cox and Johnson (2012) failed to find a significant effect of chewing gum on self-reported alertness, such an effect of chewing gum has been found on pre-test alertness (Smith, 2009b, 2010), and on post-test alertness (Johnson, Jenks, Miles, Albert, & Cox, 2011; Johnson, Muneem, & Miles, 2012; Scholey et al., 2009; Smith, 2009b, 2009c, 2010). Chewing gum has been found to reduce a fall in alertness induced by a vigilance task (Morgan, Johnson, & Miles, 2013). Another study found that chewing gum did not moderate a fall in self-reported alertness, although self-rated sleepiness in the gum condition increased to a lesser extent than in the no-gum control (Johnson, Miles, et al., 2012). This study differed from others in that it did not involve a response-demanding cognitive performance task; participants had to stare at an infrared dot in a darkened lab while resting their heads on a chin rest. In addition to increasing alertness compared to a no-gum control, chewing menthol gum increased alertness in participants with cold symptoms, who generally reported lower alertness than healthy participants (Smith & Boden, 2012). Chewing gum may thus be specifically useful for restoring alertness when it has been depleted. The lack of an alerting effect in Sketchley-Kaye et al. and Gray et al. may be due to their use of an efficient psychosocial stressor which was not associated with a fall in alertness.

In an intervention study involving two weeks of chewing gum and two weeks of avoiding gum, chewing gum reduced fatigue in a sample of workers (Smith, Chaplin, & Wadsworth, 2012), although Smith and Woods (2012) did not find a significant effect of gum chewing on tiredness in students. This suggests that an alerting effect of gum may be visible over longer periods of chewing, although further research on this is required.

Despite some evidence to the contrary, chewing gum generally exerts a positive effect on subjective alertness, and particularly post-test alertness (see Table 2-1). As this effect appears to be quite robust, one might expect attention to be enhanced by chewing gum. However, the mixed findings from cognition discussed below indicate that chewing gum’s enhancing of subjective alertness may not necessarily translate into effects on cognitive performance.

Table 2-1: Findings from research on chewing gum and reported alertness

	Dependent variable	Design	Time of day	Sample	Habitual gum & smoking	Significant Effect	Effect size[2]	Chewing gum	Gum before or during task	Order of tasks
Gray et al. (2012)	Alertness	Independent measures (gum, no gum)	15.00-17.00	N = 40 (M = 20, F = 20), Age: M = 20 & 3 months	Non-smokers	No	0.09[3]	1 piece Wrigley's Extra Spearmint 3 times (10 + 10 + 10 minutes total)	During Trier prep, present-ation and recovery	Initial mood, Trier social stress, post-stress mood, mood again 10 minutes post-stress
Johnson et al. (2011)	Alertness	Crossover (gum, no gum)	11.00-13.00	N = 30 (M = 9, F = 21) Age: M = 21.24	Regular chewers, chewed less than ten times per week. Non-smokers	No	0.17[4]	Mint for 20 minutes	During	Mood tasks before and after stressful multitasking task
Johnson, Miles, et al. (2012)	Alertness	Crossover (gum, no gum, sham chewing)	14.00-17.00	N = 30 (M = 9, F = 21) Age: M = 21 & 7 months	Habitual gum n/a. Non-smokers	Increase	0.03[4] 0.17[5]	1 piece Wrigley's Extra Spearmint for 11 minutes	During	Mood tasks before and after PUI measurement
Johnson, Muneem et al. (2012)	Alertness (pre-test)	Crossover (gum, no gum)	n/a	N = 20 (M = 10, F = 10) Age: M = 21 & 10 months	n/a	No	0.24	One piece Wrigley's Cool Breeze for 13 minutes	During	Mood tasks before and after SART
	Alertness (post-test)					Increase	1.95			

[2] Effect sizes were calculated by dividing the difference of mean scores for gum and no chewing control by their mean standard deviations (except where otherwise indicated)
[3] Partial eta squared for main effect of gum condition
[4] Partial eta squared for interaction between gum and experimental stage
[5] Partial eta squared for main effect of gum condition

Morgan et al. (2013)	Alertness	Independent measures (gum, no gum)	9.00-17.00	N = 40 (M = 38, F = 2) Age: M = 19.8, range = 18 & 3 months- 22 & 6 months	n/a	Increase	0.31[6]	1 piece Wrigley's sugarfree spearmint for 30 minutes	During	Mood tasks before and after Bakan vigilance task
Scholey et al. (2009)	Alertness	Crossover (gum, no gum)	n/a	N = 40, (M = 8, F = 32)[7] Age: M = 22, SD = 4.79	Gum at least once in previous week (25% chewed 1-3 pieces, 57.5% chewed 4-9, 17.5% chewed 10+). Non-smoking	Increase	0.4 (LI) 0.36 (MI)	Choice of available flavours 20 minutes[8] (34 chose mint flavour, 4 cherry, 1 liquorice, 1 menthol & eucalyptus)	During	Mood tasks before and after stressful multitasking task
Sketchley-Kaye et al. (2011)	Alertness	Independent measures (gum, no gum)	11.00-14.00	N = 36 (M = 5, F = 31), Age: M = 20 years 5 months	Regular chewers, chewed less than ten times per week. Non-smokers	No	0.06[9]	1 piece Wrigley's Extra Spearmint 3 times (10 + 10 + 5 minutes)	During Trier prep, present-ation and recovery	Initial mood, Trier social stress, post-stress mood, mood again 10 minutes post-stress
Smith (2009b)	Alertness (pre-test)	Independent measures (gum, caffeinated gum, no gum)	Test session: 16.00-17.00	N = 120, (M = 60, F = 60), Age: range = 18 - 30	Excluded if lower than "at least occasional"	Increase	0.69	Two pieces of mint gum for 20 minutes	Before	Random order of performance tasks (repeated digits vigilance, simple RT,

[6] Partial eta squared for main effect of gum, using pre-test scores as covariate
[7] Number of males and females
[8] There were two 20-minute gum sessions, but these took place on different days
[9] Partial lambda squared for main effect of gum

					gum chewers or smoked > 5 cigarettes in the daytime					choice RT, focused attention, categoric search)
	Alertness (post-test)					No	0.21			
Smith (2009c)	Alertness (pre-test)	Crossover (control v. gum at learning and/or test) Measured on two weeks	n/a	120 (Gender & age n/a)	Gum habit n/a. Excluded if smoked > 10 cigarettes in the daytime and evening	No No	<u>Week 1</u> 0.04 <u>Week 2</u> 0.16	Choice of available flavours (numbers n/a) for 35 minutes (if chewing during both learning and recall)	During	Mood, recall, logical reasoning, semantic processing, delayed recall, recog. memory, story recall, mood (*part 1*) mood, story recall, Alice Heim task, mood (*part 2*)
	Alertness (post-test)					Increase No	<u>Week 1</u> 0.47 <u>Week 2</u> 0.32			
Smith (2010)	Alertness (pre-test)	Crossover (gum, no gum)	Start time at 10.00, 11.30, 15.00, 16.30, 18.00, 19.30	N = 133, (M = 64, F = 69), Age: M = 22.6, SD = 4.4	62 chewed more than one pack per week, 71 chewed less. Excluded if smoked > 10 cigarettes per day	Increase	0.24	Spearmint or Juicy fruit 90 minutes	During	Mood, immediate and delayed free recall, delayed recognition, logical reasoning, spatial memory, semantic processing, simple RT, focussed attention, categoric search, repeated-digits vigilance
	Alertness (post-test)					Increase	0.35			
Smith & Boden	Alertness (visit 1)	Crossover (gum, no gum)	n/a	N = 31 (M = 6, F = 25),	n/a	Increase	0.23	Airwaves for 15 minutes	During	Mood, simple reaction time,

(2012)				Age: M = 20.8				(cherry, black mint, green mint and menthol & eucalyptus)		repeated digits vigilance, mood
	Alertness (visit 2)					Increase	0.2			
Torney et al. (2009)	Alertness	Independent Measures (gum, no gum)	n/a	N = 40 (M = 20, F = 20), Age: M = 20, 11 months	n/a	No	0.01[10]	1 piece Wrigley's Spearmint for 10 minutes + time to complete mood tasks	During	Mood tasks before and after stressful/non-stressful anagram tasks

[10] Partial eta squared for main effect of gum

2.3 Chewing gum and cognitive performance

A review of the research with both humans and non-human animals has indicated that impaired mastication can lead to impaired cognition (Weijenberg, Scherder, & Lobbezoo, 2011). The chewing of gum in particular has been examined for its effects on a number of aspects of cognitive performance. Some of this research has been conducted in educational settings. Allen, Galvis and Katz (2006) found a slight improvement in exam performance between students who chewed gum during a lecture and those who did not. However, such an improvement was not observed in another study after controlling for Grade Point Average and gender (Allen, Norman, & Katz, 2008). Another study required US high school students to chew gum or avoid gum during maths classes (Johnston, Tyler, Stansberry, Moreno, & Foreyt, 2012). The chewing group performed better at a standardised test aligned with the state curriculum, although there was no group difference for performance on a more general maths assessment task. This suggests that chewing gum may have enhanced encoding of information learnt in class, rather than improving general cognitive performance or ability.

Given the effect of gum on subjective alertness, one might expect attention to be enhanced and reaction time to be shortened by chewing. In line with the tentative findings that chewing gum can enhance learning, much experimental research has also been conducted on chewing gum and memory. The observed effects of gum on these specific aspects of cognitive performance are described below.

2.3.1 Chewing gum and attention

The effect of chewing gum on various types of attention has been assessed. These forms of attention include sustained attention, i.e. directing attention to information for a relatively long period of time, vigilance, i.e. a form of sustained attention which involves the detection of occasionally-occurring target stimuli, selective attention, i.e. attention maintained in the presence of distracting stimuli, and divided attention, i.e. simultaneous attention to multiple tasks (Van Zomeren & Brouwer, 1994).

In an experiment by O. Tucha et al. (2004), chewing gum led to an improvement in performance on a computerised test of sustained attention taken from a battery of cognitive performance tasks (Zimmerman & Fimm, 2001). Smith (2010) found a positive effect for a repeated digits vigilance task, although a main effect of gum on a sustained attention task (taken from Zimmerman & Fimm, 1993) was not observed in an experiment by L. Tucha and Simpson (2011). Performance on the DL-KG test (Kleber, Kleber, & Hans, 1999) (a 16-minute concentration task which required participants to either cross or dot symbols), was higher towards the end of the task when participants (schoolchildren aged eight to nine) chewed gum (Tänzer, von Fintel, & Eikermann, 2009). The fact that participants were together in class would undermine the independence of the observations, and suggests that a multilevel models analysis for hierarchical data would have been more appropriate (c.f. Field, 2009). Johnson, Muneem and Miles (2012) observed a positive effect of chewing gum on performance of a sustained attention task (the sustained attention response task or SART; Robertson & Manly, 1997).

Johnson et al. (2011) did not find a significant effect of gum on divided attention (assessed using a multi-tasking framework), although performance on a similar framework was improved by gum for Scholey et al. (2009). Two tasks used in Johnson et al.'s multi-tasking framework (auditory monitoring and visual tracking) differed from those used in that of Scholey et al. (visual monitoring and Stroop), although both frameworks used four tasks in total, both included a mental arithmetic and memory search task. O. Tucha et al. (2004) did not find a significant effect on reaction time or accuracy for a divided attention task.

With regard to selective attention, chewing gum led to wider breadth of attention (Smith, 2010). Chewing gum also led to faster encoding of information on the focused attention task, and was associated with shortened reaction times on a categoric search task. However, the same effects had not been demonstrated in earlier work looking at the after-effects of chewing (Smith, 2009b). O. Tucha et al. (2004) did not find a significant effect of gum on a selective attention task.

To summarise, there is mixed evidence for an effect of chewing gum on vigilance and divided and selective attention. There is some evidence that sustained attention may be improved, perhaps particularly later in a task (see Section 2.7 for further discussion). Table 2-2 below summarises the relevant findings.

Table 2-2: Findings from research on chewing gum and attention

	Dependent variable	Design	Time of Day	Sample	Habitual gum & smoking	Significant Effect	Effect size	Chewing gum	Gum before or during task	Order of tasks
Johnson et al. (2011)	Divided attention (Multi-tasking)	Crossover (gum, no gum)	11.00-13.00	N = 30 (M = 9, F = 21) Age: M = 21.24	Regular chewers, chewed less than ten times per week. Non-smokers.	No	n/a	Mint for 20 minutes	During	Mood tasks before and after stressful multitasking task
Johnson, Muneem et al. (2012)	Sustained attention (SART) correct withhold of response	Crossover (gum, no gum)	n/a	N = 20 (M = 10, F = 10) Age: M = 21 & 10 months	n/a	Increase	0.49[11]	One piece Wrigley's Cool Breeze for 13 minutes	During	Mood tasks before and after SART
	SART RT					Reduction	0.52[11]			
Scholey et al. (2009)	Divided attention (Multi-tasking)	Crossover (gum, no gum)	n/a	N = 40, (M = 8, F = 32)[12] Age: M = 22, SD = 4.79	Gum at least once in previous week. (25% chewed 1-3 pieces, 57.5% chewed 4-9, 17.5% chewed 10+) Non-smoking	Increase	0.27 (LI) 0.29 (MI)[13]	Choice of flavours for 20 minutes[14] (34 chose mint flavour, 4 cherry, 1 liquorice, 1 menthol & eucalyptus)	During stressful task	Mood tasks before and after stressful multitasking task
Smith (2009b)	Repeated digits vigilance RT	Independent measures (gum,	Test session: 16.00-	N = 120, (M = 60, F = 60), Age: range = 18	Excluded if lower than "at least	No	0.04	Two pieces of mint gum for 20	Before	Random order of performance tasks (repeated digits

[11] Partial eta squared for main effect of gum
[12] Number of males and females
[13] LI = low intensity, MI = medium intensity
[14] There were two 20-minute gum sessions, but these took place on different days

		caffeinated gum, no gum)	17.00	- 30	occasional" gum chewers or smoked > 5 cigarettes in the daytime			minutes		vigilance, simple RT, choice RT, focused attention, categoric search)
Smith (2010)	Sustained attention hits	Crossover (gum, no gum)	Start time at 10.00, 11.30, 15.00, 16.30, 18.00, 19.30	N = 133, (M = 64, F = 69), Age: M = 22.6, SD = 4.4	62 chewed more than one pack per week, 71 chewed less. Excluded if smoked > 10 cigarettes per day	Increase	0.25	Spearmint or Juicy fruit for 90 minutes	During	Mood, immediate and delayed free recall, delayed recognition, logical reasoning, spatial memory, semantic processing, simple RT, focussed attention, categoric search, repeated-digits vigilance
	Sustained attention RT for hits					No	0.13			
	Focussing of attention					Reduction	0.46			
	Focussed attention errors					No	<0.01			
Tänzer et al. (2009)	DL-KG test (1999)	Independent measures (gum, no gum)	n/a	N = 86 (Gender n/a) Age: range = 8-9	n/a	Increase (later in task)	0.07[15]	Strawberry for 16 minutes	During	One task
Tucha et al. (2004a) *(Experiment 1)*	Divided attention	Crossover (flavoured gum, flavourless gum, sham chewing, no chewing)	n/a	N = 58 (M = 29, F = 29) Age: M = 22.9 SD = 4.6	n/a	No	0.06	1 piece spearmint (unspecified sweetener) for 40 minutes	During	Attention tasks randomised, start and end with recall tasks.

[15] Partial eta squared for interaction between gum condition and phase of task

Tucha et al. (2004a) *(experiment two)*	Sustained attention RT	Crossover (flavoured gum, flavourless gum, sham chewing, no chewing)	n/a	N = 58 (M = 29, F = 29,) Age: M = 22.2 SD = 2.3	n/a	Reduction	0.5	1 piece spearmint (unspecified sweetener) for 80 minutes	During	Attention tasks randomised, start and end with recall tasks. Vigilance was after the other attention tasks.
	Vigilance RT					No	0.07			
Tucha & Simpson (2011)	Vigilance RT	Crossover (gum, no gum)	n/a	N = 42 (M = 21, F = 21) Age: M = 22, SD = 2.4	n/a	Increase (later in task)	0.11[15]	1 piece sugarfree spearmint for 30 minutes	During	One task
Wilkinson et al. (2002)	Digit Vigilance Accuracy	Independent Measures (gum, no gum, sham chewing)	n/a	N = 75 (Gender n/a) Age: M = 24.6	n/a	No	0.06	One piece Wrigley's Extra Spearmint for 3 minutes	Before	Immediate Word Recall, Simple RT, Digit Vigilance, Choice RT, Spatial WM, Numeric WM, Delayed Word Recall, Word Recognition and Picture Recognition
	Digit Vigilance RT					No	0.19			

2.3.2 Chewing gum and reaction time

There is evidence that chewing gum does not shorten simple reaction time (Smith, 2009b, 2010) to a variable fore-period reaction time task using visual stimuli, and Wilkinson et al (2002) did not observe a significant effect of chewing gum on simple reaction time or choice reaction time to visual stimuli. In two experiments by O. Tucha et al. (2004), a spearmint gum condition led to significantly lengthened tonic alertness reaction time compared to a no-chewing control (c.f. Zimmerman & Fimm, 2001).

With regard to the effect of chewing gum before testing on reaction time, Sakamoto, Nakata and Kakigi (2009) found that reaction time was shortened compared to baseline for three post-chewing gum sessions on an auditory oddball task. This pattern was not evident in a control group, who were instructed to relax (a possible confound) without chewing gum. Rhythmic jaw movement and finger tapping in a second experiment did not produce similar effects in reaction time to chewing gum in the first experiment, suggesting that the effect of chewing is not simply due a general effect of motor activity. It should be noted, however, that more than half of the participants in the second experiment had also participated in the first experiment, so the lack of a difference between conditions in the second experiment could be due to practice on the oddball task. Another experiment on prior chewing has similarly indicated that reaction time is shortened over repeated sessions following chewing gum and increases over repeated control sessions (Sakamoto, Nakata, Honda, & Kakigi, 2009).

Overall, the research suggests that prior chewing gum shortens simple reaction time to an auditory stimulus, but current gum chewing may have lengthening effect or no effect on reaction time to a visual stimulus. Table 2-3 below summarises the relevant findings.

Table 2-3: Findings from research on chewing gum and reaction time (RT)

	Dependent variable	Design	Time of Day	Sample	Habitual gum and smoking	Significant Effect?	Effect size	Chewing gum	Gum before or during task	Order of tasks
Sakamoto, Nakata et al. (2009)	Auditory oddball RT	Crossover (gum, no gum)	n/a	N = 11, (M = 8, F = 3) Age: M = 30.9, range = 24-42	n/a	Reduction	1.42[16]	Flavourless gum base (containing polyvinyl acetate, wax, and polyisobutylene) 15 minutes (Three 5-minute sessions)	Before	One task
Sakamoto, Nakata, Honda et al. (2009)	Warning-imperative stimulus RT	Crossover (gum, no gum)	Same time of day (n/a) for each condition	N = 12 (M = 12), Age: M = 28.4, range = 25-34.	n/a	No	n/a	Flavourless gum base (as above) for 15 minutes (Three 5-minute sessions)	Before	One task
Smith (2009b)	Simple RT	Independent measures (gum, caffeinated gum, no gum)	Test session: 16.00-17.00	N = 120, (M = 60, F = 60), Age: range = 18 - 30	Excluded if lower than "at least occasional" gum chewers or smoked > 5 cigarettes in the daytime	No	0.03	Two pieces of mint gum for 20 minutes	Before	Random order of performance tasks (simple RT, choice RT, focused attention, categoric search, vigilance)
	5 choice serial RT					Increase	0.22			
Smith (2010)	Simple RT	Crossover (gum, no gum)	Start time at 10.00, 11.30, 15.00, 16.30,	N = 133, (M = 64, F = 69), Age: M = 22.6,	62 chewed more than one pack per week, 71 chewed less. Excluded	No	0.02 (variable fore-period) 0.09	Spearmint or Juicy fruit for 90 minutes	During	Mood, immediate and delayed free recall, delayed recognition, logical reasoning, spatial

[16] Comparing differences between RT following third chewing and control session and pre-test RT

			18.00, 19.30	SD = 4.4	if > 10 cigarettes per day		(fixed fore-period)			memory, semantic processing, simple RT, focussed attention, categoric search, repeated-digits vigilance
	Focused attention RT					No	0.1			
	Categoric search RT					Reduction	0.2			
Tucha et al. (2004a) *(Experiment 1)*	Tonic alertness RT	Crossover (flavoured gum, flavourless gum, sham chewing, no chewing)	n/a	N = 58 (M = 29, F = 29) Age: M = 22.9 SD = 4.6	n/a	Increase	0.42	1 piece spearmint (unspecified sweetener) for 40 minutes	During	Attention tasks randomised, start and end with recall tasks.
	Phasic alertness RT					No	0.05			
	Divided attention RT					No	0.06			
	Selective attention RT					No	0.16			
Tucha et al. (2004a) *(Experiment 2*)	Tonic alertness RT	Crossover (as above)	n/a	N = 58 (M = 29, F = 29,) Age: M = 22.2 SD = 2.3	n/a	Increase	0.45	1 piece spearmint (unspecified sweetener) for 80 minutes	During	Attention tasks randomised, start and end with recall tasks.

	Phasic alertness RT					No	0.09			
Wilkinson et al. (2002)	Simple RT	Independent Measures (gum, no gum, sham chewing)	n/a	N = 75 (Gender n/a) Age: M = 24.6	n/a	No	0.16	1 piece Wrigley's Extra Spearmint for 3 minutes	Before	Immediate Word Recall, Simple RT, Digit Vigilance, Choice RT, Spatial WM, Numeric WM, Delayed Word Recall, Word Recognition and Picture Recognition
	Choice RT					No	>0.01			
	Choice RT Accuracy					No	0.1			

2.3.3 Chewing gum and memory

Immediate and delayed word recall have been found to be better in a gum condition than in a no-gum control (Baker, Bezance, Zellaby, & Aggleton, 2004, Experiment 1; Wilkinson, Scholey, & Wesnes, 2002). Similarly, Stephens and Tunney (2004a) found that chewing gum led to an improvement in immediate recall and delayed recall when compared to sucking a sweet (suggesting that an effect may not be purely due to flavour). However, later research has not supported a facilitating effect of gum on word recall (Smith, 2009c, 2010; O. Tucha et al., 2004). Smith (2009c) also found that chewing gum did not improve memory of a more complex and meaningful stimulus (recall of a story).

A possible explanation for this disparity in findings has come from Aggleton (personal communication cited in Scholey, 2004), who suggested that a change in context may induce disparities in recall, as the flavour and texture of chewing gum can change between learning and recall. There is some evidence that chewing gum induces context-dependent memory effects (i.e. if participants chew gum in the learning trial, their recall will be improved by chewing gum during recall) (Baker et al., 2004, Experiment 1; Miles, Charig, & Eva, 2008). The research in maths classes conducted by Johnston et al. (2012) also indicated the possibility of context-dependent recall. Furthermore, where different amounts of gum can be given to participants (one piece versus four pieces), memory is better where the same number are chewed at learning and recall (Rickman, Johnson, & Miles, 2012).

However, other research has failed to find a context-dependent effect of chewing gum. Two separate experiments by Johnson and Miles (2008) showed that although flavourless gum and mint-flavoured strips led to reported change in current mouth activity and mint intensity respectively, they did not induce context-dependent memory, which indicates that neither flavour nor the sensation of chewing leads to context effects in memory. Overman, Sun, Golding and Prevost (2009) did not find a difference between chewing gum and sucking a sweet with the same flavour on context-dependent memory (where context was the oral activity undertaken during learning). In addition to failing to find an effect on context-dependent memory in two experiments, Miles and Johnson (2010) also found no context effect of gum on number of errors in recall. It should be noted that gum was only chewed for a short amount of time in these experiments, compared to other investigations of the cognitive effects of chewing gum.

With regard to working memory, Stephens and Tunney (2004a) found that chewing gum (compared to sucking a sweet) led to an improvement in digit span and spatial span. Hirano et al. (2008) found that performance on two *n*-back tasks (2-back and 3-back) improved following chewing gum. However, Wang et al. (2009) failed to find an effect of chewing on *n*-back performance. Stephens and Edelstyn (2011) found a positive effect of gum for digit and spatial span, but only under conditions of greater difficulty (a dual-task version of the working memory tasks).

In summary, although chewing gum has previously been found to improve recall, later studies have not indicated such an effect. Some initial findings that chewing gum has a context-dependent effect on memory have not been replicated elsewhere. There is also some evidence for an effect on working memory, although it may be dependent on level of difficulty. The research on chewing gum and memory has been quite extensive, without arriving at any clear overall conclusions. Consequently, this thesis does not aim to investigate the effects of chewing gum on memory further.

2.4 Findings from electrophysiological studies

Sakamoto, Nakata & Kakigi (2009) found that chewing gum had an effect on event-related potentials (ERPs) when participants performed an auditory oddball task. The P300 component of the EEG was affected by chewing gum; this component has been associated with recognition and classification of stimuli (Hillyard, 1999), and its latency has been described as being associated with speed of encoding stimuli (Kutas, McCarthy, & Donchin, 1977). Consequently, the effect of gum suggests that the observed shortened reaction time was due to faster stimulus evaluation, rather than faster response selection. Similarly, Sakamoto et al. proposed that the effect of gum on N100 represented an effect of chewing on target detection processing. Sakamoto et al. offered hypotheses as to why the ERP data was different in the chewing gum trials, including increased arousal. It is of interest if changes in heart rate as well as central nervous system arousal may be associated with chewing gum effects on attention.

Other ERP research has indicated that chewing flavourless gum leads to increased amplitude in contingent negative variation (CNV) (an ERP which is associated with cognitive processing, motivation and expectancy), but not in movement-related cortical potentials (MRCPs) (which are associated with movement preparation processing) (Sakamoto, Nakata, Honda, et al., 2009). The change in CNV was observed during a second and third post-chewing session, so the effect took time to occur. As with the effects on P300 and N100, Sakamoto et al. speculated that the observed effect may be due to an increase in arousal.

Other EEG research has looked at gum chewing *per se*, rather than the effects of chewing gum during a cognitive task. Masumoto, Morinushi, Kawasaki, and Takigawa (1998) found that alpha frequencies were higher at T3, F3 and F4 in a post-chewing recording than during the control, using spearmint gum. Findings from a later experiment indicated that chewing flavourless and odourless gum base leads to increased alpha and theta activity, and that chewing gum base with sucrose leads to increased alpha activity but reduced beta activity (Masumoto, Morinushi, Kawasaki, Ogura, & Takigawa, 1999). Masumoto et al. found no significant effects for chewing gum with spearmint oil (although this may not generalise to marketed mint gum, which often contains sweeteners). They interpreted their findings as indicating that chewing gum base will lead to arousal, while chewing gum base with sucrose will lead to relaxed concentration. The interpretation that chewing gum with sucrose leads to relaxed concentration is consistent with findings that indicate that chewing gum increases self-reported alertness (see Section 2.2) and reduces chronic stress (see Section 2.5). Morinushi, Masumoto, Kawasaki and Morikuni (2000) replicated the finding that chewing gum base with sucrose leads to increased alpha and decreased beta activity.

Further evidence has indicated differences between flavoured and flavourless chewing gum using source modelling (Yagyu et al., 1998). The alpha-2 band (10.5 - 13Hz) mean source shifted anterior (suggesting drowsiness) and right (suggesting positive affect) after flavoured gum and shifted posterior and left after flavourless. The flavoured gum Yagyu et al. used was “Relax gum”, which is available in Japan and contains herbal essence oils such as valerian, liquorice, lavender and perfumes such as lemon, peppermint and lavender. The presence of a number of different flavours makes it difficult to speculate on which flavour or combination thereof was key to the observed effect, and whether or not this would generalise to gum with a single mint flavour.

Electrophysiological research has indicated mixed evidence for an effect of chewing gum on EEG frequency, although differing findings may be due to differences between flavoured and flavourless gum. ERP research has allowed for the closer examination of an effect of gum on reaction time, with the evidence suggesting an effect of gum on speed of encoding of stimuli. Only two of the reviewed papers included complementary behavioural data (Sakamoto, Nakata, Honda, et al., 2009; Sakamoto, Nakata, & Kikigi, 2009); these do not include any of the experiments examining the effect of chewing on general EEG frequency, so further research is required to ascertain if change in EEG activity are associated with improved cognitive performance.

EEG data are typically screened for artefacts such as movement which can make them difficult to analyse. The need to reduce or avoid motion artefacts has meant that research on chewing gum using EEG measures has been more likely to measure performance after chewing gum rather than during chewing, when compared to research using purely behavioural measures. In addition, in purely behavioural research control groups have tended to involve performance of a cognitive task without chewing gum, whereas control groups in EEG have often involved sitting quietly. These factors should be borne in mind when comparing studies that used electrophysiological techniques to studies that did not. The findings from EEG studies are summarised in Table 2-4.

Table 2-4: Findings from EEG research on the effects of chewing gum

	Design	Time of Day	Sample	Habitual gum and smoking	Effect of chewing gum	Effect size	Chewing gum	Complementary behavioural task	Gum before or during task	Order of tasks
Masumoto et al. (1998)	Repeated measures (gum, rest)	17.00-19.00	N = 11, (M = 7, F = 4) Age: M = 28.1, range = 24-32	n/a	No EEG effect	n/a	Spearmint gum with sugar for 3 minutes	None	Before (1 minute rest between gum and measure)	No behavioural task
Masumoto et al. (1999)	Repeated measures (gum, rest)	17.00-19.00	N = 20, (M = 11, F = 9) Age: M = 28.8, range = 24-34	Had not smoked since lunch	No EEG effect	n/a	Spearmint oil, 3 minutes per flavour	None	Before (1 minute rest between gum and measure)	No behavioural. task
					Higher α at T3	0.89	Sucrose			
					Increased β at T3	1.17	Flavourless			
Morinushi et al. (2000)	Repeated measures (gum, rest)	17.00-19.00	N = 9, (M = 6, F = 3) Age: range = 27-33	No smoking for six hours before testing	Higher α and lower β activity	n/a	Sucrose, 3 minutes per flavour	None	Before (1 minute rest between gum and measure)	No behavioural. task
					Higher α and β activity	n/a	Prepared flavour (see text)			
Sakamoto, Nakata et al. (2009)	Crossover (gum, no gum)	n/a	N = 11, (M = 8, F = 3) Age: M = 30.9, range = 24-42	n/a	Shorter peak latency of P300 post-chewing	0.59[17]	Flavourless gum base (containing polyvinyl acetate, wax, and polyisobutylene for 15 minutes (Three 5-minute sessions)	Auditory oddball	Before	One task

[17] Epsilon for gum condition X session interaction

					Shorter peak latency of N100 post-chewing	0.81[18]				
Sakamoto, Nakata, Honda et al. (2009)	Crossover (gum, no gum)	Same time of day (n/a) for each condition	N = 12 (M = 12), Age: M = 28.4, range = 25-34.	n/a	Increased amplitude for CNV but no effect on MRCPs	n/a	Flavourless gum base (as above) 15 minutes (Three 5-minute sessions)	Warning-imperative stimulus RT	Before	One task
Yagyu et al. (1998)	Repeated measures (gum, no gum, gum with theanine, RELAX gum	2-3 hours after last meal	N = 20 (M = 20), Age: M = 24.9, SD = 4.9, range = 19-37	n/a	Reduced global omega complexity (GOC) and no effect on global dimensional complexity (GDC)	n/a	Flavourless, 5 minutes per flavour	None	Before	No behavioural task
					Reduced GOC and no effect on GDC		Theanine			
					Reduced GOC and no effect on GDC		RELAX gum (containing sugar and herbal essence oils and perfumes)			

[18] Epsilon for gum condition X session interaction

2.5 Chewing gum and stress

2.5.1 The concept of stress

The personal and economic cost of stress is great; statistics published on the HSE website have indicated that out of 1,152,000 cases of work-related illnesses in the UK in 2010/2011 there were 400,000 cases of stress (HSE, 2012). Similarly, a survey of undergraduate students by Princeton Review and Wrigley (2005) indicated that 85% of students experienced tension and stress at exam times. However, the ideas underpinning the concept of stress warrant further discussion.

Researchers and theorists of stress have differed in the extent to which they have focussed on stress as an external stimulus, an internal process of the person/organism, or an interaction between the two (Fisher, 1986). The concept of "stress" has been attacked as being descriptive of a large number of different processes, rather than being able to explain specific responses to situations which, while different, could all be labelled as stressful (Ader, 1980). Different physiological indices of the "physiological stress response" may not necessarily be measuring the same thing; for example, although increases in cortisol are particularly associated with specific environmental circumstances associated with psychosocial stress, such as social-evaluative threat (Dickerson & Kemeny, 2004), the sympathetic nervous system and sympathetic adrenal medullary system respond to pleasurable as well as negative stimuli (Clow, 2001). Cortisol responses may thus be a more valid index of stress and psychosocial stress in particular.

Support for the complexity of the relationship between subjective and physiological stress response comes from a review of one of the most frequently used laboratory methods for inducing stress: the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). This methodology involves making a five-minute public presentation and a mental arithmetic exercise, and has been used in research investigating the effects of chewing gum (Gray et al., 2012; Sketchley-Kaye et al., 2011). In line with arguments that it is too simplistic to describe stress as a single, unidimensional construct, in 49 papers that measured both emotional and physiological stress, only a quarter of the papers described showed a correlation between cortisol and perceived emotional stress responses to the TSST (Ehlert & Campbell, 2012). Ehlert and Campbell suggest this may be due to psychological differences in how stressors are appraised, as well as methodological issues of controlling for confounding variables.

Nonetheless, despite the fact that the word “stress” may be use to describe different psychophysiological states, subjective stress has been associated with negative states of well-being. Depression has been linked to stress (Gruen, 1993), although the effect size may be relatively small (Rabkin, 1993). Similarly, although nurses in an occupational study identified a large number of different events as “stressful”, general levels of subjective occupational stress were associated with poorer job performance, as assessed by a supervisor or colleague (Motowildo, Packard, & Manning 1986). This suggests that a global perception of stress is predictive of observable patterns of behaviour.

Although chewing gum is unlikely to affect exposure to stressors in the environment, it may affect levels of subjective stress, through mechanisms such as brain or peripheral nervous system effects (see below for discussion of possible mechanisms for chewing gum effects). In line with this reasoning, most of the research discussed below has examined subjective stress, although some work has dealt with the presence of stressors as well as feelings of stress (Smith, 2009a). Anxiety and depression have also been assessed. In the case of Zibell and Madansky (2009), the concepts of stress is somewhat conflated with that of anxiety; a measure of anxiety (the state-trait anxiety inventory) is described as assessing stress.

While the subjective stress response is no doubt moderated by different appraisals of environmental “stressors”, the observed negative effects of subjective stress in previous research offers a convincing rationale for investigating whether a particular behaviour can reduce subjective stress *per se*.

2.5.2 Chewing gum, chronic stress, anxiety and well-being

Abbreviated Progressive Relaxation Training, which involves tensing and relaxing various parts of the body (similar to the process of chewing) has been found to reduce stress (Pawlow & Jones, 2002), and chronic stress has been found to be associated with bruxism (Ahlberg et al., 2002), so it would seem that clenching the jaw muscles is a natural reaction to stressors which may reduce the intensity of experienced stress. Thirty-six percent of respondents in the Princeton Review and Wrigley survey reported chewing gum while studying, and of these respondents, 41% chewed gum to alleviate stress. However, participants were only asked to select one reason (the other two options being improvement in focus/concentration and combating boredom). This did not allow respondents to give a different reason for chewing (e.g. enjoyment of flavour, freshening breath), which may have inflated the number of students endorsing stress reduction as a reason for chewing.

In a survey of workers (*N* = 2,248), participants were classified as "chewers" or "non-chewers" (most of the gum chewing participants described themselves as chewing gum "sometimes", rather than "often" or "very often"). Rather than simply testing if respondents would report chewing gum as a means of reducing stress, this survey probed respondents on their level of experienced stressors and feelings of stress. Gum chewers reported more exposure to negative characteristics at work (e.g. long or unsociable hours), but fewer participants in this group described themselves as being "extremely stressed" at work (Smith, 2009a). Gum chewers were also less likely to report high levels of life stress than non-chewers. This suggests that chewing gum may ameliorate strong, chronic stress, or perhaps that it is used in an attempt to reduce stress. A second cross-sectional investigation indicated an inverse linear relationship between stress level and amount of habitual gum chewing (Smith, 2012).

Smith's cross-sectional investigations are complemented by a crossover intervention study by Smith et al. (2012). Participants (*N* = 101) were required to chew gum every day for two weeks, and to try to chew gum when they felt stressed. In the non-chewing condition they were required to abstain from gum for two weeks. The chewing gum condition was associated with self-report of lower anxiety and depression, improved affect and lower occupational stress. In line with the survey finding of a dose-response relationship (Smith, 2012), those who chewed more gum during the intervention experienced a larger positive shift in outcomes. Participants were university staff members, and those who reported at baseline that they experienced no stress at work were not included in the study. A two-week intervention with a student sample reduced stress and led to enhanced productivity, although it did not affect the other measures of well-being assessed previously (Smith & Woods, 2012).

In two studies (one using frequent gum chewers as participants and another using infrequent chewers) 56% of frequent gum chewers (those who chewed 11 or more pieces of gum a week, and chewed gum on four or more days per week) and 42% of infrequent chewers said that dealing with everyday stress was a reason that they chewed gum (Zibell & Madansky, 2009). Following initial questioning, frequent chewers (N = 280) were required to abstain from chewing gum for 3 days and chew gum as normal for another 3 days, and non-regular chewers (N = 212) were required to abstain for 7 days and chew at least three times a day for another 7 days. At the end of each period, participants were questioned about stress, using a simple 5-point scale, and about anxiety levels, using the State-Trait Anxiety Inventory/STAI (Spielberger, 1983). Although a shorter intervention than Smith et al. was used, abstaining from chewing gum resulted in significant increases in stress and anxiety for frequent and non-frequent chewers, with reductions in stress and anxiety being observed following periods of chewing. The fact that stress was reduced for non-regular chewers suggests that factors other than familiarity of chewing gum are at work, and that frequency of chewing should not be a confounding factor in research on chronic stress, at least as long as participants occasionally chew gum.

Suh, Kim, Chang and Kim (2008) had participants in a two-week intervention chew gum with yeast hydrolysate or placebo gum. Similar to other intervention research, they found that the anxiety of participants who chewed the “placebo” gum fell between pre- and post-intervention. There was not a no-gum control group for this study.

In summary, chewing gum has been found to reduce self-reported, naturally occurring stress when chewed over a relatively long period of time. Longer-term research on the effects of chewing gum on heart rate and levels of cortisol could give a clearer view of whether such effects are visible at a physiological level.

Table 2-5: Findings from research on chewing gum, chronic stress and associated problems

	Dependent variables	Design	Time of day	Sample	Habitual gum and smoking	Significant effect	Effect size	Chewing gum
Smith (2009a)	Number of participants reporting extreme stress at work	Cross-sectional	n/a	N = 2248, (M = 719, F = 1529), Age: Mean = 35, range = 18-74	1381 = chewers (73% female, 17.4% smoke), 867 = non-chewers (61% female, 13.6 % smoke)	Reduction	1.96[19]	Habitual chewers versus non-chewers compared
	Number of participants reporting extreme life stress					Reduction	1.65	
Smith (2012)	Number of participants reporting very high/extreme work stress	Cross-sectional	n/a	N = 388, (M = 122, F = 266), Age: M = 42, range = 17-64	71 chew gum 5 days or more, 171 chew gum occasionally to once a week, 146 never chew gum. Smoking n/a	No	0.11[20]	Never chew, occasionally to once a week, and five times a week or more compared
	Number of participants reporting very high/extreme life stress					Reduction	0.16	

[19] OR from logistic regression

[20] Cramer's V

	Number of participants reporting clinical anxiety					Reduction	0.14	
	Number of participants reporting clinical depression					Reduction	0.13	
Smith and Woods (2012)	Stress	Intervention (independent measures)	n/a	N = 78 (M = 6, F = 72) Age: M = 19.5, range = 18-24	n/a	Reduction	n/a	Minimum of two pieces of gum 20 minutes per day. 20 chewed < 40 pieces, 17 chewed > 40. (Choice of available flavours)
	Tiredness					No		
	Anxiety					No		
	Depression					Reduction		
Smith et al. (2012)	Work stress	Intervention (crossover)	n/a	N = 101 (M = 38, F = 63) Age: M = 32, range = 16-58	n/a	Reduction	0.26	Minimum of two pieces of gum 20 minutes per day (Choice of available flavours)
	Life stress					Reduction	0.49	
	Fatigue					Reduction	0.28	

	Anxiety					Reduction	0.39	
	Depression					Reduction	0.25	
Suh et al. (2008)	Anxiety	Independent measures (gum with yeast hydrolysate versus “placebo” gum)	n/a	N = 120, (M = 86, F = 34) Age: range = 19-48	n/a	Reduction	0.28[21]	One piece of gum for 30 minutes five times a day
	Depression					Reduction	0.35	
Zibell and Madansky (2009)	Anxiety	Intervention (crossover)	n/a	280 frequent chewers, 212 non-frequent	Frequent chewers: > 10 pieces a week, 212 non-frequent: not in 7 days before study. Smokers were included.	Reduced anxiety for both groups	<u>Frequent chewers</u> 0.32[22] 0.21[23] <u>Infrequent chewers</u> 0.24[22] 0.2[23]	Three times a day minimum

[21] Change from baseline score for placebo gum divided by standard deviation
[22] Increase during non-chewing
[23] Reduction during chewing

2.5.3 Chewing gum, acute stress and anxiety

In an experimental investigation, chewing gum was associated with reduced self-reported stress and anxiety following performance of a stressful multi-tasking framework that requires participants to work on multiple tasks at the same time (Scholey et al., 2009). Stress generally increased during performance of the framework, indicating that the task successfully induced stress. Johnson et al. (2011) also tested the effects of chewing gum on a multi-tasking framework; this framework also led to increased stress, but Johnson et al. did not find an effect of chewing gum on reported stress or anxiety.

The effect of gum has also been studied for stress induced by the Trier Social Stress Test (TSST). Measures were taken at baseline, before the test, after the test and following a recovery period. Gum reduced self-rated anxiety, and this effect was greatest for the post-baseline sessions (Sketchley-Kaye et al., 2011). A later study using the same stress-induction method (Gray et al., 2012) found that stress was lower for the gum condition following the TSST and post-recovery, although gum did not have an effect on anxiety.

Torney et al. (2009) failed to find a benefit of chewing gum on self-reported stress following attempts at an insoluble anagram. Torney et al. described the insoluble anagram task as a social stressor, although the social nature of stress may be more salient for the TSST. There were methodological differences between this study and previous work apart from the different nature of the stressor: for example, Torney et al.'s task did not last as long as the framework used by Scholey et al. However, Torney et al. analysed the changes in self-reported stress in response to the stressor for the no gum condition in both their study and that of Scholey et al., and found no significant difference. Participants were not required to chew gum for as long in Torney et al.'s study; this may be a potential explanatory factor.

Smith (2009b) found that participants reported lower anxiety after chewing non-caffeinated placebo gum (caffeinated gum was also investigated), relative to a no-gum control, although a stressor was not included for this study. Smith (2010) addressed this by testing participants on the same battery of tasks under either quiet or noisy conditions. No effect of chewing gum was observed on a self-report measure of anxiety, although noise was rated as less annoying during gum conditions. Trait anxiety was measured and controlled for. Similarly, Ekuni et al. (2012) did not show an effect of chewing gum on subjective stress or state anxiety under noise stress.

In summary, experimental research looking at short-term, induced stress has shown contradictory findings on self-reported stress and anxiety, and calmness has generally not been affected by gum (see Table 2-6). The observed effects sizes on self-reported stress and anxiety have been small or moderate. The differences in results may be due to notably different methods of stress induction being employed in different studies, although relatively similar stressors were used in two investigations (Johnson et al., 2011; Scholey et al., 2009).

Table 2-6: Results of studies investigating chewing gum and acute reported feelings of stress or anxiety

	Dependent variable	Design	Time of Day	Sample	Habitual gum & smoking	Significant Effect?	Effect size[24]	Chewing gum	Gum before or during task	Order of tasks
Ekuni et al. (2012)	Stress	Crossover (gum, no gum)		N = 67 (M = 34, F = 33) Age: range = 22-27	Non-smokers	No	0.26	1 piece sugarfree mint gum for 5 minutes	During noise stress	Stress and anxiety before and after stress exposure
	Anxiety					No	0.04			
Gray et al. (2012)	Stress	Independent measures (gum, no gum)	15.00-17.00	N = 40 (M = 20, F = 20), Age: M = 20 & 3 months	Non-smokers	Reduction	0.5[25] 0.5[26]	1 piece Wrigley's Extra Spearmint 3 times (10 + 10 + 10 minutes total)	During Trier prep, present-ation and recovery	Initial mood, Trier social stress, post-stress mood, mood again 10 minutes post-stress
	Anxiety					No	0.04[27]			
Johnson et al (2011)	Stress	Crossover (gum, no gum)	11.00-13.00	N = 30 (M = 9, F = 21) Age: M = 21.24	Regular chewers, chewed less than ten times per week. Non-smokers	No	< .001[27]	Mint for 20 minutes	During	Mood tasks before and after stressful multitasking task
	Anxiety					No	n/a			
Johnson,	Calmness	Crossover (gum, no	14.00-	N = 30 (M = 9,	Habitual	No	0.11[27]	1 piece	During	Mood tasks

[24] For all summary tables, effect sizes were calculated by dividing the difference of mean scores for gum and no chewing control by their mean standard deviations (except where otherwise indicated)
[25] Post-stressor
[26] Post-recovery
[27] Partial eta squared for main effect of gum condition.

Miles et al. (2012)		gum, sham chewing)	17.00	F = 21) Age: M = 21 & 7 months	gum n/a. Non-smokers			Wrigley's Extra Spearmint for 11 minutes		before and after PUI measurement
Scholey et al. (2009)	Self-reported stress	Crossover (gum, no gum)	n/a	N = 40, (M = 8, F = 32)[28] Age: M = 22, SD = 4.79	Gum at least once in previous week (25% chewed 1-3 pieces, 57.5% chewed 4-9, 17.5% chewed 10+). Non-smoking	Reduction	0.2 (LI) 0.39 (MI)	Choice of available flavours (34 chose mint flavour, 4 cherry, 1 liquorice, 1 menthol & eucalyptus) for 20 minutes[29]	During stressful task	Mood tasks before and after stressful task
	Anxiety					Reduction	0.28 (LI) 0.28 (MI)			
	Calmness					No	0.16 (LI) 0.09 (MI)			
Sketchley-Kaye et al. (2011)	Anxiety	Independent measures (gum, no gum)	11.00-14.00	N = 36 (M = 5, F = 31), Age: M = 20 years 5 months	Regular chewers, chewed less than ten times	Reduction	0.13[30]	1 piece Wrigley's Extra Spearmint 3 times (10 + 10 + 5 minutes)	During Trier prep, present-ation and recovery	Initial mood, Trier social stress, post-stress mood, mood again 10 minutes

[28] Number of males and females
[29] There were two 20-minute gum sessions, but these took place on different days
[30] Partial lambda squared for main effect of gum

					per week. Non-smokers					post-stress
	Calmness					No	n/a			
Smith (2009b)	Anxiety (pre-test)	Independent measures (gum, caffeinated gum, no gum)	Test session: 16.00-17.00	N = 120, (M = 60, F = 60), Age: range = 18 - 30	Excluded if lower than "at least occasional" gum chewers or smoked > 5 cigarettes in the daytime	No	0.27	Mint for 20 minutes	Before	Random order of performance tasks
	Anxiety (post-test)					Reduction	0.57			
Smith (2009c)	Calmness (pre-test)	Crossover (control v. gum at learning and/or test) Measured on two weeks	n/a	120 (Gender & age n/a)	Gum habit n/a. Excluded if smoked > 10 cigarettes in the daytime and evening	No No	<u>Week 1</u> 0.18 <u>Week 2</u> 0.02	Choice of available flavours (numbers n/a) for 35 minutes (if chewing during learning and recall)	During	Mood, recall, logical reasoning, semantic processing, delayed recall, recog. memory, story recall, mood (*part 1*) mood, story recall, Alice Heim task, mood (*part 2*)
	Calmness (post-test)					No No	<u>Week 1</u> 0.14 <u>Week 2</u>			

							<0.01			
Smith (2010)	Anxiety (pre-test)	Crossover (gum, no gum)	Start time at 10.00, 11.30, 15.00, 16.30, 18.00, 19.30	133	62 chewed more than one pack per week, 71 chewed less. Excluded if smoked > 10 cigarettes per day	No	0.07	Spearmint or Juicy fruit for 90 minutes	During	Mood, immediate and delayed free recall, delayed recognition, logical reasoning, spatial memory, semantic processing, simple RT, focussed attention, categoric search, repeated-digits vigilance
	Anxiety (post-test)					No	0.02			
Torney et al. (2009)	Self-reported stress	Independent Measures (gum, no gum)	n/a	40	n/a	No	<0.001[31]	Spearmint for 10 minutes + time to complete mood tasks	During	Mood tasks before and after stressful/non-stressful tasks
	Calmness					No	0.005**Error! Bookmark not defined.**			

[31] Partial eta squared for main effect of gum

2.6 Possible mechanisms for chewing gum effects

2.6.1 Brain activity

The findings of an EEG pattern consistent with relaxed concentration suggests that a subjective state stemming from the central nervous system may explain some effects on self-reported mood, as well as some positive findings on attention. Sakamoto, Nakata and Kagigi's (2009) finding that the peak latency of the P300 component was reduced in a post-chewing gum condition is consistent with Smith's (2010) finding that chewing gum led to better encoding of stimuli, since the latency of the P300 component is associated with speed of encoding stimuli (Kutas et al., 1977).

Recent research has indicated that a reduction by gum of stress in response to noise was associated with lower activity in the bilateral superior temporal sulcus and the left anterior insula (Yu, Chen, Liu & Zhou, 2013). Furthermore, stress-induced functional connectivity between the dorsal anterior cingulate cortex and the left anterior insula increased by a lesser amount when chewing gum. It is possible that chewing gum may also affect stress through neurotransmission effects. Research by Kamiya et al. (2009) indicated that heightened activity in the ventral prefrontal cortex leads to increased activity of serotonergic neurons in the dorsal raphe nucleus and reduced nocioceptive flexion reflex.

Research with rats (Gómez et al., 1999) has found that a stressor (tail pinching) led to a smaller increase in dopaminergic metabolism when rats engaged in non-functional masticatory activity (NFMA), such as gnawing. Gómez et al. proposed that this indicated that NFMA attenuated stress-induced neurochemical changes in the brain. However, as the research by both Kamiya et al. and Gómez et al. investigated responses to pain, care should be taken in assuming the same effects will hold for psychological stress. Despite the plausibility of brain activity leading to chewing gum effects, it remains unclear how chewing gum affects brain function in the first instance; notwithstanding the negative findings from Sakamoto et al.'s control experiment involving finger tapping and jaw movement, it may simply be through motor activity (see next section).

2.6.2 Motor activity

The extent to which the effect of chewing gum can be attributed to the motor activity involved in chewing can perhaps best be studied by contrasting chewing gum with some other simple repetitive activity of similar physical intensity that can be performed at the same time as a task. Sham chewing (i.e. making chewing movements with nothing in one's mouth) is one such activity; it has been found to be more similar to a no-gum control than a chewing gum condition in terms of its effect on physiological and self-rated sleepiness (Johnson, Miles, et al., 2012). In one experiment, participants had lengthened reaction time on a divided attention task for a sham chewing condition (compared to a no gum control and a flavoured gum condition), and reaction time similar to control but lower than chewing gum on a selective attention task (O. Tucha et al., 2004). In their second experiment, reaction time was lengthened for sham chewing on a sustained attention task and between flavoured gum and no gum for vigilance reaction time. For both experiments, heart rate during sham chewing was higher than the no-gum control but lower than the flavoured chewing gum condition. Another study indicated that, for sham chewing, heart rate was lower than a gum chewing condition but higher than a no-chewing control (Wilkinson et al., 2002). Wilkinson et al. found that participants in a sham-chewing group did worse than the control group on a simple reaction time task. An effect of sham chewing being smaller than that of chewing gum has been interpreted as indicating that the level of resistance in what one is chewing may increase the effect of chewing movements (Scholey, 2003). Indeed, research controlling for rate of chewing has found that harder chewing gum leads to increased blood pressure and heart rate compared to softer gum (Farella, Bakke, Michelotti, Marotta, & Martina, 1999). However, memory performance was not enhanced by chewing a larger amount of gum compared to a smaller amount (Rickman et al., 2012). With regard to sham chewing in particular, Wilkinson et al. pointed out that participants in a sham-chewing group could have been distracted by having to perform the novel task of making chewing movements with nothing in their mouths. This might explain why divided attention in particular was negatively affected by sham chewing (O. Tucha et al., 2004), given that the performance of this novel behaviour during a divided attention task could lead to an even greater division of attention.

Early psychological research (Hollingworth, 1939) indicated a reduction in motor restlessness and muscular tension in participants who chewed gum. The finding that chewing paraffin wax and clenching one's teeth following a stressful task reduces salivary cortisol levels (Tahara, Sakurai, & Ando, 2007), suggests that the process of biting or tensing one's jaw has an effect on stress. Although a cross-sectional study failed to find a significant effect of exercise on stress (Gerber, Kellmann, Hartmann, & Pühse, 2010), moderate exercise was more likely than strenuous exercise to be associated with reduced stress. Where people are otherwise physically inactive, chewing gum could have a mild exercise effect. It may be that as gum is being chewed, heart rate and alertness rise, and after chewing cessation stress reduction will follow. Scholey et al. (2009) have suggested that increased heart rate induced by chewing might reverse the dilation of blood vessels associated with the stress response and consequently reduce stress. This mechanism may take time to work, which could help to explain why research has more consistently suggested that chewing gum reduces chronic rather than acute stress. Although greater resistance to chewing has been manipulated directly (e.g. by giving people more or less gum to chew), it could also be of interest whether perceived hardness of chewing leads to changes in subjective mood. Furthermore, if level of motor activity is important, then gum may have clearer effects on attention when it is chewed at certain speeds.

2.6.3 Flavour

It has been suggested that flavour may be a mechanism for chewing gum effects on cognition (Stephens & Tunney, 2004b), and it is plausible that mint flavour might enhance alertness; mint-flavoured gels have been rated as more “refreshing” than peach flavoured gels (Labbe, Gilbert, Antille, & Martin, 2009). Differences in central nervous system activation is indicated by EEG research comparing gum with/without flavour (e.g. Masumoto et al., 1999). Odour may also play a role in mood effects of chewing gum; orthonasal administration of peppermint scent has been found to attenuate the negative effects of time on vigour and fatigue to a greater extent than cinnamon scent or a no-odour control (Zoladz & Raudenbush, 2005), although neither orthonasal administration nor chewing gum flavour of peppermint or cinnamon affected reaction time. Although sugar may moderate gum flavour, the amount of sugar typically found in chewing gum is not sufficient to induce pharmacological effects (Scholey et al., 2009). Mint flavours were the most commonly used both in previous research which showed an alerting effect and in previous research which did not (see Table 2-1); this is also the case for past research on attention (see Table 2-2). Thus, although there is some evidence that mint flavour and odour may affect cognition and mood, previous research on chewing gum does not suggest that choice of flavour is a clear explanatory factor for equivocal findings.

2.6.4 Gum and psychophysiology

Notwithstanding the possible motor effects of gum, how plausible are psychophysiological effects? Following a stress loading condition (having to perform a mental arithmetic task for twenty minutes), both chewing paraffin wax and clenching one's teeth have been found to reduce salivary cortisol levels (Tahara et al., 2007). Chewing gum was associated with reduced cortisol during performance of a stressful multi-tasking framework (Scholey et al., 2009). However, the effect of gum on cortisol during multi-tasking was not replicated by Johnson et al. (2011), and chewing gum led to higher levels of heart rate and salivary cortisol elsewhere (Gray et al., 2012; Smith, 2010). Smith emphasised the rise in cortisol as indicating increased alertness (which was supported by the self-reported alertness data), but a rise in cortisol also indicates a heightened physiological stress response, though this interpretation is somewhat problematic given the reduced reported stress in Gray et al. It is possible that time spent chewing and timing of measurement of cortisol could explain differing effects, consistent with the time-on-task trends discussed in Section 2.7 below.

Cortisol levels have been found to fall to a greater extent between baseline and following a post-chewing rest when chewing flavourless gum quickly compared to chewing slowly, using an arithmetic task for stress loading (Tasaka, Tahara, Sugiyama, & Sakurai, 2008). This could be interpreted as indicating that greater levels of activity during chewing will have a greater effect, consistent with the moderating effect of level of motor activity mentioned above. However, slow and fast chewing rates were defined as 15% faster or slower than each participant's habitual speed of chewing. Consequently, assuming that participants will chew at their own habitual rate in an experiment unless instructed otherwise, this study may not have really identified a confounding variable in other research. However, it may be worthwhile to observe participants chewing as they perform tasks, as faster chewing may lead to a clearer effect on stress, attention and alertness. As a physiological measure, cortisol may be considered the most objective indicator of stress, but Scholey et al. have pointed out that giving a saliva sample can be a social stressor.

Chewing sugarless mint gum has been found to lead not only to reduced salivary cortisol, but also to reduced salivary testosterone, as well as increasing progesterone (Schultheiss, 2013). In contrast, another study found that chewing sugarless gum increased salivary testosterone (van Anders, 2010). Compared to mixed nutrient food, neither flavourless gum, sweetened gum nor sweetened gum with mint flavour affected pancreatic polypeptide (PP) (Teff, 2010). Teff did not observe any effect of gum on insulin levels; the release of PP is associated with vagal efferent activity, which in turn is associated with insulin release and glucose homeostasis (Teff & Townsend, 2004). Thus, although the evidence is equivocal for some hormones, it is plausible that chewing gum may affect a number of unmeasured salivary hormones besides cortisol which may contribute to psychological effects.

Evidence for a physiological alerting effect has been provided by research that measured pupil diameter fluctuations, with participants in the chewing condition scoring lower than a no-gum control on a pupillary unrest index (Johnson, Miles, et al., 2012). Some research has not shown a significant effect of gum on heart rate (O. Tucha et al., 2004), although other studies have (e.g. Wang et al., 2009), and it has been argued that the literature overall suggests that chewing gum increases heart rate in the short run (Weijenberg et al., 2011). Skin conductance has found to be lower when chewing gum in response to noise stress (Yu et al., 2013).

2.6.5 Demand characteristics

The issue of demand characteristics is highly salient for research in chewing gum, particularly when one considers that the more robust effects in this area (reported alertness and chronic stress) are quite subjective. Although performance on an attention task may be less subjective than reported mood, demand characteristics may still induce motivational differences which manifest as an apparent effect of chewing gum on attention.

Unfortunately, a single- or double-blind methodology for chewing gum has yet to be designed. On the other hand, researchers can highlight the importance of chewing gum in their hypotheses to a greater or lesser extent to participants. For example, Zibell and Madansky (2009) may have heightened demand characteristics by asking participants if they chewed gum to reduce stress during the pre-intervention screening process. In contrast, a number of past studies have not explicitly mentioned that their hypotheses concerned chewing gum before debriefing. For example, in a study with child participants they were told that the chewing gum was just a thank-you for taking part (Tänzer et al., 2009). The extent to which demand characteristics play a role can be clarified by manipulating them directly to test if they moderate any observed effects of gum.

2.7 Factors moderating psychological effects of chewing gum

2.7.1 Length of chewing and length of performance

Post-test alertness has been more likely to be affected by chewing gum than alertness at the beginning of chewing, suggesting that alerting effects of chewing gum are stronger after some time has elapsed. Sketchley-Kaye et al. (2011) note clear descriptive evidence that chewing gum had a greater effect on alertness for later stages of their procedure. This was also the case for anxiety, suggesting that gum effects on anxiety may also be more clearly visible over time. The fact that chewing gum has shown a more consistent effect on chronic stress than on acute stress offers support for a similar process with chewing and stress. Chewing gum may lead to an increase in arousal as it happens, followed by relaxation. In addition to having possible effects on mood, the initial increase in arousal may affect cognitive performance after a certain amount of time chewing and testing, or after the act of chewing has finished.

As mentioned above, although Torney et al. (2009) did not show an effect of gum on alertness, they only required participants to chew for a relatively short period of time (10 minutes plus time to complete mood tasks). Other papers which did show alerting effects generally required longer periods of chewing (e.g. 30 minutes in Morgan et al., 2013, 90 minutes in Smith, 2010). In addition to these trends in mood effects, it has been suggested that time may be a moderating factor in the effects of chewing gum on cognition (Tucha & Koerts, 2012). Consistent with this idea, Wilkinson et al. (2002) did not show an effect of chewing gum on vigilance, but only required participants to chew for three minutes, whereas O. Tucha et al. (2004a) and Smith (2010) showed positive effects for designs where gum was chewed for 80 and 90 minutes respectively.

It is thus worth considering if tasks which are performed later in a cognitive performance battery (where tasks are presented in a fixed order) are more likely to be positively affected by chewing gum. This hypothesis is borne out to some extent in the findings of Smith (2010) and Wilkinson et al. (2002). In the latter paper, performance was better in the gum conditions for spatial and numeric working memory tasks, which were completed later in the battery, while gum did not improve performance on a vigilance task, which was completed earlier. Immediate and delayed recall were both improved despite being early and late in the battery respectively, although this is not surprising given the connection between these tasks. In Smith

(2010), gum had a negative effect on immediate recall and no effect on simple reaction time; both were assessed early in order of testing. However, gum had a positive effect on later tests (focused attention reaction time and vigilance hits). Similarly, Sakamoto, Nakata, Honda et al. (2009) observed a time-on-task effect for simple reaction time: it was only significantly shortened by gum during a final post-chewing session.

Some studies have examined time-on-task effects directly. In one study, children in a no-gum group performed better on a concentration task for the first twelve minutes but were then overtaken by those in the chewing gum group (Tänzer et al., 2009). L. Tucha and Simpson (2011) tested the effect of chewing gum over consecutive blocks of a sustained attention task. They found that reaction time was initially lengthened in the gum condition, but shortened compared to the no-gum condition during the later parts of the task. They speculated that a time-on-task moderating effect could be due to an initial distracting effect of chewing gum, followed by a positive effect due to underlying biological factors (such as an effect on heart rate). Secondary analysis of the data from Smith (2010) indicated shortened reaction time, fewer false alarms and more correct hits for a vigilance task, but only for the last minute. However, in another study an interaction between time-on-task and gum condition was not observed for vigilance in either healthy children or children with ADHD, who should typically have greater difficulty with vigilance tasks (L. Tucha et al., 2010). It may be the case that effects were not observed here as Tucha et al. used a shorter task, and did not break the task into as many blocks of time as research which did show an effect. Johnson, Muneem et al. (2012) observed an improvement in sustained attention performance throughout the SART, which was not dependent on a general decrement in task performance over time. This may be because the SART assesses continuous performance rather than vigilance, given its higher stimulus rate (Spikman & Van Zomeren, 2010). The sustained attention task used by Johnson, Muneem et al. did not lead to a significant fall in accuracy or speed of performance across testing blocks. In contrast, vigilance performance has been found to decline after less than ten minutes (Helton, Dember, Warm, & Matthews, 1999; Helton et al., 2007), so this type of attention task may be particularly well-suited to studying the effects of chewing gum on alertness and cognitive performance over time. This clearer effect of gum when one must continue with the task following a decline in performance is in line with

Stephens and Edelstyn’s (2011) argument that chewing gum may have a greater effect for more difficult task performance.

The possible role of time of chewing was further elaborated in another three experiments (Onyper, Carr, Farrar, & Floyd, 2011). In the first two experiments participants chewed gum before performing a battery of cognitive tasks (including tests of episodic memory, working memory, verbal fluency and a symbol digit modalities task assessing perceptual processing and motor speed). In the first experiment the tasks were performed in one order and in the second experiment the tasks were performed in the opposite order. For both orders of tasks, prior chewing gum improved performance of the tasks that were performed shortly after chewing, but not those that came towards the end of the battery. In a third experiment, participants in a gum condition chewed gum while performing the tasks; they did not show any improvement relative to no-gum controls. The findings indicate that chewing gum enhances performance for a limited time (15-20 minutes) after chewing, but does not have an enhancing effect during chewing. Furthermore, as the first two experiments presented the tasks in reverse order, the time-on-task effect across tasks cannot be attributed to chewing gum only having an effect on a certain type of task. Onyper et al. suggested that the detrimental distracting effect of gum masked the enhancing arousal effect during simultaneous chewing and task performance, leading to a lack of an overall effect. For gum chewing prior to task performance, the arousal effect persisted for a time, but the distracting effect no longer applied. Although chewing during task performance has been shown to have a positive time-on-task effect elsewhere (Tänzer et al., 2009; L. Tucha & Simpson, 2011), Onyper et al.’s findings suggests that the time-on-task moderation of chewing gum effects may be clearest just after chewing has finished.

2.7.2 Gender and age

A survey of people aged 19-74 has indicated that gum chewers are younger on average (M = 33.6 years) than non-chewers (M = 39.4 years) (Smith, 2009a). Chewing gum has been found to lead to higher activation in the pre-frontal cortex for older adults compared to younger adults (Onozuka et al., 2003). Based on this, it has been speculated that chewing will have a clearer effect on cognitive performance for older participants (Weijenberg et al., 2011). However, the experimental literature on the effects of chewing gum on alertness and attention has consistently used participants in their twenties, so this research has not been able to test if chewing gum has differing effects on older adults compared to younger. In contrast, some of the literature on stress has included a broader age range of participants. Both Smith et al. (2012), with a sample of mean age 32 and ranging from 16-58, and Smith and Woods (2012), with sample of mean age 19.5 with a narrower range of 18-24, showed a reduction in stress with a chewing gum intervention. However, this age difference may still be too small to show differences in gum effects on cognition and mood which may exist between adults with greater age differences.

In terms of sex, female survey respondents have been found to be more likely to chew gum (Smith, 2009a). Some EEG research on chewing gum has used all-male samples (Sakamoto, Nakata, Honda, et al., 2009; Yagyu et al., 1998), whereas a number of studies on the effects of chewing gum on cognition and mood have used predominantly female samples (e.g. Johnson et al., 2011; Scholey et al., 2009). In experimental research, some studies have used an equal number of male and female participants, but interactions between chewing gum and sex are not generally reported. It is thus difficult to draw any conclusions on the moderating effects of gender in previous research.

2.7.3 Other possible moderating factors

Time of day may moderate any effects of chewing gum on the stress response. Cortisol follows a diurnal pattern of a strong awakening response (c.f. Fries, Dettenborn & Kirschbaum, 2009, for a review) followed by a gradual decline over the day, which means that participants tested in the morning will be closer to ceiling in terms of cortisol level compared to those tested in the afternoon; this higher cortisol in the morning should be associated with higher levels of stress and alertness. However, there is not a clear relationship between time of testing and the presence or absence of chewing gum effects in the previous research.

It is also plausible that habitual level of chewing could moderate effects of chewing gum on cognition and mood, particularly given the dose-response relationship for habitual chewing and well-being previously observed in survey research (Smith, 2012). In research that assigns participants to chewing gum conditions, those participants who do not chew gum may find it less pleasant than those who chew regularly, and may find this activity more distracting, given its novelty. However, Smith (2010) did not find any interactions between gum condition and regular gum chewing (regular = more than one pack a week) in terms of cognition or mood.

Gum chewers have been found to be more likely to smoke than non-chewers (Smith, 2009a). In previous experimental research, where smoking is reported, either non-smokers were used or at least heavy smokers were excluded, so it is unlikely that cigarette smoking is a major confound in past research.

2.8 Discussion of previous literature

Chewing gum has been found to be associated with enhanced subjective alertness during performance of cognitive tasks. The evidence on the effect of gum on cognitive performance is less clear. Although characteristics of samples such as gender and age, smoking and habitual gum chewing do not seem to offer a clear explanation of why findings have differed between studies, moderation by time-on-task seems like a plausible explanation for variable findings on attention. Similarly, it is unclear if chewing gum affects acute stress or anxiety, although chewing gum seems to reduce chronic stress, and perhaps improve some outcomes of stress (anxiety and depression) and work performance. Possible mechanisms for chewing gum effects include psychophysiology (for which there is equivocal evidence, notwithstanding the possibility that this may also display time-on-task trends) and demand characteristics (which have yet to be investigated).

Although some effects have not been inconsistent across studies, substantial effect sizes have been observed in previous research. For example, an effect of nearly two standard deviations was observed for post-test alertness in Johnson, Muneem et al. (2012), who also observed large effect sizes on sustained attention performance and Smith (2010) observed a comparably large effect size for breadth of attention (see Tables 2-1 & 2-2). For stress, an effect size as large as 0.5 standard deviations has been observed for life stress (Smith et al., 2012). It is thus reasonable to expect that medium-large effects sizes may be visible in well-controlled studies.

When the effects of gum on stress and anxiety are contrasted with those on cognitive performance and alertness, it is interesting that a proposed mechanism for reduced anxiety (the discharge of excessive motor energy) and a proposed mechanism for improved cognitive performance (increased arousal) seem to suggest that chewing gum is having contradictory effects. However, EEG (Masumoto et al., 1999) and self-report (Smith, 2010) findings suggesting a state of relaxed concentration, or perhaps a change in effect over time (enhanced arousal being followed by a state of relaxation) may help to reconcile these seemingly opposing ideas.

2.9 Rationale for current research

Previous research has indicated that chewing gum effects are sensitive to time-on-task. There is scope for studying this in greater depth – it remains to be seen if the key factor in time-on-task trends is the length of chewing or the length of performance. In order to ascertain why chewing gum may have certain effects, a thorough examination of effects should include the measurement of physiological arousal in the central nervous system (given previous findings using EEG methods), in cortisol (with a longer period of testing, which may demonstrate clearer effects than previous research) and in heart rate. Demand characteristics as a mechanism for effects should also be studied.

Before these specific topics are dealt with, survey methods will assess how chewing gum is typically consumed in daily life; this will help to ensure that participants are not made to chew gum in a highly artificial manner when gum consumption is manipulated in later studies. It is also of interest if the chronic effects of chewing gum, as demonstrated by Smith (2009a, 2012) can be replicated in further survey research in differing populations (e.g. students).

Intervention research will be used to examine if chewing gum during a single workday has effects which are comparable to those observed in a two-week intervention by Smith et al. (2012). Experimental research will be used to ascertain if the effects of chewing gum on attention and alertness observed by Smith (2010) can be shown when these tasks are presented without memory tasks.

Chapter 3 Habitual chewing gum consumption in students and workers

3.1 Introduction

The aim of the research described in this chapter was to obtain detailed information on habitual, everyday chewing gum consumption in students and workers. Although surveys concerning chewing gum consumption have previously been carried out (e.g. Smith, 2009a), some questions remain unanswered or explored in insufficient depth. Such questions include the times of day at which chewing gum is typically consumed, brands chewed, attitudes towards the effects of gum and reasons for chewing gum. Although previous surveys have briefly asked respondents why they chew gum, they have asked participants to choose one of a limited number of reasons for chewing, as was the case with the Princeton Review and Wrigley survey (2005). At a broader level, the review of the literature has indicated that findings from survey research and the results of controlled experiments have not always been consistent. For example, although surveys have indicated a stress-reducing effect of chewing gum, the experimental evidence on stress has been more equivocal (see Section 2.5). It may be the case that patterns of chewing differ under experimental conditions compared to in daily life; the current surveys aimed to ensure that any experimental research would be similar to habitual gum consumption.

Within the research on chewing gum, students are likely to be the participants for experimental studies, while workers are more likely to participate in interventions. This is also the case for the research described in this thesis. Consequently, it is worthwhile establishing the pattern of habitual consumption of gum (and correlates) for both groups. The first study surveyed undergraduate students, while the second surveyed workers.

Surveys of workers have indicated that gum chewers are less likely to report high levels of stress, anxiety or depression (Smith, 2009a, 2012). This survey also aimed to test for similar associations between chewing gum and well-being in both students and workers, but in addition to measures of stress, anxiety and depression that had been used previously, items assessing positive and negative mood were also included. These had previously been shown to be affected by chewing gum during an intervention study (Smith et al., 2012), so it was of interest if they would also be associated with habitual chewing gum consumption. The existing evidence that chewing gum enhances alertness (see Section 2.2) suggests that this particular aspect of mood may be enhanced by habitual gum consumption.

If chewing gum is used as a means of dealing with stress, it may act as an alternative to other, less healthy means of coping (Smith & Woods, 2012). For example, respondents who chew gum have been found to be more likely to smoke (Smith, 2009a). Given the experimental finding that chewing gum reduced withdrawal symptoms following a stressor during cigarette abstinence (Britt, Cohen, Collins, & Cohen, 2001), it is plausible that smokers use chewing gum when they do not have access to cigarettes, in order to cope with withdrawal symptoms or other stressors. Differences between habitual and non-habitual chewers in their patterns of health-relevant behaviours, such as smoking, are thus of interest.

It was hypothesised that higher chewing gum consumption would be correlated with lower stress, anxiety, depression and negative mood, as well as with higher positive mood, and that gum chewers would have a more positive attitude towards the effect of gum on such factors. Given the robust finding from previous research that chewing gum enhances alertness, it is likely that people should be more inclined to chew gum during periods of low circadian arousal, particularly early in the day. Smoking was hypothesised to be more prevalent among gum chewers, consistent with previous research (Smith, 2009a). As mentioned above, it has been speculated that chewing will have a clearer effect on cognitive performance for older participants (Weijenberg et al., 2011). Age may thus be relevant, and so was included as a covariate.

3.2 Study 1a: Method

3.2.1 Design

This was a cross-sectional survey. Consistent with Smith (2012), participants were divided into regular chewers (chewing at least 5 pieces of gum a week), less regular (chewing up to 4 pieces a week) and those who never chewed. To test for a dose-response relationship between gum and well-being, Spearman correlations between gum consumption and well-being were also calculated.

In examining whether there was an association between chewing gum and well-being, age, gender and smoking status were used as covariates. Smoking status has previously been shown to be associated with chewing gum (Smith, 2009a); it may be the case that smokers may have different reasons for chewing gum, or prefer different flavours. Since some participants were in their forties (see below) age was included, as a previous review has indicated that cognitive benefits of chewing may increase with age (Weijenberg et al., 2011). Although the previous literature is limited in terms of conclusions regarding the role of gender in chewing gum effects, it is plausible that men and women may differ in terms of their motivations for chewing gum. (See Section 2.7.2 for a brief discussion of the role of gender and age in previous research on chewing gum). The possible interactions between these covariates and chewing gum consumption were also examined, to investigate if smoking/gender/age are associated with differences in patterns of chewing gum consumption.

3.2.2 Participants

Three hundred and seventy-eight participants (three hundred and twenty-nine females, forty-seven males, two no replies) were undergraduate psychology students at Cardiff University who were requested to take part during an introduction to research laboratory session. Mean age was 19 (range = 17-47, SD = 2.9).

3.2.3 Sample size considerations

G*Power (Buchner, Erdfelder, & Faul, 1997) was used to calculate an appropriate sample size. With alpha set at .05 and power of .8, a sample of twenty-one participants per group was required to detect a large effect size of $d = 0.8$ using a one-tailed test (a one-tailed test was used as, where effects have been observed on alertness and stress in previous research, they have been positive). At least this number of participants was thus recruited to each study described in this thesis (although the final sample in Study 7 fell slightly below this figure).

3.2.4 Materials

The survey was designed and administered using the Survey Tracker program (Training Technologies Inc., Ohio, USA), and participants accessed it through the internet. The survey asked if respondents chewed gum, if they chewed gum every day and how many pieces of gum they chewed per week (see Appendix 3.1). Time of day during which chewing gum is consumed and brands of gum chewed were assessed. Reasons for chewing gum were assessed (options were freshening breath, flavour, dental health, appearance/to look cool, concentration, stress reduction, substitute for sweets, no particular reason, and other), as well as attitudes towards chewing gum (measured using a Likert scale of -3 to 3). Attitudes regarding chewing gum’s effect on concentration and mental processing were combined to form a measure of attitudes to attention.

Following the items on chewing gum, respondents were asked if they smoked and, if so, how frequently. The survey included the Hospital Anxiety and Depression scale (HADS; Zigmond & Snaith, 1983) and the positive and negative affect scales (PANAS; Watson, Clark, & Tellegen, 1988); the item on alertness from the PANAS was also analysed separately, given the consistent finding that chewing gum can enhance aletrness. A 5-point (0-4) Likert scale for life stress was also included. Given findings that the HADS is inconsistent in terms of its factor structure (Cosco, Doyle, Ward, & McGee, 2012), a principal components analysis (PCA) with orthogonal rotation (varimax) was conducted on the responses to the HADS.

3.2.5 Procedure

Students completed the survey online in a computer laboratory, and did so at their own pace. Other surveys were also completed during this session, and all surveys were completed in random order. Once they had finished, participants were debriefed.

3.3 Results

3.3.1 Chewing gum consumption

Habitual chewing was classified as follows: one hundred and thirty-four participants were regular chewers (Median = 10, range = 5-40), one hundred and sixty were infrequent (Median = 2, range = 0.05-4) and eighty-four never chewed. The median is reported due to positive skew in habitual level of gum consumption. For those students who answered the question on their average length of chewing a piece of gum (N = 145), 0.7% reported chewing gum for less than one minute, 22% for one-five minutes, 49.7% for 5-30 minutes and 27.6% for more than thirty minutes. The percentage of respondents who reported chewing each named brand of gum are summarised in Table 3-1. Mint flavours were generally popular.

The times of day at which participants chewed is summarised in Figure 3-1. Gum consumption was reported as occurring most frequently around the middle of the day, with fewer respondents saying they chewed at earlier and later times.

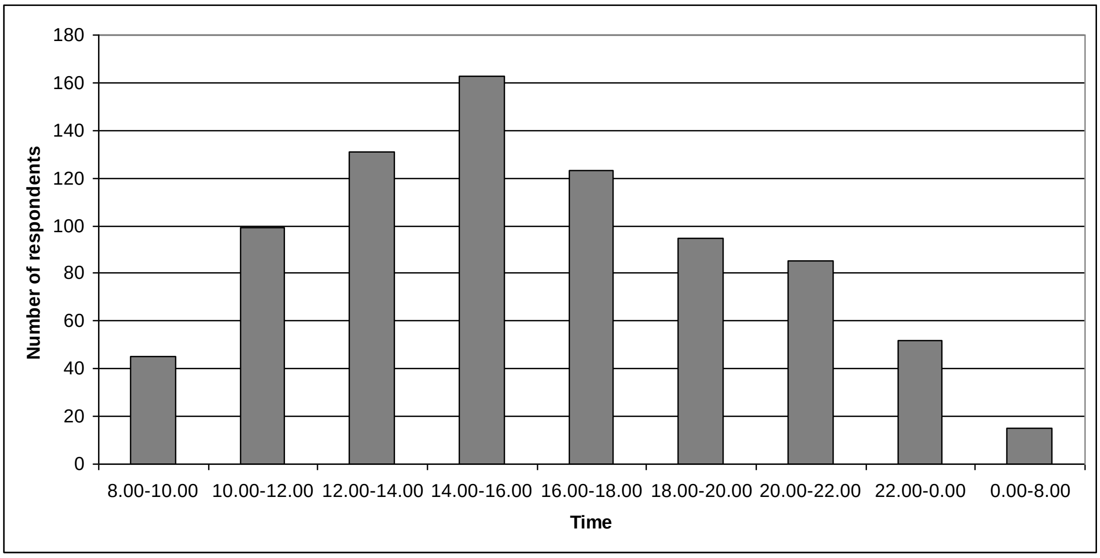

Figure 3-1: Number of student respondents who report chewing gum at given times of day

Table 3-1: Percentage of gum-chewing respondents chewing flavours/brands of gum

Brand	Respondents	Brand	Respondents
Airwaves Cherry	13%	Orbit Spearmint	19.7%
Airwaves Black Mint	7%	Orbit Peppermint	11.3%
Airwaves Menthol & Eucalyptus	19.7%	Orbit Complete	8%
Airwaves Green Mint	8.3%	Hubba Bubba	14.3%
Extra Spearmint	59%	Wrigley's Spearmint	25%
Extra Peppermint	35.3%	Wrigley's Double Mint	6.7%
Extra Cool Breeze	33.7%	Wrigley's Juicy Fruit	12%
Extra Ice	42%	Wrigley's 5	3%
Extra Fusion	14%	Other	5.4%

Other flavours: Watermelon, strawberry, Trident soft, mentos, Trident strawberry and lime, "the one in the children's chewing gum machine"

3.3.2 Attitudes towards chewing gum

Freshening breath was the most commonly endorsed reason for chewing gum, while appearance/to look cool was least frequently reported (see Table 3-2). Seventeen respondents indicated that they chewed gum both for concentration and for stress reduction.

Table 3-2: Percentage of gum-chewing participants endorsing reasons for chewing gum

Reason	Percent respondents
Freshen breath	94.3%
Flavour	48.7%
Dental health	15%
Appearance/to look cool	1%
Concentration	12.3%
Substitute for sweets	20%
Stress reduction	11%
No particular reason	12%
Other	6.7%

Other reasons: To avoid hunger (N = 8), take it when offered it (N = 3), to stop stomach aches, while driving, cigarette substitute, to keep mouth occupied, for chewing sensation, dry mouth/cough, boredom (N's = 1).

Respondents who chewed gum regularly generally reported more positive attitudes towards chewing gum (see Table 3-3). Although the effect of habitual chewing on attitudes to stress was non-significant, habitual chewing led to significantly more positive attitude towards chewing gum being pleasurable, $F(2, 374) = 133.55$, $p < .001$, as well as chewing gum's effects on mood, $F(2, 375) = 4.05$, $p = .18$, attention, $F(2, 371) = 8.04$, $p < .001$, and being less rude, $F(2, 375) = 15.99$, $p < .001$.

Table 3-3: Attitudes towards gum and frequency of gum consumption[32]

Attitude to gum	Regular	Infrequent	Never
Pleasurable	1.7 (0.9)	1.1 (0.7)	-0.4 (1.2)
Improves mood	0.4 (0.8)	0.3 (0.8)	0.1 (0.8)
Improves attention	0.8 (1.8)	0.4 (1.7)	-0.1 (1.5)
Reduces stress	0.8 (0.9)	0.7 (0.9)	0.7 (0.9)
Rude in most social situations	-0.4 (1.4)	0.1 (1.4)	0.7 (1.5)

3.3.3 Chewing gum and covariates

Forty students smoked (Mean cigarettes per week = 37, SD = 29.3). Among habitual chewers, 13.8% smoked, compared to 7.4% of non-habitual chewers (OR = 2.02). This difference was significant, $\chi^2(1) = 4.17$, $p = .04$. Habitual chewers were older (M = 18.9, SD = 1.8; for non-habitual chewers: M = 18.7, SD = 3.7) and more likely to be male (12.8%, compared to 12.2% of non-habitual chewers), although neither of these differences were significant.

[32] Higher score indicates agreement. Standard errors in brackets

Females chewers were significantly more like to report using chewing gum as a substitute for sweets, $\chi^2(1) = 6.03$, $p = .014$, and smokers were more likely to report chewing gum for dental health, $\chi^2(1) = 5.39$, $p = .02$. There were no other significant association between reported motivation for chewing gum and gender, age, or smoking status.

Table 3-4: Gender, age and smoking status of chewers endorsing reasons for chewing gum

	Percent of males/females who endorse reason	Percent of smokers/ non-smokers who endorse reason	Mean age of chewers who do/do not endorse reason
Freshen breath	90.3%/95.4%	90.3%/95.4%	18.7 (0.14)/18.9 (0.49)
Flavour	51.6%/48.3%	54.8%/48.3%	18.5 (0.22)/18.9 (1.7)
Dental health	22.6%/13.8%	29%/13.3%	19 (0.77)/18.6 (0.09)
Appearance/to look cool	0%/1.1%	3.2%/0.8%	18.3 (0.33)/ 18.7 (0.14)
Concentration	16.1%/12.3%	12.9%/12.5%	18.6 (0.23)/ 18.7 (0.16)
Substitute for sweets	3.2%/21.8%	35.5%/39.2%	18.8 (0.19)/ 18.6 (0.17)
Stress reduction	6.5%/11.9%	12.9%/11%	19 (0.35)/ 18.6 (0.15)
No particular reason	22.6%/10.7%	12.9%/11.8%	18.5 (0.2)/ 18.7 (0.16)
Other	9.6%/6.8%	12.9%/6.4%	19.2 (0.38)/18.8 (0.16)

3.3.4 Well-being and chewing gum consumption

A principal components analysis with orthogonal rotation (varimax) was conducted on the responses to items on the HADS. The sample was of adequate size for this analysis according to the Kaiser-Meyer-Olkin measure, KMO = .91, and Bartlett's test of sphericity indicated that variables were sufficiently correlated to perform principal components analysis, $p < .001$.

Three factors with eigenvalues greater than one were extracted, labelled anxiety (comprising the items "I feel tense or 'wound up'", "I get a sort of frightened feeling like something awful is about to happen", "worrying thoughts go through my mind", "I get a sort of frightened feeling like 'butterflies in the stomach'" and "I get sudden feelings of panic"), depression ("I look forward with enjoyment to things", "I feel cheerful", "I still enjoy the things I used to enjoy", "I can laugh and see the funny side of things", "I feel as if I am slowed down") and inattention/hyperactivity ("I feel restless as if I have to be the move", "I have lost interest in my appearance" and "I can enjoy a good book or radio or TV programme").

Depression and inattention/hyperactivity were somewhat lower for regular gum chewers, but there were no significant effects of gum consumption frequency on the well-being indices (see Table 3-5 below). Spearman correlations were calculated between chewing gum frequency and the well-being ratings (non-parametric correlations were used due to skew in chewing gum frequency). Chewing gum frequency was associated with lower depression ($\rho = -0.11$, $p = .04$). There were no interactions between gender and habitual gum consumption.

Table 3-5: Mean well-being rating and gum chewing[33]

Well-being index	Regular chewers	Infrequent chewers	Non-chewers
Life stress	2.6 (0.07)	2.7 (0.07)	2.6 (0.08)
Anxiety	6.2 (0.24)	6.2 (0.24)	6.3 (0.34)
Depression	1.9 (0.16)	2.5 (0.17)	2.6 (0.22)
Inattention/hyperactivity	1.9 (0.11)	2.3 (0.12)	2.2 (0.16)
Positive Mood	3.5 (0.05)	3.4 (0.05)	3.5 (0.08)
Alertness	3.2 (0.08)	3.2 (0.07)	3.2 (0.11)
Negative Mood	2.1 (0.06)	2.2 (0.06)	2.2 (0.08)

[33] Standard errors in brackets

3.4 Study 1b: Introduction

In contrast with Smith's survey findings (2009a, 2012), Study 1a did not find an association between chewing gum consumption and life stress in a student sample. In contrast to the intervention findings of Smith and Woods (2012), chewing gum frequency was associated with lower depression. Study 1b used a method similar to that of Study 1a to examine chewing gum consumption and associated attitudes and well-being in workers. Workers may have differing levels and habits of chewing gum consumption compared to students, and may also experience effects on stress and well-being differently.

One possible reason for the contrasting findings between past research and Study 1a is that any effect of chewing gum consumption may be small relative to the effects of other factors. Research of this kind thus needs to control for other aspects of life that may impact on well-being, in order to see if chewing gum has an effect on well-being at a given level of relevant factors (e.g. exposure to stressors). Consequently, a broader range of possible confounding factors were measured than in Study 1a.

3.5 Method

3.5.1 Design

Similar to Study 1a, this was a cross-sectional survey. Age, gender, health related behaviours (including smoking), level of education, wage and personality were used as covariates. Participants were split into regular chewers (chewing at least 5 pieces of gum a week), less regular (chewing up to 4 pieces a week) and those who never chewed.

3.5.2 Participants

One hundred and twenty participants (eighty-seven females, twenty-eight males, five no replies) were staff at Cardiff University who were recruited via an advertisement on the University notice board, asking for people to volunteer to complete a questionnaire on "well-being in university staff". Mean age was 37 (range = 21-64, SD = 10.7). Although this sample was smaller than that of Study 1a, it was large enough (>90) to detect a medium effect size.

3.5.3 Materials

The survey was administered using the Survey Tracker program. Chewing gum and well-being questions were the same as in Study 1a. Questions were also included concerning level of education, wage, personality, health related behaviours and job characteristics (see Appendix 3.3). Personality questions assessed conscientiousness, extraversion, openness, agreeableness and emotional stability, using one item for each personality trait. Health related behaviours questioned respondents on whether they smoked, how often they drank alcohol, had caffeinated drinks (tea and coffee) and ate snacks. Job characteristics assessed how frequently (on a 1-4 scale) participants had to work inflexible hours, at night, shift work or for long or unpredictable hours, were exposed to noise, harmful materials or fumes and how frequently they experienced ringing in their ears.

3.5.4 Procedure

The questionnaire was put online. The questions were included as part of a larger questionnaire which also included questions about attributional style, self efficacy, self esteem, coping, and mental health knowledge. Following recruitment, staff participants were emailed a link to the survey, which they could complete in their own time.

3.6 Results

3.6.1 Chewing gum consumption

There were twenty-six respondents who chewed regularly (Median = 6.5, range = 5-16), forty who chewed infrequently (Median = 2, range = 1-4) and fifty-four respondents who never chewed gum. Of respondents who answered the question on their average length of chewing a piece of gum (N = 55), 1.7% reported chewing gum for less than one minute, 25% for one-five minutes, 50% for 5-30 minutes and 23.3% for more than thirty minutes.

The percentage of respondents who reported chewing each named brand of gum are summarised in Table 3-6. Again, mint flavours were relatively popular. Similar to the student sample, gum consumption was reported as occurring most frequently around the middle of the day, with fewer respondents saying they chewed at earlier and later times. The times of day at which participants chewed is summarised in Figure 3-2.

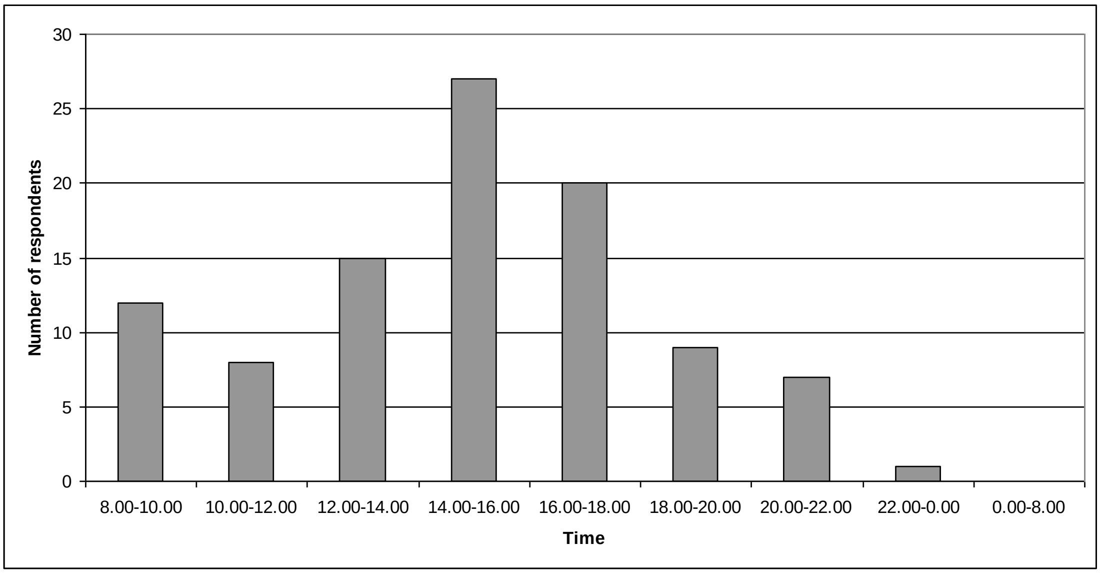

Figure 3-2: Number of working respondents who report chewing gum at given times of day

Table 3-6: Percentage of respondents reporting chewing named brands of gum

Brand	Respondents	Brand	Respondents
Airwaves Cherry	1.7%	Orbit Spearmint	11.7%
Airwaves Black Mint	6.7%	Orbit Peppermint	10%
Airwaves Menthol & Eucalyptus	0%	Orbit Complete	21.7%
Airwaves Green Mint	10%	Hubba Bubba	3.3%
Extra Spearmint	6.7%	Wrigley's Spearmint	1.7%
Extra Peppermint	11.7%	Wrigley's Double Mint	5%
Extra Cool Breeze	3.3%	Wrigley's Juicy Fruit	1.7%
Extra Ice	0%	Wrigley's 5	0%
Extra Fusion	16.7%	Other	0%

3.6.2 Attitudes towards chewing gum

Freshening breath was the most commonly endorsed reason for chewing gum (see Table 3-7). Three respondents indicated that they chewed gum both for concentration and for stress reduction. The attitudes of habitual and non-habitual chewers are summarised in Table 3-8 below. Again, higher habitual chewing was associated with generally more positive attitudes, with gum chewers considering gum to be more pleasurable, $F(2, 116) = 44.12$, $p < .001$, less rude, $F(2, 112) = 7.4$, $p = .001$, and having more positive effects on mood, $F(2, 109) = 4.28$, $p = .016$, attention, $F(2, 111) = 3.74$, $p = .03$, and stress, $F(2, 110) = 4.48$, $p = .014$.

Table 3-7: Percentage of gum-chewing participants endorsing reasons for chewing

Reason	Percent respondents
Freshen breath	88.3%
Flavour	21.7%
Dental health	36.7%
Appearance/to look cool	0%
Concentration	10%
Substitute for sweets	11.7%
Stress reduction	28.3%
No particular reason	0%
Other	0%

Table 3-8: Attitudes towards gum and frequency of gum consumption[34]

Attitude to gum	Regular	Infrequent	Never
Pleasurable	0.7 (1.5)	0.9 (1.1)	-0.9 (1.5)
Improves mood	0.4 (0.9)	0.3 (0.5)	-0.1 (1.1)
Improves attention	1.7 (1.6)	1.8 (1.4)	0.8 (2.2)
Reduces stress	0.5 (0.8)	0.5 (0.7)	0.0 (0.8)
Rude in most social situations	0.6 (1.6)	0.5 (1.1)	1.6 (1.6)

3.6.3 Chewing gum and covariates

Non-chewers were significantly older, $F(2, 110) = 4.1$ $p = .02$, and significantly more likely to drink tea, $\chi^2(2) = 8.6$, $p = .014$. Non-chewers were also more likely to be female, earn less than £20,000 per year, have a degree or higher level of education, be more conscientious, drink fewer alcoholic drinks, and regular chewers were exposed to more negative job characteristics, drank more coffee and ate more snacks, although none of these differences were significant. Habitual chewing frequency and covariates are summarised in Table 3-9 below. Consistent with the previous survey, age, gender and smoking were used as covariates, as well as consumption of tea, given that it differed between groups in this sample.

[34] Higher score indicates agreement. Standard errors in brackets

Table 3-9: Habitual gum chewing and candidate covariates[35]

	Regular chewers	Infrequent chewers	Non-chewers
Age	34.4 (1.5)	34.3 (1.7)	39.9 (1.6)
Gender	64% female	77.5% female	80% female
Salary	59.3% earn > £20,000	60% earn > £20,000	57.7% earn > £20,000
Education	76.9% degree or higher	77.5% degree or higher	68.5% degree or higher
Negative job characteristics	12.3 (0.6)	11.6 (0.5)	11.6 (0.6)
Personality			
Emotional stability	7.6 (0.33)	7.1 (0.28)	7.6 (0.25)
Extraversion	6 (0.51)	6.3 (0.35)	6.5 (0.29)
Agreeableness	8.4 (0.24)	8 (0.25)	8.3 (0.12)
Conscientiousness	7.9 (0.35)	8 (0.25)	8.4 (0.22)
Openness	8 (0.37)	7.2 (0.34)	7.9 (0.23)
Health Behaviours			
Alcoholic drinks per week	3.5 (0.35)	3.3 (0.27)	2.8 (0.3)
Smoking	7.7% smoke	15% smoke	7.4% smoke
Coffee	80.8% drink coffee	65% drink coffee	75.9% drink coffee
Tea	73.1% drink tea	70% drink tea	92.5% drink tea
Snacks	73.1% most days/ every day	67.5% most days/ every day	62.3% most days/ every day

There were no significant differences between males and females, smokers and non-smokers or differences associated with age in terms of reported motivation for smoking.

[35] Standard errors in brackets

Table 3-10: Gender, age and smoking status of chewers endorsing reasons for chewing gum

	Percent of males/females who endorse reason	Percent of smokers/ non-smokers who endorse reason	Mean age of chewers who do/do not endorse reason
Freshen breath	83.3%/72.3%	100%/72.4%	33.1 (1.3)/38 (2.4)
Flavour	22.2%/17%	100%/20.7%	31.6 (2.34)/35 (1.33)
Dental health	44.4%/25.5%	37.5%/29.3%	32.6 (2.02)/35 (1.42)
Appearance/to look cool	0%/0%	0%/0%	No respondents
Concentration	11.1%/6.4%	12.5%/6.9%	40 (5.23)/33.8 (1.18)
Substitute for sweets	16.7%/8.5%	25%/8.6%	37.9 (4.83)/33.9 (1.17)
Stress reduction	22.2%/27.7%	62.5%/20.7%	35.9 (2.52)/33.8 (1.3)
No particular reason	0%/0%	0%/0%	No respondents
Other	0%/0%	0%/0%	No respondents

3.6.4 Well-being and chewing gum consumption

The same three factors extracted in Study 1a were used for analysing the HADS. Although depression was somewhat higher for regular chewers, none of the observed differences were significant. There were no other effects of habitual gum consumption frequency on the well-being indices (see Table 3-11 below). Spearman correlations between chewing gum frequency and the well-being ratings were also insignificant. There were no interactions between gender and habitual gum consumption.

Table 3-11: Mean well-being and gum chewing[36]

Well-being index	Regular chewers	Infrequent chewers	Non-chewers
Life stress	2.8 (0.14)	2.7 (0.1)	2.8 (0.09)
Anxiety	5.6 (0.7)	5.7 (0.55)	5.8 (0.47)
Depression	4.1 (0.69)	2.9 (0.4)	3.1 (0.38)
Inattention/hyperactivity	2.4 (0.36)	2.4 (0.31)	2.1 (0.2)
Positive Mood	3.7 (0.14)	3.4 (0.09)	3.7 (0.08)
Alertness	3.6 (0.18)	3.4 (0.14)	3.6 (0.09)
Negative Mood	2 (0.13)	2.2 (0.08)	2.2 (0.09)

[36] Standard errors in brackets

3.7 General discussion

3.7.1 Patterns of chewing gum consumption and reasons for chewing gum

A clear majority of student respondents were gum chewers, while just over half of the workers reported chewing gum. Across both surveys, about half reported typically spending between 5 and 30 minutes chewing a piece of gum, with a quarter reporting chewing for more than 30 minutes and a quarter between 1 and 5 minutes. A small minority of both groups reported chewing for less than one minute. This indicates that requiring participants in an experiment to chew for between 5 and 30 minutes should be representative of the typical length of time over which gum is chewed. Much of the past experimental research investigating the effect of chewing gum on attention has required participants to chew for similar time periods, although some studies have had participants chewing for longer than 30 minutes (e.g. Smith, 2010; O. Tucha et al., 2004). Where time-on-task trends have emerged over a period of thirty minutes or so, this is unlikely to be due to participants having to chew for a considerably longer period than they would in daily life. Much previous research has used mint-flavoured gum; the general popularity of mint flavours in this survey suggests that mint is an ecologically valid flavour to use in controlled research.

Participants were most likely to chew gum between two and four pm (presumably following lunch for most people) and least likely in the early morning and late evening/night. This contrasts with findings on caffeine (Brice & Smith, 2002), which have indicated that caffeine is most frequently consumed in the morning. Caffeine is likely to be consumed during periods of low circadian arousal, to increase alertness; the fact that the diurnal pattern of chewing gum is somewhat different suggests that different motivations and habits may underpin chewing gum for some individuals, despite the experimental evidence for an alerting effect of gum. Similar to the findings of Zibell and Madansky (2009), freshening breath was the most commonly endorsed reason for chewing gum, so it is plausible that people will chew gum after lunch for this reason. Given that more working respondents reported chewing gum between 08.00 and 18.00 relative to other times of day, an intervention study carried out over the course of a workday will thus mimic the typical timing of chewing gum consumption.

When questioned on why they chew gum, some respondents to both surveys indicated that they chewed gum both for concentration and for stress reduction. This suggests that chewing can have both a relaxing and an attention-enhancing effect within individuals, or at least that it is perceived as doing so, consistent with findings suggesting gum can lead to relaxed concentration (Masumoto et al., 1999; Smith, 2010). However, only a minority of participants reported concentration or stress reduction as a reason for chewing gum. Despite the evidence base for chewing gum's effect on dental health (e.g. Deshpande & Jadad, 2008), a smaller number of respondents indicated that they chewed gum for dental health reasons compared to freshening breath. Although the option "substitute for sweets" was often endorsed as a reason for chewing gum, the most frequently mentioned "other" reason was avoiding hunger, suggesting that using chewing gum as a substitute for sweets may be sometimes due to attempts at weight loss rather than concern for healthy teeth.

3.7.2 Chewing gum and well-being

Despite the fact that chewers were often more likely to report that chewing gum should have a positive effect, and in contrast with Smith's survey findings (2009a, 2012), chewing gum frequency was not associated with life stress in the current samples. Students who chewed gum frequently were more likely to smoke, consistent with the findings of Smith (2009a). The fact that "substitute for cigarettes" was spontaneously reported as a reason for chewing gum in the "other" option gives evidence that smokers may sometimes chew gum as an alternative to smoking. Although a majority of participants chewed gum, a rather small proportion reported smoking; it is possible that smoking is becoming increasingly less fashionable. There was evidence that smoking decreased slightly in English university students between 1990-2000 (Steptoe et al., 2002), and the rate of smoking observed here was lower than that seen in 2000 by Steptoe et al. The question of whether chewing gum can act as a useful alternative to smoking may thus be of greater interest in developing nations, where a greater number of deaths occur due to smoking (WHO, 2003), and where poor healthcare and a lack of smoking regulation may place a greater onus on individuals to find an inexpensive way to stop smoking themselves.

3.7.3 Critique and summary

Although reduced depression was the only measured aspect of well-being associated with habitual gum consumption, previous evidence has indicated that a chewing gum intervention of two weeks can have positive effects on all of the well-being outcomes measured here, as well as some indicators of performance such as being behind with work (Smith et al., 2012). It may be that some effects of chewing gum, such as an alerting effect, are only clearly visible over a shorter period of time; a brief intervention may also show such effects.

A problem for the type of survey research described above is that it cannot establish the direction of causation, as it is not clear whether chewing gum leads to, for example, reduced stress or if people with lower stress are more likely to take up chewing gum consumption. Although confounding variables can be controlled for, one can only control for as many variables as one measures, and in a cross-sectional survey one cannot control for individual differences in the variable of interest. By manipulating chewing gum, rather than just assessing amount typically chewed, and by controlling for individual differences in the variables of interest using baseline measures, intervention research will help to establish the direction of causality by having chewing come before assessment of well-being and by controlling for the most relevant individual differences.

The main findings of the current surveys are that most respondents chewed gum, and gum was most likely to be chewed in the afternoon. Some respondents chewed gum for both stress reduction and concentration, although breath freshening was the most popular reason. Those with higher habitual gum consumption had more positive attitudes towards chewing gum. Intervention research may be able to establish if chewing gum effects on well-being and performance exist, using a more controlled methodology.

Chapter 4 A one-day chewing gum intervention and its effects on occupational performance, well-being and associated physiology

4.1 Introduction

Although Study 1a indicated that chewing gum was associated with lower depression, Study 1b did not indicate an effect of chewing gum on stress, anxiety or depression. However, the conclusions that can be drawn from such research regarding the effect of gum chewing are limited, since cross-sectional survey research has problems in attributing causation. Research using an intervention methodology, which can better isolate cause and effect relationships, has shown that well-being can be also improved by a two week crossover intervention (Smith et al., 2012; Smith & Woods, 2012, Suh et al., 2008) as well as interventions of either three or seven days (Zibell & Madansky, 2009).

The lack of an effect of chewing gum consumption on alertness in Chapter 3 contrasts with the robust experimental finding that chewing gum increases alertness following the performance of cognitive tasks (Johnson et al., 2011; Scholey et al., 2009; Sketchley-Kaye et al., 2011; Smith, 2009c, 2010), as well as the positive effect on fatigue observed in intervention research (Smith et al., 2012). In contrast to the effects on stress and performance shown in intervention research, under experimental conditions there has been mixed evidence for an effect of chewing gum on stress or on performance of cognitive tasks. This suggests that there is a difference in the effects of chewing on stress, alertness and cognition when one compares longer and shorter periods chewing and performing. Consequently, it is of interest if shorter interventions may lead to noticeable effects on occupational stress, fatigue, performance and mental well-being. Zibell and Madansky successfully indicated a positive effect on anxiety after three days (for frequent chewers, or seven days for infrequent); the current studies investigated if occupational well-being would be affected by a one-day chewing gum intervention.

The surveys in Chapter 3 indicated that some people who chew gum do so in order to maintain concentration (12.3% of student respondents and 10% of worker respondents), although this was a relatively small proportion of respondents. Although the experimental evidence for chewing gum effects on cognitive performance has been mixed, some effects on attention have been observed. Smith (2010) observed faster encoding of new information, a broader focus of attention and shortened reaction time for selective attention tasks. Chewing gum has enhanced performance on sustained attention tasks over time (Tänzer et al., 2009; L. Tucha & Simpson, 2011), although this was not demonstrated in another paper (L. Tucha et al., 2010). It has also been shown that chewing gum has a clearer effect on cognitive performance shortly after being chewed, rather than during chewing (Onyper et al., 2011). As attention is improved for approximately twenty minutes immediately after a short period of chewing, it is possible that effects of chewing may be visible for longer following a longer period of chewing. In contrast to previous research on chewing gum and performance of experimental tasks, which only looked at chewing for a short period of time, this study aimed to ascertain if chewing gum affects attention and reaction time (selective attention, simple reaction time and vigilance), as well as mood (alertness, hedonic tone and anxiety) following one workday of chewing.

In summary, this study aimed to investigate if chewing gum during one workday could improve occupational well-being and performance, and if mood and attention would also be improved at the end of the workday.

4.2 Study 2: Method

4.2.1 Design

The study comprised a one-day intervention with a between participants design. Participants were randomly assigned to a chewing or non-chewing condition.

4.2.2 Participants

One hundred and twenty-six participants (eighty-seven females, thirty-nine males) completed the study. Mean age was 29 (SD = 6.7). Similar to Smith et al. (2012), university staff were used as participants. Participants were full-time workers; their occupations were administration/secretarial (N = 36), researcher/lecturer (36), management (12), technician (10), applied psychologist (4), marketing (4), support worker (4), dentist (2), teacher (2) and other occupations indicated by one participant each (16). People taking medication, who had medical problems were excluded from participation (it was simply requested at recruitment that participants not take part if they were taking any medication, if they were feeling unwell or if they suffered from any serious medical condition). Participants who consumed more than 40 units of alcohol per week or who smoked more than 10 cigarettes in the daytime and evening were also excluded from participation. Participants were recruited through the Cardiff University notice board and an online experimental management system. Six participants began the procedure but either did not finish the procedure or had to be excluded due to missing data.

4.2.3 Materials

Pen-and-paper questionnaires were used to assess occupational well-being. Similar to the surveys, the HADS was used to assess anxiety, depression, and inattention/hyperactivity, and the fatigue subscale from the profile of fatigue-related symptoms (PFRS: Ray, Weir, Phillips, & Cullen, 1983) was used to assess fatigue, as well as a single-item question on how stressful participants found their job (as opposed to life in general, assessed in the previous chapter). Single item questions were also used to assess occupational performance (see Appendix 4.2); these questioned participants on cognitive failures and productivity/being behind with work (on scales from 0 to 4). These measures had all been used in Smith et al. (2012).

The following commercially available chewing gum brands were used: Wrigley's Spearmint, Wrigley's Extra (flavours: Spearmint, Peppermint, Cool Breeze, Ice) and Wrigley's Airwaves (flavours: Cherry, Green Mint, Black Mint, Menthol & Eucalyptus). Unit weight was approximately 1.4g per piece. All brands were sugarfree, with the exception of Wrigley's spearmint. Ingredients of the different brands are listed in Appendix 4.3.

The mood and performance tasks were presented on a desktop PC. Participants completed the tasks using a purpose-built response box with three large square buttons ("A" on the left, "B" on the right and "Space" in the centre). The tasks were completed in the following order:

Mood

This was measured before and after the attention tasks using 18 bi-polar visual analogue scales or VAS. Scores for alertness (maximum score = 400), hedonic tone (maximum score = 300) and anxiety (maximum score = 150) were derived from these scales. The component scales for alertness were drowsy-alert, strong-feeble, coordinated-clumsy, attentive-dreamy, lethargic-energetic, muzzy-clear headed, incompetent-proficient, mentally slow-quick witted. The scales for hedonic tone were contented-discontented, happy-sad, antagonistic-friendly, interested-bored, self centred-outward going and withdrawn-sociable. The scales for anxiety were relaxed-excited, troubled-tranquil and tense-calm. There was no time limit for this task.

Selective attention tasks (Broadbent, Broadbent, & Jones, 1986)

1. Focused attention task

In this task target letters appeared as upper case A's and B's in the centre of the screen. Participants were required to identify as quickly and as accurately as possible if the target letter was an A or a B, by pressing A or B with the forefinger of the left or right hand, while ignoring any distracters presented elsewhere on the screen. Before each presentation of the target, three warning crosses were displayed for 500ms. The middle cross was then replaced by the target, and the outer crosses by distracters (in the case of trials with distracters). The outer crosses were separated from the middle cross by 1.02° or 2.6°. The target letter was accompanied by nothing, letters which were the same as the target, letters which were different from the target or asterisks.

Mean reaction time, number of errors and number of long responses (> 800ms) were measured. The threshold for long responses was based on previous research (Smith, Sutherland, & Christopher, 2005). Breadth of attention was also assessed (the difference in reaction time and accuracy between targets with distracters presented near versus those with distracters at a further distance). The difference in reaction time between conditions where the target changed from the previous trial and where it remained the same was used as a measure of speed of encoding of new information. Following 10 practice trials, participants completed five blocks of 64 trials. This test lasted approximately 5 minutes.

2. Categoric search task

This task was similar to the focused attention task previously outlined, including number of practice and experimental trials. However, in this task participants did not know where the target would appear. At the start of each trial, two crosses appeared 2.04° or 5.2° apart or further apart, located towards the left or right extremes of the display. The target then replaced one of these crosses. For half the trials the target was presented alone and for half it was accompanied by a distracter (a digit from 1-7).

Mean reaction time, accuracy and long responses (>1000ms) were recorded, as well as reaction time and accuracy with which new information was encoded. Differences in reaction time and accuracy for trials where the position of the target stimulus and response key were compatible versus where they were incompatible were used as a measure of response organisation. The effect of the stimulus appearing in a different location versus the same location as the previous trial was measured, as well as the effect of not knowing the location of the target. This task also lasted approximately 5 minutes.

Psychomotor task

Variable Fore-period Simple Reaction Time Task (Smith, Kendrick, Maben, & Salmon, 1994)

In this task a box was displayed on the screen, followed by a square being presented in the middle of the box. The participant had to press the "Space" button as soon as the square was detected. The period of time elapsed before each appearance of the square varied. This task lasted 3 minutes.

Sustained attention task

Repeated-digits Vigilance Task (Smith et al., 1994)

Three-digit numbers were shown on the screen at the rate of 100 per minute. Each number was normally different from the preceding one, but for 8 occasions per minute the number presented was the same as that presented on the previous trial. Participants had to detect these repetitions and respond by hitting the "Space" button as quickly as possible. The number of hits (correctly detected repetitions), reaction time for hits and number of false alarms were recorded. The task lasted 5 minutes.

4.2.4 Procedure

During familiarisation with the tasks performed on the PC (which occurred before the main testing day), participants were asked to fill in a questionnaire concerning general levels of well-being and performance at work (these acted as baseline scores of well-being and performance). Participants also provided information about demographics, occupation and habitual level of chewing gum. On the testing day, participants completed a full battery of the mood and attention tasks in the morning as baseline measures. They were required to chew gum (one full packet of 10 pieces - participants chose whichever type they preferred) or avoid chewing gum over the course of the working day. Participants were informed they could chew when they wished during the working day, although they were encouraged to chew when they felt stressed, and they were told to eat and drink as much as they usually would. They returned to the laboratory following work and completed the same well-being questionnaire as in the familiarisation, except this time pertaining to how they felt that workday. They then completed the full battery again, to assess the effects of gum chewing during the workday; no one chewed gum during this battery.

4.2.5 Analysis

Analyses of covariance were used to determine if the independent variables (gum condition) affected occupational well-being and performance measures, as well as attention and mood (see Table 4-1 for a list of dependent variables), and habitual gum consumption (categorised as regular, infrequent or non-chewer) and gender were also entered to test for interactions with intervention condition. Baseline scores were used as covariates. Where data violated parametric assumptions, Mann-Whitney tests were performed on change-from-baseline data.

Table 4-1: Dependent variables assessed

Occupational performance	Productivity (being behind with work)
	Cognitive problems
Occupational well-being	Stress
	Fatigue
	Anxiety
	Depression
	Inattention
Mood	Pre-test alertness
	Post-test alertness
	Pre-test hedonic tone
	Post-test hedonic tone
	Pre-test anxiety
	Post-test anxiety
Categoric search	Mean reaction time
	Speed of encoding
	Spatial uncertainty
	Response organisation
	Place repetition
	Total errors
	Total long responses
Focussed attention	Breadth of attention
	Mean RT
	Speed of encoding
	Total errors
	Long responses
Simple reaction time	Mean SRT
Repeated digits vigilance	Total hits
	Total false alarms
	Mean RT

4.3 Results

4.3.1 Gum consumption

Habitual chewing was classified as follows: forty-eight participants were regular chewers (Median pieces chewed per week = 7.25, range = 5-30), forty-eight were infrequent (Median = 2.5, range = 0.25-4) and twenty-four never chewed. Those in the chewing intervention had a slightly higher level of habitual gum chewing (Mean pieces chewed per week = 5.6, SD = 7.1) than those in the control group (M = 4.4, SD = 5.6). However, this difference was not significant, $t(118) = 1.06$, $p > .05$, Cohen's $d = .19$. There were no significant interactions between level of habitual gum consumption and intervention condition for well-being and performance during the day, nor were there any such interactions for mood or cognitive performance tasks at the end of the day.

4.3.2 Reported workday well-being and performance

Baseline well-being values for the intervention groups are summarised in Table 4-2. Depression at baseline was higher in the chewing gum group, although this was not significant. During the one-day intervention, chewing gum was significantly associated with reporting of fewer cognitive problems, $F(1, 122) = 7.18$, $p = .004$ (one-tailed), *partial* $\eta^2 = .06$ and lower levels of being behind with work, $F(1, 122) = 5.5$, $p = .01$, *partial* $\eta^2 = .04$. This was also the case with occupational stress, $F(1, 119) = 3.83$, $p = .027$, *partial* $\eta^2 = .03$, inattention/hyperactivity, $F(1, 118) = 3.0$, $p = .04$, *partial* $\eta^2 = .03$ and fatigue, $F(1, 123) = 3.57$, $p = .03$, *partial* $\eta^2 = .03$. Anxiety was slightly higher in the chewing gum group as was depression, although these differences were insignificant (see Table 4-3). There were no significant interactions between gender and gum condition.

Table 4-2: Baseline well-being values for those in chewing gum intervention/no-gum control

	Chewing gum	No gum
Behind with work	2.3 (0.1)	2.5 (0.11)
Cognitive problems	2 (0.12)	2 (0.1)
Job Stress	1.4 (0.1)	1.5 (0.08)
Fatigue	2.4 (0.12)	2.3 (0.11)
Anxiety	5.1 (0.34)	4.6 (0.29)
Depression	2.7 (0.28)	2.1 (0.24)
Inattention	2.2 (0.17)	2.3 (0.18)

Table 4-3: Well-being and performance indices following one-day chewing gum intervention/no gum control[37]

	Chewing gum	No gum
Behind with work†	1.4 (0.13)	1.8 (0.13)
Cognitive problems**	1 (0.11)	1.4 (0.12)
Job Stress*	1.1 (0.12)	1.4 (0.11)
Fatigue*	2.2 (0.14)	2.3 (0.12)
Anxiety	3 (0.3)	2.6 (0.29)
Depression	2.4 (0.28)	2 (0.23)
Inattention*	2 (0.2)	2.5 (0.21)

4.3.3 Performance and mood assessed at the end of the day

Chewing gum during the day did not have any significant effects on mood or attention, as assessed by the battery completed at the end of the workday intervention. Mean scores are summarised in Table 4-4.

[37] Standard errors in parentheses. † indicated $p < .01$, ** indicates $p = .01$, * indicates $p < .05$

Table 4-4: Gum intervention, mood and cognitive performance[38]

Test	Gum	No gum
Pre-test alertness	242.9 (4.9)	235 (4.4)
Post-test alertness	192.9 (6.0)	189.4 (4.0)
Pre-test hedonic tone	196.2 (3.7)	195.5 (3.3)
Post-test hedonic tone	175 (3.7)	171.7 (3.5)
Pre-test anxiety	-1.1 (1.5)*	-3 (1.4)*
Post-test anxiety	85.8 (1.6)	84.1 (1.2)
Categoric search mean reaction time (ms)	524.8 (4.9)	526.1 (5.0)
Categoric search speed of encoding (low score = faster encoding of new information)	13.2 (2.3)	10.4 (2.6)
Categoric search spatial uncertainty (ms) (high score = greater uncertainty)	107.1 (2.5)	99.9 (3.2)
Categoric search response organisation (ms) (lower score = better organisation)	24.4 (1.5)	24.7 (1.7)
Categoric search place repetition (ms) (high score = greater effect of place repetition)	15.9 (2.1)	22.2 (1.8)
Categoric search errors	13.2 (0.8)	12.8 (0.9)
Categoric search long responses	2.2 (1.0)*	2.2 (1.0)*
Breadth of attention (high score = broader focus)	11.5 (3.0)	9.3 (2.6)
Focussed attention mean RT (ms)	0.1 (3.6)*	-13.7 (2.5)*
Focussed attention errors	1.5 (0.5)*	1 (0.4)*
Focussed attention long responses	0.6 (0.2)*	-0.2 (0.5)*
Focussed attention speed of encoding (low score = faster encoding of new information)	16 (2.2)	14 (2.1)
Mean simple RT (ms)	348.4 (5.6)	347.2 (4.8)
Repeated digits hits	-2.7 (0.5)*	-2.3 (0.4)*
Repeated digits false alarms	18.1 (0.7)	16.2 (0.6)
Repeated digits RT (ms)	701.2 (7.1)	711.2 (8.7)

* Change from baseline data

4.4 Study 2 discussion

Consistent with Smith et al. (2012), chewing gum during one workday reduced reported cognitive problems, fatigue, inattention/hyperactivity and occupational stress and increased productivity, compared to abstaining from gum. The reduction in cognitive problems is also consistent with previous research indicating that chewing gum can enhance sustained attention over time (Tänzer et al., 2009; L. Tucha & Simpson, 2011). These effects were not moderated by habitual level of chewing gum, indicating that these effects are not simply due to familiarity with chewing gum. Despite the evidence for positive effects on well-being, the observed effects were less highly significant than in previous intervention work using the same scales (Smith et al., 2012), and the intervention had little or no effect on anxiety or depression, despite the lower levels of general anxiety reported in Study 1b.

[38] Standard errors in parentheses

The chewing gum intervention did not affect mood or cognitive performance measured at the end of the workday. This suggests that any effect may be restricted to while gum is being chewed or only shortly after chewing, as no participants chewed gum when they were completing the battery of tasks at the end of the workday. A shortcoming of the current study is that there was no measurement of when the gum was chewed; participants may not have chewed shortly before completing the end-of-day assessment, or indeed may have chewed all/most of the gum shortly before testing if they forgot to do so earlier in the day. A measure of timing of chewing during the day will have clarify if this were the case or not. An alternative explanation to a short-term effect is that gum does not actually improve well-being, but such effects have been picked up by retrospective self-report measures, as it is difficult for participants to recall how they felt during the workday; ongoing assessment of dependent variables may thus be preferable.

4.5 Study 3: Introduction[39]

This study examined the robustness of the intervention by testing it in using a crossover design. Although the survey research described in Chapter 3 did not indicate an effect of habitual gum consumption on life stress, some gum chewing respondents to both Study 1a and 1b endorsed concentration and stress reduction as reasons for chewing, so it is possible that chewing gum may attenuate stress and enhance concentration within individuals. This study aimed to track the effect of chewing gum more closely by taking measures of current well-being at regular intervals, so as to observe if there are any short-term effects which may not be detected by retrospective assessment which occurs solely at the end of the workday. Effects on some variables may follow on from effects on others; for example, higher stress has been shown to lead to worse productivity (Smith, Johal, Wadsworth, Davey-Smith, & Peters, 2000). By measuring different aspects of well-being and performance across the day, it may be possible to see if effects of chewing gum earlier in the day are associated with differing effects later in the day. Timing of gum chewing was also measured, in order to investigate if variations in effects are attributable to chewing at certain times. Given the lack of any effect of gum on mood and attention measured at the end of the workday in Study 2, the battery of mood and attention tasks was not included in this study.

Given the possibility that psychophysiological changes may underlie subjective effects of chewing gum (see Section 2.6.3), this study also aimed to investigate if gum affected any physiological factors associated with the psychological variables measured. Experimental evidence has been inconsistent, with findings suggesting that chewing gum can reduce cortisol (Scholey et al., 2009), or increase it (Smith, 2010). However, the past research has focused on the effects of short-term chewing over the space of an hour or so; given the fact chewing gum over a relatively longer period of time has shown a clearer effect on self-reported stress, it may also be the case that a stronger trend in cortisol levels may be visible over a longer period of time. Smith also found that heart rate was increased by gum, as did Wilkinson et al. (2002),

[39] The section describing this study is an extended version of Allen, A.P. & Smith, A.P. (2012). A brief intervention method for investigating the effects of chewing gum on occupational well-being. In Anderson, M. (Ed). *Contemporary ergonomics & human factors 2012* (pp. 211-218). London: CRC Press

although other research has not indicated an effect (O. Tucha et al., 2004). Again, over a longer period of time, a clearer picture may emerge.

The hypothalamic-pituitary-adrenal (HPA) axis responds to situations which are interpreted as stressful: the hypothalamus releases corticotrophin-releasing factor, leading the pituitary gland to release adrenocorticotropin, which in turn leads the adrenal gland to secrete cortisol (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007). Salivary cortisol has been found to correlate well with serum cortisol, suggesting that salivary cortisol is useful as a non-invasive means of tracking serum cortisol (Teruhisa et al., 1981). However, the half-life of these measures differs, with a half-life of 102 minutes (SD = 30) for serum cortisol and 72 (SD = 12) for salivary cortisol Tunn, Müllman, Barth, Derendorf, & Krieg, 1992); another study indicated a half-life for salivary cortisol of about one hour in response to psychological stress (Hellhammer, Kirschbaum, & Belkien, 1987). Comparing different stress-induction paradigms use in the laboratory, cortisol secretion is heightened in response to psychosocial stress in particular (Dickerson & Kemeny, 2004). Research using the Trier Social Stress Test has indicated that salivary cortisol peaks approximately 20 minutes after the onset of a psychosocial stressor (e.g. Kirschbaum, Pirke, & Hellhammer, 1993). However, cortisol release also has a predictable diurnal pattern, with levels peaking in the morning, gradually declining over the course of the day and displaying a sudden increase following the first few hours of sleep (Lupien et al., 2007). When comparing cortisol levels across conditions, sampling should thus occur at the same time of day. As well as showing a characteristic diurnal pattern, cortisol varies over the course of shorter periods of time than 24 hours (Young, Abelson, & Lightman, 2004); some endogenous pulses observed in secretion are similar to the effects of the TSST.

Measuring heart rate and cortisol over the course of a day may clarify the psychophysiological effect of chewing gum. Given the increase in productivity reported in Study 2, it is possible that chewing gum led to higher physical arousal and activity, which should be observable in an increase in heart rate. Salivary cortisol was measured at regular intervals throughout the day, similar to the self-report measures, and heart rate was measured constantly. It was hypothesised that chewing gum would reduce cortisol and increase heart rate; this would be consistent with observed electroencephalographic patterns during chewing described as relaxed concentration (Morinushi et al., 2000).

4.6 Method

4.6.1 Design

This study comprised a crossover intervention design, with order of gum conditions and habitual gum consumption included as between-participants factors. Participants were randomly assigned to an order of gum condition.

4.6.2 Participants

Thirty full-time university staff (twenty-three females, seven males) completed this study; mean age was 30.4 (SD = 6.9). Their occupations were administration/secretarial (N = 12), researcher (9), and other occupations indicated by only one participant each (9). One participant withdrew following familiarisation. Participants were recruited through the University notice board. To minimise demand characteristics regarding gum, the study was described as a "study on consumption habits". Exclusion criteria were the same as those in Study 2. With power set at 0.8, this sample was approximately of an adequate size to detect an effect of $\rho = 0.4$.

4.6.3 Materials

Polar s610 monitors were used to measure heart rate throughout the workday. The electrodes of the heart rate monitor were dampened with Spectra 360 gel to improve transmission. Saliva samples were taken using Sarstedt salivettes (Nümbrecht, Germany), which were held upright in foam in a tall plastic box. Questionnaires filled in at the end of the workday were the same as those used in Study 2.

A series of short questionnaires were used during the workday. These included single item-questions for anxiety, depression, stress, physical fatigue, mental fatigue, exhaustion, cognitive problems and productivity, as well as food and caffeine consumption. There was also a question on gum consumption for the gum condition (see Appendix 4.5). These were either filled out in hard copy or completed online (using Survey Tracker software). Available chewing gum was the same as in Study 2.

4.6.4 Procedure

For familiarisation, participants spent a day wearing a heart rate monitor, giving saliva samples and recording well-being and performance at the same times as they did during the main testing days. The main testing took place over two separate days. Chewing gum was consumed during one testing day, and avoided during the other, control day. The testing days were at least one week apart, in order to avoid carryover effects. Participants came in to the lab before work (between 8am and 9.30am) to collect heart rate monitors, salivettes, gum (in the gum condition) and questionnaires (if using hard copies).

Participants were requested to chew a full packet of gum during the intervention day. Participants were emailed online links to or given hard copies of questionnaires, which were filled in at 10am, 11am, 12 noon, 2pm and 3pm. Participants were free to chew gum before filling in the first questionnaire at 10am. Saliva samples were taken at the same time as the questionnaires. Heart rate was measured throughout the working day.

During the testing days, participants were instructed to eat and drink the same amount they would on a normal day, but to avoid alcoholic drink and chewing gum other than the provided gum. Participants were requested not to eat for one hour before the post-work session. After work, well-being and performance were assessed again and saliva samples were collected. Participants were instructed to keep saliva samples refrigerated after being taken. Saliva samples were frozen in a conventional freezer as soon as they were returned at the end of the day, and transported for assay in dry ice.

4.6.5 Analysis

Saliva cortisol levels were assessed by a researcher who was blind to the conditions the samples corresponded to. Cortisol levels were measured in duplicate by radioimmunoassay adapted from Read, Fahmy and Walker (1977). The limit of detection was 0.7 nmol/L, intra-assay coefficient of variation was 10.8%, 8.8% and 5.3% at 3.3, 6.4 and 24.7 nmol/L respectively and inter-assay variation was 11.0%, 10.8% and 10.7% at 2.5, 5.1 and 26.4 nmol/L. Heart rate data was visually examined for artefacts (e.g. heart rate staying exactly the same for more than five minutes, readings consistently exceeding 200 beats per minute for longer than two minutes or falling to zero for any amount of time) and these were removed.

Results taken during the workday and at the end of the workday were analysed using mixed ANOVAs, with gum condition, habitual gum consumption and time of day (for measures taken during the workday) being independent variables. Dependent variables were physiological (heart rate and salivary cortisol), and reported well-being and performance (productivity, cognitive problems, anxiety, depression, inattention, stress, and fatigue). Inattention was only taken at the end of workday, as this was part of the complete HADS, and single-item measures for anxiety and depression were used during the workday. As gum was a repeated measures factor, change scores are reported as descriptive statistics.

4.7 Results

The intervention had a mean duration of 8 hours and 24 minutes (SD = 33.6 minutes) for the gum condition and 8 hours 26 minutes (SD = 40 minutes) for the control.

4.7.1 Gum consumption and caffeine consumed

Habitual chewing was classified as follows: nine participants were regular chewers (Median pieces chewed per week = 7, range = 5-30), nine were infrequent (Median = 2.5, range = 0.8-2.5) and twelve never chewed. Similar amounts of gum were chewed between the start of testing and 12.00 (Median number of pieces = 4) and between 12.00 and 15.00 (Median = 4). There were no interactions between gum condition and habitual gum consumption for reported performance and well-being or for heart rate or salivary cortisol.

Consumption of tea and cola was slightly lower during the gum intervention, but caffeinated drink consumption generally changed little between conditions, with mean fall for the intervention in servings of coffee = 0 (SD = .9), tea = -.3 (SD = .8), cola = -.1 (SD = .1) and other caffeinated drinks = 0 (SD = .1). None of these change scores was significantly greater than 0.

4.7.2 Self-reported well-being and performance

Work done reported during the day was significantly higher in the gum condition $F(1, 23) = 3.28$, $p = .04$ (*one-tailed*), *partial* $\eta^2 = .13$, with participants reporting being less behind with work (see Figure 4-1). There were no other effects of gum on well-being or performance during the workday; the non-significant effects are summarised in Table 4-5. There were no significant interactions between gum condition and time of day for well-being and performance.

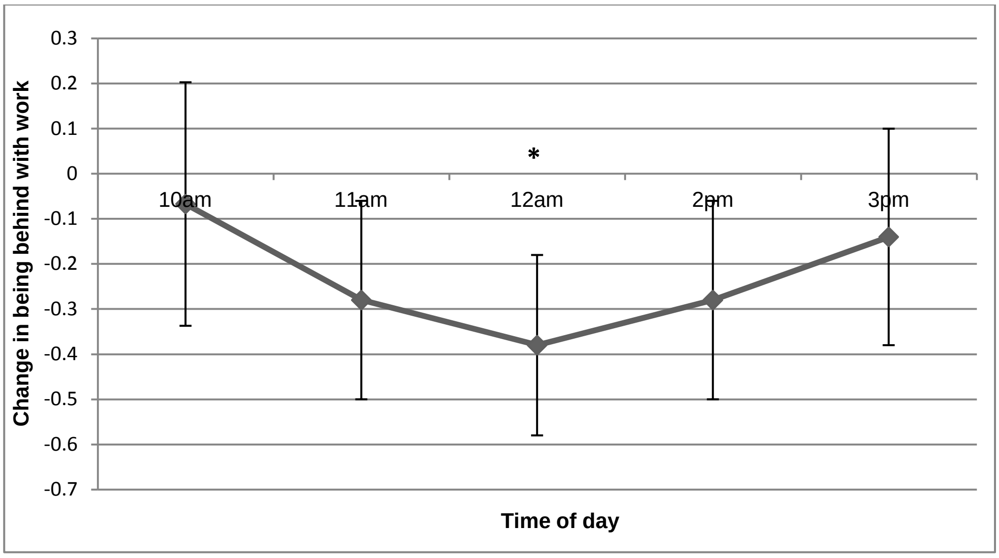

Figure 4-1 Change in work done (being behind with work) by gum during working day[40]

Table 4-5: Mean change between gum and control conditions in well-being and performance during the workday[41]

	10am	11am	12noon	2pm	3pm
Cognitive problems	-0.03 (0.13)	-0.03 (0.18)	-0.27 (0.2)	-0.11 (0.17)	-0.41 (0.22)
Job stress	0 (0.25)	-0.07 (0.25)	-0.17 (0.17)	-0.32 (0.21)	-0.24 (0.18)
Fatigue	-0.16 (0.32)	-0.24 (0.36)	-0.25 (0.39)	-0.9 (0.4)	-0.81 (0.45)
Anxiety	0 (0.21)	0 (0.16)	-0.4 (0.17)	-0.07 (0.1)	0.07 (0.16)
Depression	0.13 (0.14)	0.18 (0.13)	-0.03 (0.14)	0.07 (0.09)	0.14 (0.15)

At the end of the workday, reporting of cognitive problems was lower in the gum condition than in the control, $F(1, 26) = 5.31$, $p = .02$, *partial* $\eta^2 = .17$. The gum intervention reduced anxiety and inattention/hyperactivity reported at the end of the day, although these effects were not significant. The effects of chewing gum reported at the end of the intervention conditions are summarised in Table 4-6.

Table 4-6: Mean change between gum and control conditions in well-being and performance reported at the end of the workday[42]

Behind with work	-0.13 (0.21)
Cognitive problems*	-0.35 (0.15)
Job Stress	-0.12 (0.12)
Fatigue	0.02 (0.11)
Anxiety	-0.49 (0.36)
Depression	0.25 (0.35)
Inattention	-0.37 (0.25)

[40] Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)
[41] Standard errors in parentheses
[42] Negative score indicates lower score in gum condition. Standard errors in parentheses, * indicates $p < .05$

4.7.3 Physiological measures

Overall cortisol levels were almost identical for the gum condition, M = 6.11, SD = 1.5, and the control, M = 6.11, SD = 1.7. The interaction between gum condition and time of day was non-significant overall, $F(2.97, 65.3) = 0.82$, $p = .24$, *partial* $\eta^2 = .04$ (Greenhouse-Geisser adjusted). However, salivary cortisol was higher in the gum condition for the first testing period at 10am (see Figure 4-2).

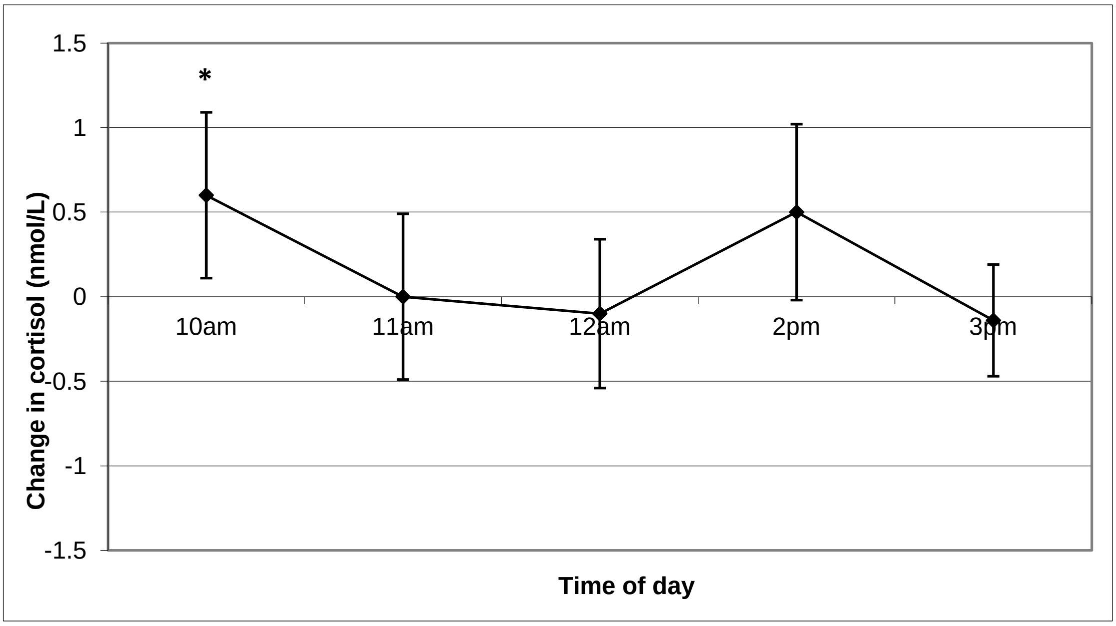

Figure 4-2: Change in salivary cortisol levels by chewing gum during working day[43]

Heart rate was higher during the gum condition for both regular chewers, M = 1.6 (change in beats per minute), SD = 8.8, and non-regular chewers, M = 0.8, SD = 5.9. However, there was no significant main effect of gum, nor were there any interactions.

4.7.4 Mediating effects of outcomes

In order to assess if effects of gum on one outcome in the morning led to an effect on another outcome in the afternoon, while keeping number of comparisons relatively low, the overall number of gum pieces chewed during the morning (start of testing to 12.00) were examined for Spearman correlations with changes between gum and control conditions in mean well-being and performance indices and physiological factors recorded during this period. No correlations were significant, so no further analyses were made to test for mediating effects on outcomes in the afternoon.

[43] Positive scores = higher cortisol in gum condition. Error bars represent standard error. Asterisk indicates significant effect ($p < .05$)

4.8 Study 3 discussion

4.8.1 Chewing gum and self-report

Similar to Study 2, chewing gum enhanced productivity and reduced cognitive problems. Inattention/hyperactivity was reduced, although this effect was not statistically significant, perhaps due to lower power than Study 2. Anxiety was not reduced by gum, nor did gum reduce stress; this contrasts with previous findings that longer interventions reduced anxiety (Zibell & Madansky, 2009) and stress (Smith et al., 2012).

4.8.2 Chewing gum and physiological data

Gum did not affect cortisol or heart rate overall. However, contrary to the hypothesis that gum would reduce cortisol (in line with previous intervention findings that gum reduced reported stress), gum actually increased cortisol early in the workday. The initial increase is consistent with the finding that chewing gum can increase cortisol over the space of a few hours (Smith, 2010). The lack of an effect on heart rate contrasts with some experimental research indicating that heart rate can be increased by chewing gum over a short period of time (Wilkinson et al, 2002); such an effect may only be visible under more controlled circumstances.

4.8.3 Chewing gum and caffeine consumption

Although worker respondents to the survey indicated chewing more frequently in the afternoon compared to the morning, there was no significant difference in gum consumption between the morning and afternoon. Caffeinated drink consumption did not differ between intervention conditions. This indicates that the differences observed were not simply due to differing levels of caffeinate drink consumption. It also suggests that participants did not alter their consumption of such drinks in response to any perceived effect of gum. People may change their behaviour on an ongoing basis to deal with factors such as stress, fatigue, lack of productivity etc. (Matthews, Warm, Reinerman, Langheim, & Saxby, 2010). Given the alerting effect of caffeine (e.g. Hewlett & Smith, 2007) and the fact that people consume caffeine during periods of low ciracadian arousal to increase alertness (Brice & Smith, 2002), if participants had a clear perception that gum reduced fatigue, they may have reduced their caffeine consumption if they were using caffeine to reduce fatigue.

4.9 General discussion

4.9.1 Results and critique

Both studies indicated that chewing gum can reduce cognitive problems and increase productivity. Taken together, these findings provide clear evidence for a perceived positive effect of chewing gum on performance in a natural setting. Cortisol was increased in the gum condition at 10am, although given the half life of cortisol, subjective effects associated with such a change in cortisol would be expected to occur between 9am and 9.30, and subjective effects were not measured at this time point. Despite the observed increase in cortisol, reported stress was reduced in Study 2, although not in Study 3. Neither anxiety nor depression was affected in either study. Given that the intervention and control condition were one week apart in Study 3, a carryover effect is not a likely explanation for any of the observed effects.

The differing findings from physiological and subjective reports are reminders that the relationship between physiology, emotion and cognition are multi-faceted, and more complete accounts can be offered when these factors are studied together. Arousal can increase cognitive performance, but such effects may differ depending on whether the arousal is a form of tension or if it is energetic arousal (Matthews et al., 2010). The measurement of multiple types of variable in this research allowed this advice to be followed: the fact that anxiety was either unaffected or reduced, while work performance were enhanced, indicates that the arousing effect of chewing gum is not associated with increasing tension, but rather energetic arousal.

As a method, intervention research is less tightly controlled than experiments, although it has the advantage of looking at the effects of chewing gum in the context of participants' daily lives, as well as being able to look at the effects of chewing for longer periods of time than are employed in experiments. Comparing the acute effects of gum during interventions and experiments may depend on people's timing of chewing during a workday; if people are more likely to chew gum during lunch, coffee breaks etc, then the acute effects of chewing gum on their mood will be more comparable to the experiment with no attention tasks. In contrast, if they chew at the same time as they are carrying out their work, than the acute effects during an intervention should be more similar to the other experiments described in this thesis. There were differences between the current research and past intervention research other than the length of the intervention and the inclusion of physiological data. The current studies specified a precise amount of gum to be chewed (one packet), whereas previous research either only specified a minimum amount or requested participants to chew as much as they usually would. It is probable that, when an intervention does not specify a particular amount of gum to be chewed, participants with higher habitual levels of chewing will chew more during such an intervention. By requiring participants to chew one full packet of gum, the current studies thus controlled for any effects of habitual chewing on amount chewed during the intervention itself. The fact that the amount of gum to be chewed was quite substantial may have been responsible for the presence of some effects over a shorter time period. This may not explain the effect of gum on cortisol, which was restricted to 10am, before most participants had chewed a large amount of gum, although given the finding from Study 1b that most workers do not chew much gum in the morning, it may be a larger amount than many were used to at that time of day. The present research included participants who were not regular chewers as well as participants who were, although the level of habitual gum consumption did not vary between intervention groups in Study 2, so this would not have been a confound. The current research also differed from previous work in that the questionnaires used did not explicitly ask participants whether they thought that chewing gum had had an effect (as the design aimed to minimise demand characteristics).

4.9.2 Future intervention research and applications

Further research is required to establish if positive effects of chewing gum are robustly observable, and after what time period significant effects will emerge. In addition to overall heart rate, heart rate variability could be assessed; research using an acute noise stressor has indicated that chewing gum can alter heart variability, although there was not a corresponding change in reported stress or anxiety (Ekuni, Tomofuji, Takeuchi, & Morita, 2012).

Future research could explicitly measure level of physical activity. Motor activity could be part of the reason why chewing gum affects well-being, particularly in jobs which are physically sedentary. Such jobs are quite prevalent (e.g. Choi et al., 2010), and a large proportion of the samples in the current research were administrative staff or researchers, whose work often does not require much physical activity.

There are comparative benefits to using chewing gum as a means of enhancing well-being and performance. Chewing gum could be a cheap way of dealing with stress, relative to other interventions. As well as being inexpensive financially, it does not require a time commitment in occupations where gum can be chewed while working.

One can control the level of one’s chewing more precisely than level of drug consumption. Chewing gum may also be associated with fewer iatrogenic effects. Although the effects of chewing gum may be relatively small in size, changes that lead to improvement in well-being at a population level may have a larger impact than interventions targeted solely at individuals with very low well-being (Huppert, 2009), so the overall effect of chewing gum consumption could be considerable.

4.9.3 Conclusions

In summary, the research described in this chapter indicates that chewing gum over a single workday has positive effects on worker performance during the day. Chewing gum also has an initial effect on cortisol, although it does not have an effect on heart rate over the workday. Gum does not have an overall effect on anxiety, although this may be moderated by habitual level of gum consumption.

Although intervention research can be used to manipulate chewing gum consumption, the participants in this chapter’s research would have had different experiences during the workday intervention. The remainder of this thesis will examine the short-term effects of chewing gum under experimental conditions, which allow for tighter control of possible confounding variables. This research begins with a closer examination of time-on-task trends in chewing gum effects on mood and attention.

Chapter 5 Chewing gum and time-on-task trends[44]

5.1 Introduction

Numerous experimental studies have indicated that gum chewing during performance of various cognitive performance tasks is associated with higher reported alertness (see Section 2.2). Consistent with the reporting of chewing gum as improving attention in Study 1, speed of encoding of new information for a selective attention task has been shown to be improved by caffeinated gum but not non-caffeinated (Smith, 2009b), although a later study did indicate such an effect with non-caffeinated gum (Smith, 2010). Experimental evidence has shown that chewing gum can enhance vigilance task accuracy (Smith, 2010), but other research has not indicated a vigilance effect (Smith, 2009b; Wilkinson et al., 2002). Recent research has indicated that chewing may improve attention only after a period of time performing a task (Smith, 2010; Tänzer et al., 2009; L. Tucha & Simpson, 2011), although another paper has not found such a within-task effect (L. Tucha et al., 2010) (see Section 2.7 for detailed discussion). This seems consistent with intervention research in Chapter 4 which indicated that chewing gum improved productivity and reduced cognitive errors over the course of the workday, which is a longer time frame than that used in experiments. Taking the findings on alertness and attention together, it seems that chewing gum may affect performance on attention tasks by enhancing alertness or attenuating an increase in fatigue over time.

The first study of this chapter was based on a previous experiment (Smith, 2010) which assessed the effect of gum on subjective alertness and various tests of cognitive performance. Participants in Smith's study completed a baseline session before completing the gum or control condition. Chewing gum impaired immediate word recall, which was assessed early in the battery, but gum had a positive effect on subsequent tests: more target stimuli were detected on a vigilance task, encoding speed for new information and breadth of attention were higher on a focussed attention task and reaction time was shortened on a categoric search task. Gum also enhanced alertness rated after these tasks.

The current research evaluated the effect of chewing gum on reported alertness and those tests of attention which seemed to be enhanced by gum chewing (Smith, 2010).

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[44] This chapter is an extended version of Allen, A.P. & Smith, A.P. (2012). Effects of chewing gum and time-on-task on alertness and attention. *Nutritional Neuroscience, 15*(4), 176-185

If the effect of chewing gum depends on having carried out previous tasks or a long period of prior chewing then it should not be observed here, where there were no previous tasks to perform and chewing was of a short duration. A positive effect of gum would thus indicate that the effect of gum may simply be restricted to a particular type of task, rather than depending on a time-on-task trend. The current study also examined time-on-task effects within each individual performance task to see whether benefits of chewing become clearer as tasks progress. Alertness was reported both before and after the performance tasks. It was predicted that these alertness ratings would also demonstrate the fatigue induced by the tasks. It was also of interest to determine if chewing gum would still enhance reported alertness when no previous tasks had been performed.

5.2 Study 4: Method

5.2.1 Design

A 2 X 2 X 2 mixed factorial design was used, with the independent-measures factor being order of gum conditions. The repeated-measures factors were gum condition (gum and no-gum control) and time-on-task (for variables where such an analysis could be performed; see Section 5.2.5).

5.2.2 Participants

Fifty-four participants took part (forty-four females, ten males). Mean age was 20 years (SD = 1.9). Exclusion criteria were the same as those in Study 2.

5.2.3 Materials

Mood and attention tasks, as well as available brands of chewing gum, were the same as those used in Study 2. Alertness, hedonic tone and anxiety were assessed before and after tests of selective attention, simple reaction time and repeated digits vigilance. The available brands of gum were: Wrigley's Spearmint, Wrigley's Extra (flavours: Spearmint, Peppermint, Cool Breeze, Ice) and Wrigley's Airwaves (flavours: Cherry, Green Mint, Black Mint, Menthol & Eucalyptus).

5.2.4 Procedure

Testing took place at 09.00 or 11.00, and participants were tested in groups of up to six people. Following a familiarization with the tasks, participants completed the tests of mood and attention; once with chewing gum and once without it. Participants completed the second testing session immediately after the first. Order of gum conditions was randomized; twenty-six participants completed the gum condition first and twenty-eight completed the no-gum control first. Participants were asked to chew constantly at their own pace throughout the tasks, and they were allowed to replace pieces of gum during the gum condition if they wished. Participants were not asked to refrain from chewing gum before beginning testing. Testing took approximately 50 minutes in total.

5.2.5 Analysis

Mixed ANOVAs were used to analyse the data, with the independent variables being gum condition and order of gum condition. Dependent variables were mood and attention (see Table 4-1). Time-on-task was also entered as an independent variable in the analysis of variables for which time-on-task data was available (i.e. alertness, hedonic tone and anxiety, categoric search errors and reaction time, focussed attention errors and reaction time, simple reaction time, repeated digits hit, false alarms and reaction time). Time-on-task was defined as pre- versus post-test for reported mood (i.e. before and after the attention tasks), 64-trial block for the selective attention tasks, and minute for the repeated digits and simple reaction time.

5.3 Results

5.3.1 The effect of time-on-task

Between pre- and post-test assessment, there was a significant reduction in alertness, $F(1, 51) = 49.45$, $p < .001$, *partial* $\eta^2 = .49$, and in hedonic tone $F(1, 51) = 26.35$, $p < .001$, *partial* $\eta^2 = .34$, but not in anxiety.

Time-on-task led to a significant lengthening of categoric search reaction time, $F(4, 200) = 834.88$, $p < .001$, *partial* $\eta^2 = .94$. Simple reaction time was lengthened over the course of the task, $F(4, 196) = 9.83$, $p < .001$, *partial* $\eta^2 = .17$. As the repeated digits task continued, reaction time lengthened, $F(4, 172) = 2.66$, $p = .04$, *partial* $\eta^2 = .06$, and hits fell, $F(4, 196) = 26.2$, $p < .001$, *partial* $\eta^2 = .35$, although false alarms did not change. However, time-on-task did not affect focussed attention reaction time or accuracy.

5.3.2 The effect of gum and gum over time on reported mood

Pre-test reported alertness was significantly higher in the gum condition than in the control (Mean Change = 11.1, SEM = 5.7), $F(1, 50) = 3.47$, $p = .04$, *partial* $\eta^2 = .07$. Similarly, post-test reported alertness was higher in the gum condition (Mean Change = 11.1, SEM = 5.2), $F(1, 49) = 4.09$, $p = .03$, *partial* $\eta^2 = .08$. Gum led to a significant improvement in all component items making up alertness.

Gum significantly increased reported hedonic tone, both at pre-test (Mean Change = 10.6, SEM = 4.1), $F(1, 50) = 6.11$, $p = .009$, *partial* $\eta^2 = .11$, and at post-test (Mean Change = 9.1, SEM = 3.5), $F(1, 49) = 6.28$, $p = .008$, *partial* $\eta^2 = .11$. For those participants who began with the control condition, reported alertness fell from M = 219.7 (SD = 10.7) at pre-test to M = 199.7 (SD = 8.8) at post-test, $t(27) = 2.64$, $p = .01$, Cohen's d = 0.5, suggesting that even a single task session reduced reported alertness. Gum had a significant effect on all items except for withdrawn-sociable ($p = .06$).

Gum did not have a significant effect on anxiety, nor was there was any significant interaction between gum conditions and pre- versus post-test reported alertness.

5.3.3 The effect of gum and gum over time on attention

For the categoric search task, gum significantly reduced the number of long responses, $F(1, 50) = 4.87$, $p = .02$, *partial* $\eta^2 = .09$, and reduced the effect of stimulus-response incompatibility, $F(1, 50) = 6.02$, $p = .009$, *partial* $\eta^2 = .11$. The other, non-significant effects of gum are reported in Table 5-1.

Table 5-1: Effect of gum on reported mood and cognitive performance

	Test	Mean Change
1.	Pre-test anxiety (High score = high anxiety.).	0.8 (1.8)
2.	Post-test anxiety	0.4 (1.4)
3.	Simple RT (ms)	-9.1 (7.1)
4.	Breadth of attention (high score = broader focus)	-2.4 (5.1)
5.	Focussed attention mean RT (ms)	-1.6 (3.1)
6.	Focussed attention errors	2.0 (1.4)
7.	Focussed attention long responses	-0.1 (0.2)
8.	Focussed attention speed of encoding (low score = faster encoding of new information)	-3.3 (2.5)
9.	Categoric search errors	1.0 (1.9)
10.	Categoric search spatial uncertainty (ms) (high score = greater uncertainty)	3.0 (4.7)
11.	Categoric search place repetition (ms) (high score = greater effect of place repetition)	0.1 (3.0)
12.	Categoric search speed of encoding (low score = faster encoding of new information)	-0.9 (2.7)
13.	Repeated digits hits	0.4 (0.8)
14.	Repeated digits false alarms	-0.7 (1.4)
15.	Repeated digits RT (ms)	-2.1 (8.0)

Standard errors in parentheses.

On the categoric search task, there was a significant interaction between gum conditions and trial order; gum reduced overall errors when the gum condition came first, $F(1, 50) = 22.76$, $p < .001$, *partial* $\eta^2 = .31$. Similarly, in the focused attention task, and only when the gum condition came first, gum led to fewer errors, $F(1, 50) = 28.6$, $p < .001$, *partial* $\eta^2 = .36$.

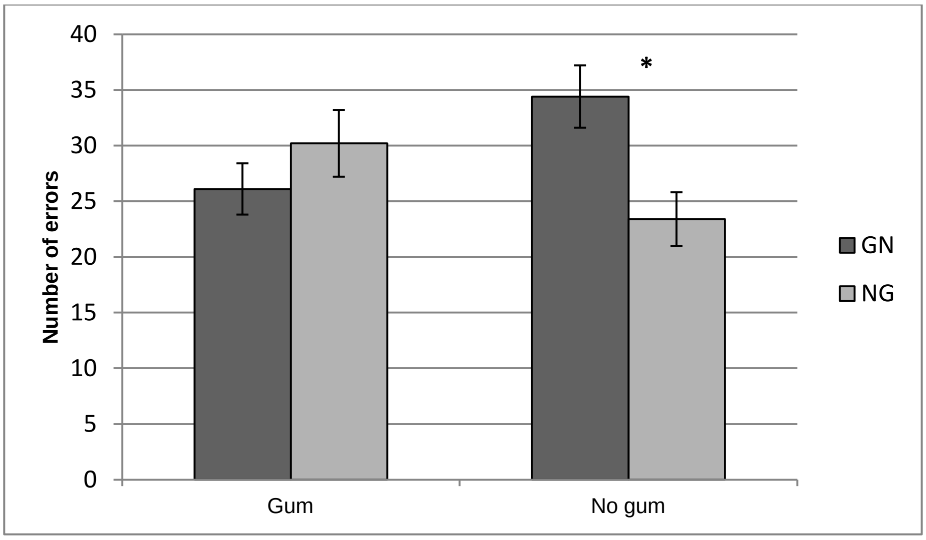


Figure 5-1: Effect of gum condition and order of gum condition on categoric search errors[45]

[45] GN = gum condition first, NG = gum condition second. Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)

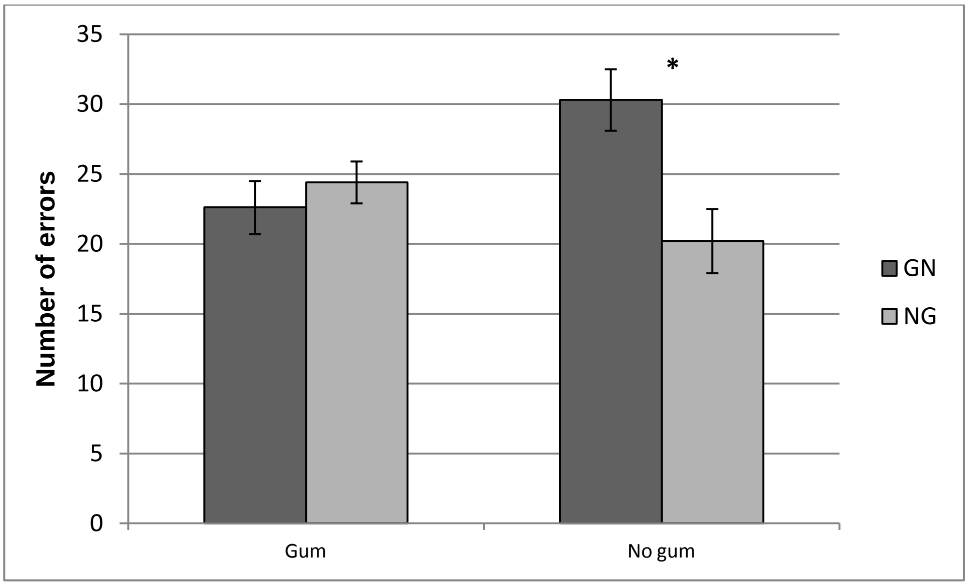


Figure 5-2: Effect of gum condition and order of gum condition on focussed attention errors

There were no statistically significant interactions between gum condition and time-on-task within the attention tasks.

5.4 Study 4 discussion

Consistent with previous experimental research chewing gum heightened alertness. Gum also improved hedonic tone, consistent with the finding from Study 1 that people tend to report gum chewing as pleasurable. Gum facilitated categoric search performance – it also increased accuracy and lengthened reaction time for the focused attention task, but only when the gum condition came first. Although speed of encoding was quickened by gum, this effect was non-significant. Although repeated digits task performance changed over time, there no time-on-task effect of gum; this contrasts with the findings that chewing gum can enhance sustained attention towards the end of a task. A possible shortcoming of the procedure was that participants were allowed to replace their chewing gum if they wished, but there was no control over if/when this would happen. This was controlled for in the next experiment. Although there was an interaction between gum condition and order of gum condition for selective attention errors in this experiment, it is difficult to ascertain if the effect is a true interaction, or if participants simply made more errors during the second testing session, regardless of gum condition. When the gum condition is followed by a no-gum condition, it is difficult to disentangle carryover effects, unless there is a complete no-gum control. The next experiment thus aimed to take a more in-depth look at these issues, by adding two testing sessions with gum and two sessions without gum.

5.5 Study 5: Introduction

Study 4 did not indicate an effect of chewing gum moderated by time-on-task. It is worthwhile investigating if the time-on-task effects observed in Smith (2010) are replicable if participants must also complete a baseline session before completing the gum and no-gum control conditions. It is likely that completing a baseline session could lead to greater fatigue during subsequent testing sessions; chewing gum may reverse a greater decrement in attention stemming from this fatigue. In addition to completing one gum and one control condition following baseline, the completion of two consecutive gum conditions or two consecutive controls will allow further questions to be probed.

Study 5 comprised a baseline session followed by two experimental sessions in which participants were assigned to a chewing gum condition or a no-gum control. The results from participants who chewed gum for both sessions (the GG group) would indicate if any effect of gum becomes more or less apparent over a continuous period of chewing. If those who chewed gum in the first session but not the second (GN) displayed an initially high level of attention and reported alertness, followed by a decline, this would suggest that chewing gum does not have persistent carryover effects. If those who only chewed gum in the second session (NG) showed lower attention and reported alertness followed by an increase, this would indicate that gum can enhance reported alertness or attention further into a testing session. If mood or attention are higher in the gum condition of NG than that of GN, this would indicate that the key factor is length of performance rather than length of chewing, as gum is chewed for the same amount of time for both conditions, but is chewed after a longer period of testing for NG. Those who did not chew gum at all (NN) acted as an overall control, to test if a longer testing protocol than Study 4 would have a greater fatiguing effect.

5.6 Method

5.6.1 Design

Following a familiarisation session and a baseline testing session, participants were randomly assigned to a gum condition or no-gum control during two experimental sessions which manipulated current chewing.

5.6.2 Participants

One hundred and twenty-six participants (eighty-seven females, thirty-nine males) who had taken part in Study 2 completed this study.

5.6.3 Materials

The computerized tests of reported mood and attention and flavours of chewing gum from Study 2 were used for this study.

5.6.4 Procedure

Participants were asked to complete a brief version of the computerized task battery as a familiarisation. They returned on a later date for testing, which began between 16.00 and 18.00. Participants completed a baseline of the full battery; no participants chewed gum during this session. This was followed by two experimental sessions: experimental session 1 (ES1) and experimental session 2 (ES2) which required the full battery to be completed with or without chewing gum. This led to four groups of participants: GG (i.e. gum in ES1 and ES2; $n = 33$), GN (i.e. gum in ES1 and no gum ES2; $n = 31$), NG ($n = 33$), and NN ($n = 34$).

During ES1 and ES2, participants in a chewing gum condition were required to constantly chew two pieces of gum at the same time while completing the battery. In order to better control chewing than in the previous experiment, they were required to just chew those two pieces. Before completing ES2, participants in the GG group replaced their current gum with two new pieces of gum of the same flavour. Participants were tested in groups of up to six people at a time.

5.6.5 Analysis

ANOVAs were used to analyse the effects of gum condition, with interactions between gum conditions for the first and second experimental being tested also for the second experimental session. Habitual gum consumption was entered into the analysis as an independent variable to test for interactions between gum condition and habitual level of consumption. Dependent variables were the same mood and attention variables as in Study 4.

Change-from-baseline scores were analyzed, except for the analysis of the general effect of time-on-task (Section 5.7.2), as the baseline and experimental session data are likely to show similar trends, which would mask the specific effect of time-on-task during the session if change-from-baseline scores were used.

5.7 Results

5.7.1 Gum chewing data

The numbers of participants selecting each flavour of gum were as follows: Extra Ice (19), Extra Cool Breeze (18), Extra Spearmint (14), Extra Peppermint (11), Airwaves Cherry (10), Airwaves Menthol & Eucalyptus (6), Airwaves Black Mint (5), and Airwaves Green Mint (5).

Habitual chewing was classified as follows: forty-eight participants were regular chewers (Median pieces chewed per week = 7.25, range = 5-30), forty-eight were infrequent (Median = 2.5, range = .25-4) and twenty-four never chewed. There was no significant difference between experimental groups in mean pieces habitually chewed per week.

There was an interaction between gum condition and habitual gum consumption for categoric search mean reaction time for ES1 and ES2, although the direction of the effect differed; non-chewers were slowed by gum on the categoric search task, but performed similar to regular chewers on the focused attention task (see Figures 5-3 and 5-4). There was also an interaction between gum condition and habitual consumption in ES1 for repeated digits total hits (non-chewers showed a greater increase in hits in the gum condition; see Figure 5-5) and post-test anxiety (gum heightened anxiety in non-chewers but reduced it in infrequent chewers; see Figure 5-6).

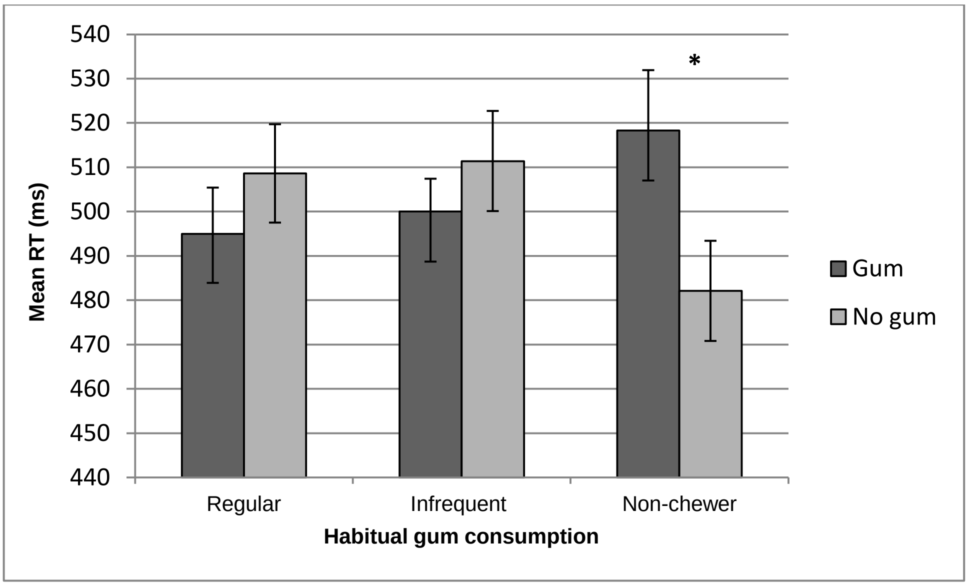


Figure 5-3: Gum condition, habitual gum consumption and categoric search mean reaction time in ES1[46]

[46] Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)

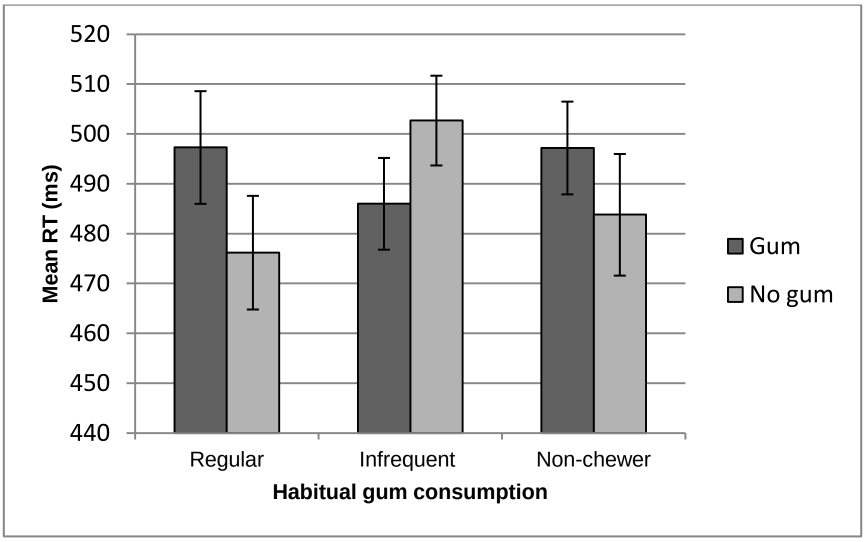


Figure 5-4: Gum condition, habitual gum consumption and categoric search mean reaction time in ES2[47]

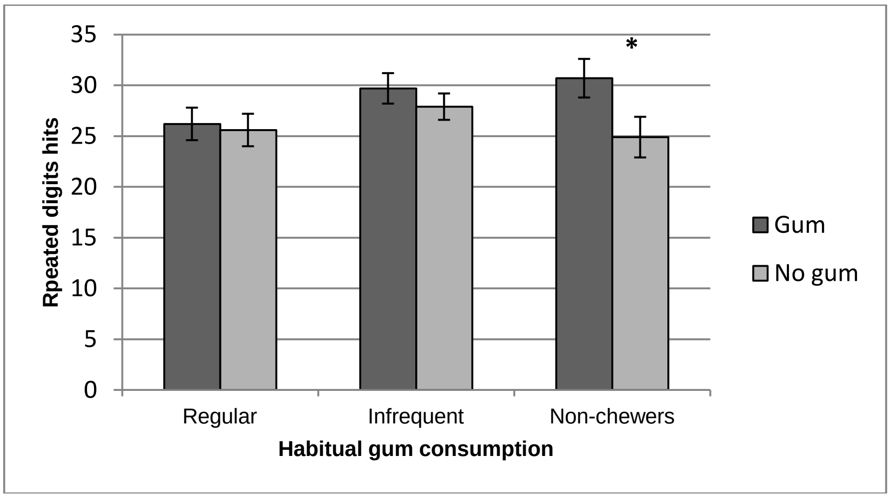
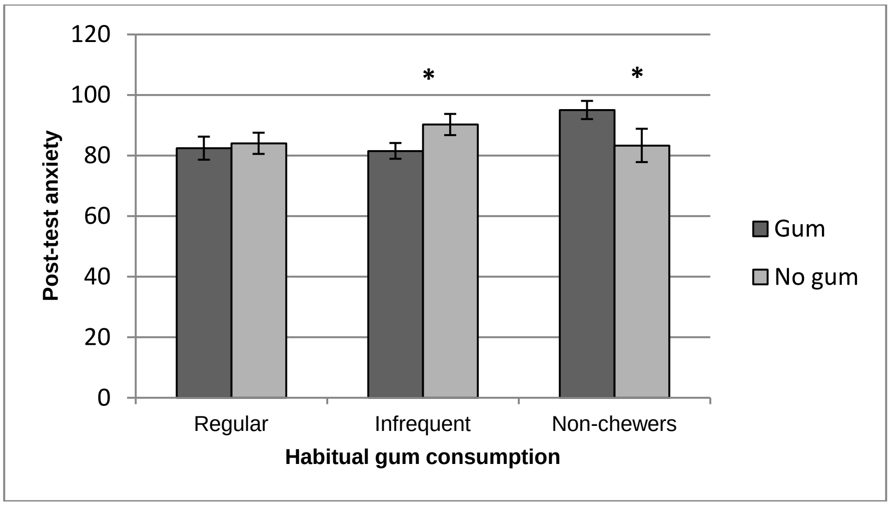


Figure 5-5: Gum condition, habitual gum consumption and repeated digits hits in ES1[47]



[47] Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)

Figure 5-6: Gum condition, habitual gum consumption and post-test anxiety in ES1[47]

5.7.2 The effect of time-on-task

Similar to those who did not chew gum for the first testing session in Study 4, reported alertness fell between pre-test, M = 238, SEM = 4.8, and post-test, M = 191.1, SEM = 5.1, during the baseline session, $t(130) = 11.33$, $p < .001$, Cohen's d = 0.99.

During ES1, significant effects of time-on-task (independent of gum condition) were lengthened categoric reaction time, simple reaction time, and repeated digits reaction time, a decrease in repeated digits hits and false alarms and a reduction in alertness and hedonic tone.

During ES2, the same general effects of time-on-task were observed, with the exception that focussed attention reaction time lengthened, and the effect on repeated digits false alarms was inconsistent across minutes.

5.7.3 The effect of chewing gum and gum over time during experimental session 1

When pre-test and post-test reported alertness scores were entered in the same analysis, gum significantly increased overall reported alertness, $F(1, 129) = 59.65$, $p < .001$, *partial* $\eta^2 = .32$, but there was no time-on-task interaction between pre- and post-test reported alertness. Separate analyses of the pre- and post-test scores showed that reported alertness was higher in the gum condition, M (mean change from baseline) = -4.5, SEM = 5.4, than in the control, M = -42.9, SEM = 5.4, at pre-test, $U = 1195.5$, $p < .001$ $r = .39$ and also at post-test (gum; M = 25, SEM = 5.6, control; M = -20, SEM = 5.8), $U = 835.5$, $p < .001$ $r = .53$.

Gum improved performance on the categoric search task by reducing the number of long responses (gum; M = -1.8, SEM = .4, control; M = .07, SEM = .3), $U = 1443$, $p = .001$, $r = 0.28$, shortening reaction time (gum; M = -20.5, SEM = 3.5, control; M = -11.8, SEM = 3.5), $U = 1565$, $p = .006$, $r = 0.22$, and increasing the speed of encoding of new information (gum; M = -3.85, SEM = 2.6, control; M = 3.18, SEM = 2.9), t(128) = 1.8, $p = .036$, Cohen's d = 0.32. Gum had no other significant effects on the attention tasks. Means scores for the baseline session and ES1 are reported in Table 5-2. There were there no significant time-on-task interactions within the attention tasks, and no effects of gum were moderated by habitual gum consumption.

Table 5-2: Reported mood and attention for baseline session and ES1

	Test	ES1 Condition	Baseline	ES1
1.	Pre-test hedonic tone	Gum	190.1 (5.0)	180.7 (5.1)
		Control	201.1 (4.8)	177.3 (5.2)
2.	Pre-test anxiety	Gum	87.2 (2.1)	86.0 (2.0)
		Control	83.3 (2.3)	83.1 (2.2)
3.	Post-test hedonic tone	Gum	166.7 (5.0)	172.0 (5.0)
		Control	179.7 (5.0)	168.6 (5.1)
4.	Post-test anxiety	Gum	85.1 (2.1)	84.6 (2.0)
		Control	84.7 (2.1)	86.6 (2.2)
5.	Simple RT (ms)	Gum	344.3 (6.9)	366.8 (7.7)
		Control	350.9 (7.7)	378.8 (7.6)
6.	Breadth of attention	Gum	5.2 (4.0)	14.1 (3.9)
		Control	15.4 (3.8)	15.7 (3.5)
7.	Focussed attention mean RT (ms)	Gum	415.8 (7.3)	403.4 (5.0)
		Control	407.7 (5.8)	401.1 (5.3)
8.	Focussed attention percent correct	Gum	95.3 (0.5)	94.3 (0.6)
		Control	96.6 (0.3)	95.2 (0.4)
9.	Focussed attention errors	Gum	10.5 (1.3)	14.7 (1.7)
		Control	10.7 (1.0)	16.7 (1.3)
10.	Focussed attention long responses	Gum	1.7 (0.6)	1.6 (0.3)
		Control	0.9 (0.2)	0.9 (0.5)
11.	Focussed attention speed of encoding	Gum	11.3 (2.9)	15.5 (3.5)
		Control	18.5 (3.1)	22.9 (3.3)
12.	Categoric search errors	Gum	12.0 (1.2)	14.2 (1.3)
		Control	13.9 (1.1)	18.4 (1.7)
13.	Categoric search spatial uncertainty (ms)	Gum	105.4 (4.3)	101.9 (4.5)
		Control	101.4 (4.0)	95.8 (4.6)
14.	Categoric search S-R compatibility (ms)	Gum	21.9 (2.5)	26.7 (2.2)
		Control	26.6 (2.1)	29.7 (2.4)
15.	Categoric search place repetition (ms)	Gum	20.6 (2.7)	19.0 (2.3)
		Control	17.7 (3.0)	18.2 (2.7)
16.	Repeated digits hits	Gum	27.9 (0.9)	28.5 (1.0)
		Control	26.4 (0.9)	26.5 (0.9)
17.	Repeated digits false alarms	Gum	17.0 (0.9)	16.3 (0.9)
		Control	17.6 (1.0)	19.3 (1.4)
18.	Repeated digits RT (ms)	Gum	711.2 (10.9)	690.0 (11.3)
		Control	698.8 (12.1)	693.0 (10.3)

Standard errors in parentheses.

5.7.4 The effect of chewing gum and gum over time during experimental session 2

Post-test reported alertness was significantly higher in the gum condition (gum; M = 17.7, SEM = 7.3, control; M = -15.2, SEM = 5.9), U = 1411, p = .001, r = .27, as well as overall reported alertness, $F(1, 127) = 13.43$, $p < .001$, *partial* $\eta^2 = .1$. Again, there was no time-on-task interaction between pre- and post-test reported alertness.

The breadth of attention in the focussed attention task was broader in the gum condition (gum; M = 9.1, SEM = 5.3, control; M = -11.4, SEM = 4.5), $t(125.3) = -2.96$, $p = .002$, Cohen's d = .52, and gum shortened reaction time on the repeated digits task (gum; M = -11.6, SEM = 8, control; M = 12.3, SEM = 8.8), $t(119) = 1.98$, $p = .03$, Cohen's d = .36.

For the focussed attention task, habitual gum consumption moderated reaction time, $F(1, 115) = 4.8$, $p = .03$, *partial* $\eta^2 = .04$, and errors, $F(1, 115) = 5.8$, $p = .02$, *partial* $\eta^2 = .05$; gum shortened reaction time and reduced errors for low habitual chewers. Habitual gum consumption similarly moderated categoric search reaction time, $F(1, 114) = 4.05$, $p = .047$, *partial* $\eta^2 = .03$.

Furthermore, repeated digits reaction time was lengthened during chewing gum for the second minute of the task, but faster for the third and fourth minute, $F(3.65, 376.1) = 2.55$, $p = .02$, *partial* $\eta^2 = .02$, Greenhouse-Geisser adjusted (see Figure 5-7).

There were no other significant main effects or interactions for attention. Mean scores for the baseline session and ES2 (further divided according to gum condition in ES1) are reported in Table 5-3.

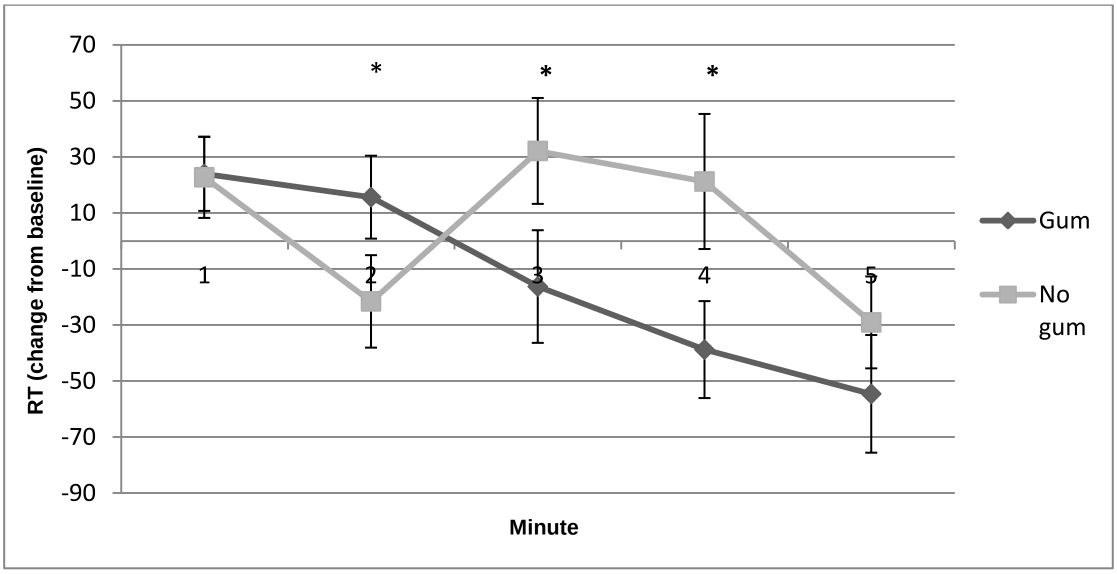


Figure 5-7: Effect of gum on repeated digits reaction time across minutes in ES2[48]

[48] Error bars represent SE

Table 5-3: Reported mood and attention for baseline session and ES2[49]

	Test	ES1 Condition	ES2 Condition	Baseline	ES2
1.	Pre-test alertness	Gum	Gum	241.7 (8.9)	236.6 (8.9)
		Gum	Control	211.1 (9.4)	207.2 (9.3)
		Control	Gum	247.4 (7.6)	215.1 (9.7)
		Control	Control	247.9 (11.0)	179.8 (9.9)
2.	Pre-test hedonic tone	Gum	Gum	197.2 (6.8)	184.4 (7.7)
		Gum	Control	182.2 (7.5)	161.2 (8.4)
		Control	Gum	206.3 (6.2)	179.5 (7.4)
		Control	Control	196.1 (7.3)	158.9 (7.5)
3.	Pre-test anxiety	Gum	Gum	90.7 (3.1)	87.9 (3.2)
		Gum	Control	83.1 (2.9)	80.8 (2.5)
		Control	Gum	82.0 (3.1)	82.2 (2.8)
		Control	Control	84.5 (3.4)	87.2 (3.3)
4.	Post-test hedonic tone	Gum	Gum	172.5 (7.3)	173.2 (6.6)
		Gum	Control	158.3 (6.8)	146.7 (7.1)
		Control	Gum	183.0 (6.6)	183.4 (6.9)
		Control	Control	176.6 (7.5)	158.6 (7.4)
5.	Post-test anxiety	Gum	Gum	86.5 (3.2)	88.6 (3.0)
		Gum	Control	84.0 (2.7)	81.2 (3.1)
		Control	Gum	83.9 (3.0)	83.2 (2.7)
		Control	Control	85.5 (2.9)	86.2 (3.1)
6.	Simple RT (ms)	Gum	Gum	338.0 (9.1)	376.4 (10.7)
		Gum	Control	351.9 (10.9)	399.2 (13.1)
		Control	Gum	361.8 (12.0)	394.1 (13.5)
		Control	Control	340.3 (9.4)	373.6 (9.5)
7.	Focussed attention mean RT (ms)	Gum	Gum	414.3 (9.8)	402.6 (7.1)
		Gum	Control	417.5 (11.6)	394.3(6.4)
		Control	Gum	409.5 (7.7)	406.0 (7.1)
		Control	Control	406.0 (8.8)	385.8 (6.5)
8.	Focussed attention percent correct	Gum	Gum	95.7 (0.7)	93.2 (1.2)
		Gum	Control	94.6 (0.9)	92.5 (0.8)
		Control	Gum	96.8 (0.4)	94.6 (0.8)
		Control	Control	96.4 (0.4)	93.3 (0.9)
9.	Focussed attention errors	Gum	Gum	8.8 (1.4)	14.5 (2.1)
		Gum	Control	12.5 (2.2)	22.7 (3.1)
		Control	Gum	11.4 (1.9)	20.6 (2.4)
		Control	Control	10.0 (0.9)	21.6 (2.8)
10.	Focussed attention long responses	Gum	Gum	1.6 (0.8)	0.8 (0.2)
		Gum	Control	2.0 (0.9)	1.1 (0.4)
		Control	Gum	1.2 (0.4)	1.1 (0.3)
		Control	Control	0.6 (0.2)	1.8 (0.4)
11.	Focussed attention speed of encoding	Gum	Gum	9.2 (4.8)	13.8 (5.8)
		Gum	Control	13.6 (3.3)	21.6 (4.1)

[49] Standard errors in parentheses

		Control	Gum	25.5 (4.6)	29.4 (5.1)
		Control	Control	11.7 (3.8)	22.5 (5.3)
12.	Categoric search mean RT (ms)	Gum	Gum	529.8 (10.0)	503.3 (9.0)
		Gum	Control	524.2 (11.8)	492.3 (10.0)
		Control	Gum	509.7 (8.0)	484.5 (6.8)
		Control	Control	517.2 (9.7)	489.4 (8.0)
13.	Categoric search errors	Gum	Gum	10.0 (1.3)	13.1 (1.7)
		Gum	Control	14.1 (2.0)	17.3 (5.9)
		Control	Gum	14.9 (2.0)	20.0 (2.2)
		Control	Control	12.8 (1.1)	19.3 (5.7)
14.	Categoric search long responses	Gum	Gum	8.8 (2.4)	4.5 (0.9)
		Gum	Control	11.2 (4.5)	6.3 (2.5)
		Control	Gum	6.7 (2.2)	3.3 (0.8)
		Control	Control	5.6 (1.7)	5.6 (1.0)
15.	Categoric search spatial uncertainty (ms)	Gum	Gum	100.8 (5.8)	96.2 (4.4)
		Gum	Control	110.1 (6.6)	75.9 (8.2)
		Control	Gum	101.3 (5.1)	84.4 (4.3)
		Control	Control	101.4 (6.2)	90.0 (4.8)
16.	Categoric search S-R compatibility (ms)	Gum	Gum	19.4 (3.1)	30.3 (3.3)
		Gum	Control	24.2 (4.0)	30.1 (3.2)
		Control	Gum	29.4 (3.1)	30.1 (3.0)
		Control	Control	23.8 (2.8)	29.3 (3.2)
17.	Categoric search place repetition (ms)	Gum	Gum	25.3 (3.5)	18.3 (4.0)
		Gum	Control	15.6 (4.0)	7.2 (3.9)
		Control	Gum	16.7 (4.0)	5.5 (3.6)
		Control	Control	18.6 (4.5)	16.7 (4.2)
18.	Categoric search speed of encoding	Gum	Gum	7.2 (4.8)	9.6 (4.7)
		Gum	Control	13.0 (5.0)	10.9 (3.7)
		Control	Gum	17.0 (5.6)	17.9 (5.3)
		Control	Control	9.3 (4.5)	19.1 (5.6)
19.	Repeated digits hits	Gum	Gum	27.5 (1.2)	27.3 (1.3)
		Gum	Control	28.3 (1.3)	28.4 (1.2)
		Control	Gum	25.8 (1.3)	25.5 (1.2)
		Control	Control	27.1 (1.2)	27.3 (1.2)
20.	Repeated digits false alarms	Gum	Gum	15.7 (1.2)	16.9 (1.2)
		Gum	Control	18.5 (1.4)	17.6 (1.4)
		Control	Gum	17.3 (1.5)	16.9 (1.4)
		Control	Control	17.5 (1.4)	20.7 (2.2)

5.7.5 Gum chewing across experimental sessions

Averaging pre- and post-test reported alertness, alertness did not differ across sessions for the GG group. Reported alertness fell in the GN group, as well as in the NN group. The gum condition was associated with higher reported alertness for the NG group (see Figure 5-8). This interaction between gum conditions and session was significant, $F(1, 117) = 4.68$, $p = .02$, *partial* $\eta^2 = .03$. There was no such interaction for attention, including the variables which indicated a gum condition by trial order interaction in Study 4.

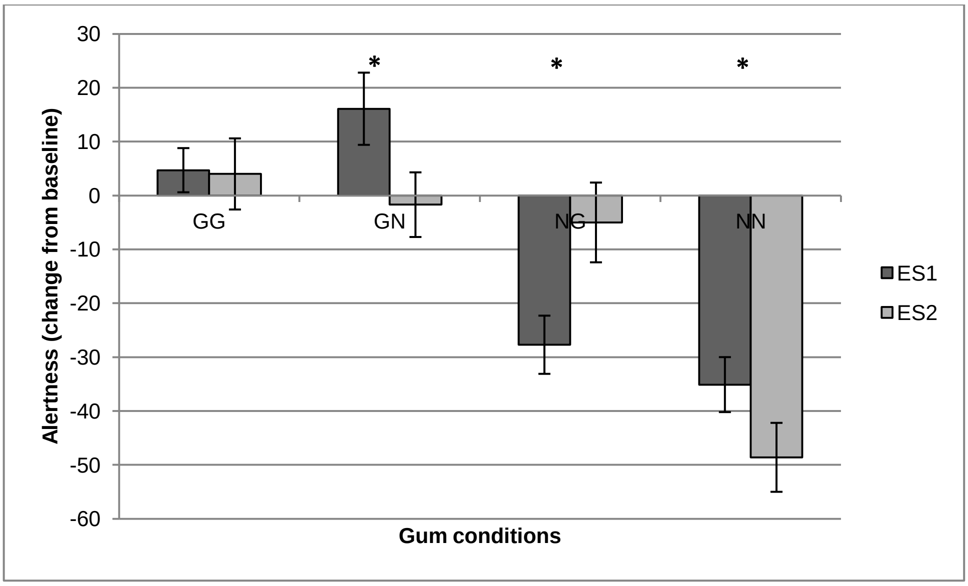


Figure 5-8: Effect of chewing gum on mean alertness for experimental testing sessions[50]

5.8 Study 5 discussion

5.8.1 Chewing gum and alertness

Current chewing gum condition increased reported alertness pre- and post-test for ES1 and post-test for ES2. In addition, participants in both the GN and NG groups showed an increase in overall reported alertness during whichever experimental session they were required to chew. As the GG group reported a similar level of alertness during both ES1 and ES2, alertness does not continuously increase over long periods of chewing; instead chewing prevents alertness from falling. Given the fatiguing effect of the baseline session, the fact that alertness was enhanced in the GN and GG groups suggests that chewing gum can return alertness to levels observed before a fatiguing task. This is further supported by the fact that alertness fell during ES1 for the NG group, but returned to baseline for ES2, when gum was chewed.

It is unlikely that chewing gum led to any persistent carryover effects on reported alertness, because the GN group reported a drop in alertness. The pre- and post-test alertness ratings from the GN group suggests that any carryover effects are short-lived, as the effect of gum on reported alertness seemed to continue shortly after ES1 had finished (i.e. pre-test reported alertness in ES2), but to have dissipated by the end of ES2.

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[50] GG = chewing gum during ES1 followed by chewing gum in ES2, GN = chewing gum in ES1 followed by no chewing gum in ES2, etc. Error bars represent SE. Asterisk indicates significant difference between gum and no-gum conditions ($p < .05$)

5.8.2 Chewing gum and attention

Chewing gum led to faster encoding of new information, shortened reaction time and fewer long responses on the categoric search task for ES1 and a broader focus of attention and shortened reaction time on the repeated digits task during ES2. This effect of gum on repeated digits reaction time was moderated by time-on-task, with a negative effect of gum in the second minute of testing being followed by a positive effect of gum in the third and fourth minutes. The finding that chewing gum initially impaired and subsequently improved vigilance over time is consistent with research elsewhere which has indicated a positive effect of chewing gum on sustained attention, but only later in testing (Tänzer et al., 2009; L. Tucha & Simpson, 2011). Chewing gum did not affect any other aspects of attention during the experimental sessions.

In contrast to the time-on-task effect observed on vigilance, after controlling for individual differences (by analysing change from baseline scores), and including conditions where participants chewed for both sessions or neither session, the interactions between gum condition and testing session for selective attention observed in Study 4 were not apparent in this study. The findings in Study 4 may thus be due to a general time-on-task effect, rather than a genuine interaction between chewing gum and time-on-task.

Higher habitual gum consumption led to lengthened reaction time on the selective attention tasks and higher errors for the focussed attention task; this is contrary to the hypothesis that people who are most used to chewing gum should perform better, as they will be less distracted by having to chew gum during performance. However, this only occurred for the second experimental session; it is possible that chewing behaviour altered over time, perhaps becoming less vigorous during ES2 for habitual chewers in particular.

5.9 General discussion

The two studies indicated a robust effect of gum on reported alertness that does not seem to depend on the prior performance of tasks. Chewing gum enhanced categoric search performance in Study 4 and during ES1 in Study 5, as well as affecting breadth of attention and shortening vigilance reaction time in ES2; specifically, vigilance was initially slower in the gum condition than in the control, but subsequently became faster in the gum condition. The order of tasks may be important in explaining these effects; manipulation of task order may shed light on this matter. As the vigilance task of ES2 came towards the very end of testing, this effect may be due to a reduction in fatigue by chewing gum later in the testing session. Nonetheless, it is curious that aspects of selective attention were only affected during specific testing sessions. As mentioned above, it is possible that chewing behaviour, such as speed of chewing, changed over time. As chewing was not directly observed here, further research is required to test this hypothesis.

The research did not show evidence for persistent carryover effects on reported alertness. This is consistent with previous research that indicated restricted carryover effects of chewing gum (Onyper et al., 2011). Apart from practical implications, carryover effects are particularly relevant in EEG research on chewing gum (see Section 2.4 for discussion of previous EEG research), where gum is chewed before testing (in order to avoid motion artefacts), and the assumption is that prior chewing will have an effect on brain activity. However, such studies usually test activity shortly after chewing, so the lack of a prolonged carryover effect on alertness may not matter for short experiments.

Studies 4 and 5 differed in terms of times of day and type of participant. Circadian variation may mean that the physiological effects of chewing may have differed between Study 4, which took place in the morning, and the experimental sessions of Study 5, which took place in the late afternoon. The participants in Study 5 were full-time workers, and around ten years older on average than their counterparts in Study 4. The fact that reported alertness was enhanced in both studies indicates the robustness of this effect across times of day and occupational types.

In conclusion, the two studies suggest that chewing gum has a positive effect on selective attention. Study 5 indicated differential effects on vigilance over time, although the current research also calls into question the robustness of time-on-task trends in cognitive performance while chewing during shorter time periods. These experiments provide further empirical evidence that chewing gum enhances reported alertness, while indicating a lack of evidence for carryover effects on reported alertness after chewing.

Although the studies in this chapter have indicated an alerting effect when completing tasks used in previous experiments, there is less evidence in the existing literature concerning the effect of gum on mood when participants are not required to complete attention tasks. Furthermore, the fact that gum could be replaced in Study 4 but not Study 5 suggests that further investigation of replacement of gum may be warranted.

Chapter 6 Chewing gum and mood without cognitive performance

6.1 Introduction

6.1.1 General introduction

Although respondents to Study 1 did not indicate an association between chewing gum and alertness, findings from the intervention research of Studies 2 and 3 indicated that gum can reduce fatigue reported at the end of the day; this suggests an alerting effect of gum. Similar to the finding that chewing gum can reduce fatigue at work, Studies 4 and 5, as well as previous experimental research (e.g. Scholey et al., 2009; Smith, 2010), have indicated a robust effect of chewing gum on subjective alertness, although this has usually been in the context of reported alertness after some time spent performing cognitive performance tasks. Furthermore, it has been pointed out that chewing gum has increased alertness both for tasks which deplete alertness and those which do not (Johnson, Miles, et al., 2012). The alerting effect of chewing gum thus seems to be robust during performance of a variety of tasks; it is of interest if such an effect occurs when the mind is less engaged. In addition, the studies that have indicated an effect of chewing gum on subjective alertness have generally either used mint flavoured gum or a choice of available flavours – there has usually not been a comparison to chewing without flavour, so it is difficult to say if an alerting effect is related to flavour or is just a product of the physical process of chewing. With regard to other aspects of mood, chewing gum improved hedonic tone in Study 4 but not Study 5; it is of interest if people will experience more positive hedonic tone as a result of chewing when cognitive tasks are not performed.

6.1.2 The effect of gum on mood with limited or no task performance

An exception to the tendency to require participants to complete performance tasks is a study by Yagyu et al. (1998). They measured subjective mood in participants without a concurrent behavioural task using visual analogue scales, with the end points “refreshed - worn down”, “calm - nervous” and “comfortable - uncomfortable”. This study also differed from the tendency to focus on flavoured gum alone in that they examined the effects of gum base and a flavoured gum available in Japan. Yagyu et al. found significant differences between the two types of gum; participants who chewed the flavoured gum reported feeling more refreshed and more comfortable.

Unfortunately, Yagyu et al. did not report comparisons with the no-chewing gum control condition. Their experiment differed from the study described in this chapter in that EEG measures were recorded - the attached electrodes and the need to remain still may have had an effect on participants' alertness, as well as the extent to which they focused on the act of chewing. Notwithstanding this difference, it is of interest if similar findings can be produced in a different cultural group.

Two studies by Hodoba (1999) tested the effect of chewing gum on sleepiness over the course of a night of sleep deprivation. In the first experiment, those in the gum condition chewed throughout the night, and replaced their gum every three hours. Participants were not required to carry out any performance tasks. Chewing gum reduced sleepiness at 1.00 and 4.00, but not at the final assessment stage at 7.00. The second study measured the effect of chewing gum versus standing or walking (for 15 minutes following participants' strongest experience of sleepiness) during a night shift. Chewing had a stronger effect on sleepiness than standing or walking.

Another possible exception to the trend of requiring test performance is a study on the effect of chewing on alertness, sleepiness and a pupillary unrest index (Johnson, Miles, et al., 2012). Participants were required to keep their heads on a chin rest while fixating on a dot; the procedure was similar to that of Yagyu et al. in that participants were required to remain still. Although participants were not required to produce any specific response to stimuli, Johnson et al. suggested that this task is a vigilance-type task. Sleepiness was lower and alertness was higher for spearmint gum compared to a no-gum control, and there was a significant attenuation by gum of a fall in physiological alertness as measured by pupillary unrest. Chewing condition did not affect contentedness.

6.1.3 Rationale and hypotheses

In the following study we required participants to chew two pieces of spearmint gum (either the same two pieces throughout or with replacement), gum base or to avoid chewing for 25 minutes. Participants were not required to complete any cognitive performance tasks during this period. As previous research which did not require performance of a task indicated some evidence for chewing gum enhancing alertness and reducing sleepiness, it was hypothesised that chewing gum would have a positive effect on mood, and particularly alertness. Both flavour and the act of chewing were hypothesised to have a positive effect on mood. Specifically, it was predicted that participants in the spearmint gum with replacement conditions would report the highest level of final alertness, followed in descending order by spearmint gum without replacement, gum base and no chewing control. As motor activity may be responsible for a reduction in anxiety (see Section 2.6.2), gum base should reduce anxiety compared to a no chewing control. Furthermore, given the findings of Yagyu et al. that flavoured gum in particular was associated with greater feelings of relaxation, spearmint gum was hypothesised to lead to a greater reduction in anxiety. Studies 4 and 5 differed in whether replacement of gum was permitted; the inclusion of conditions involving chewing with and without replacement is because it is unclear if chewing the same piece(s) of gum for a period of half an hour or so has the same effect on mood as chewing for the same amount of time with replacement as flavour diminishes. It is likely that gum lost its flavour by the end of testing for many participants in studies that required longer periods of chewing without allowing replacement of gum, or where replacement was allowed, but only after a considerable period of time (e.g. three hours in Hodoba).

Although the surveys described in this thesis did not indicate more positive mood in habitual chewers, this may have been due to the relative lack of control for other explanatory factors. The current study was run under controlled conditions, and since the surveys did indicate that people who chew gum report more positive attitudes towards gum's effect on mood than non-chewers, it was hypothesised that people who habitually chew gum more frequently should report a greater increase in positive mood when chewing gum.

6.2 Study 6: Method

6.2.1 Design

Participants were assigned to either one of three chewing conditions (spearmint gum with replacement, spearmint gum without replacement or gum base) or a no-gum control. Twenty-five participants were assigned to each condition.

6.2.2 Participants

One hundred participants (eighty-one females, nineteen males) aged 18-40 years (mean = 21.1, SD = 3.6) took part in this experiment. Participants were recruited through a university notice board and an online experiment management system. Exclusion criteria were the same as those in Study 2.

6.2.3 Materials

Mood was assessed using the same visual analogue scales as in Study 2. Participants were provided with a pen-and-paper questionnaire assessing age, gender, habitual level of chewing gum consumption and, for chewing conditions, palatability of the gum used in the experiment. Wrigley's Extra Spearmint and Wrigley's gum base were used. The gum base contained sorbitol, sweeteners (aspartame and acesulfame K), glycerine, lecithin, and emulsifier.

6.2.4 Procedure

Testing took place between 10.00 and 12.00. Participants were tested in groups of up to four people. On arriving in the lab, participants filled in the pen-and-paper questionnaire. They were then provided with two pieces of chewing gum if they were in a chewing condition and told to chew constantly throughout the procedure. Immediately after starting to chew gum they and completed the initial mood assessment tasks. They were then requested to sit quietly and continue chewing. After 15 minutes, participants in a chewing condition were verbally reminded to continue chewing, and those in the replacement condition were reminded to replace the gum with two new pellets if the current gum had lost its flavour. Psychology textbooks and journals were available for participants to read, and participants could bring their own reading material. After 25 minutes, the participants filled in the final mood assessment task. They were debriefed and thanked for their participation.

6.2.5 Analysis

The effects of gum condition and time were analysed using mixed ANOVAs, with the independent variable being gum condition and the dependent variables being alertness, hedonic tone and anxiety. The possible moderating effect of habitual gum consumption was also analysed by entering it as an independent variable in the analysis. This analysis was conducted in two stages, with the first stage testing the effect of chewing gum *per se*, by comparing the no-gum control to the three gum conditions combined. The second stage evaluated differences between all four gum conditions (i.e. spearmint gum with replacement, spearmint gum without replacement, flavourless gum and no-gum control).

6.3 Results

6.3.1 Chewing gum data

Habitual chewing was classified as follows: thirty participants were regular chewers (Median pieces chewed per week = 7, range = 5-24), fifty-one were infrequent (Median = 2.5, range = 0.25-4) and eighteen never chewed. There were no significant interactions between habitual gum consumption and gum condition (whether or not gum conditions were combined).

Spearmint gum was rated as more palatable (M = 1.5, SD = 1.4) than gum base (M = 0.5, SD = 1.5), and this difference was significant, $t(70) = 2.75$, $p = .008$, Cohen's d = .69. In the chewing with replacement condition, eight participants chewed only the two pieces they began with, whereas the remainder chewed more (the modal response, at twelve participants, was four pieces).

6.3.2 Effects of time on mood

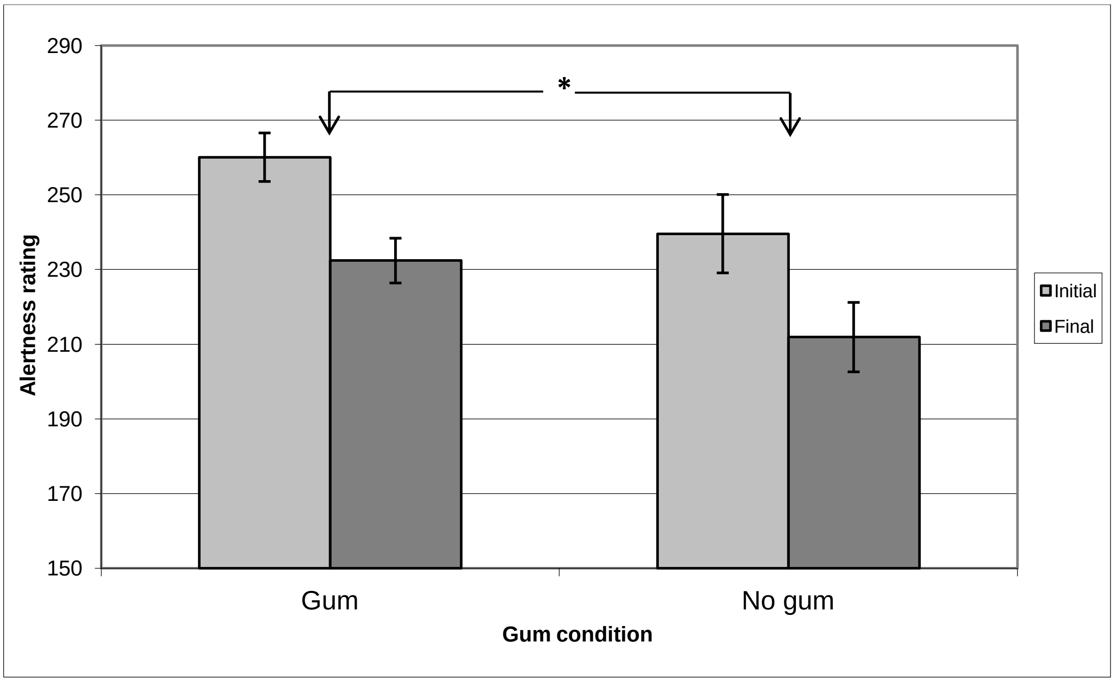
Alertness fell significantly between the initial and final assessment, $F(1, 96) = 24.17$, $p < .001$, *partial* $\eta^2 = .2$. There was a significant effect of time on all components of alertness, with the exception of coordinated-clumsy.

Anxiety rose between the initial and final measurement, although this effect was only marginally significant, $F(1, 94) = 3.57$, $p = .06$, *partial* $\eta^2 = .04$.

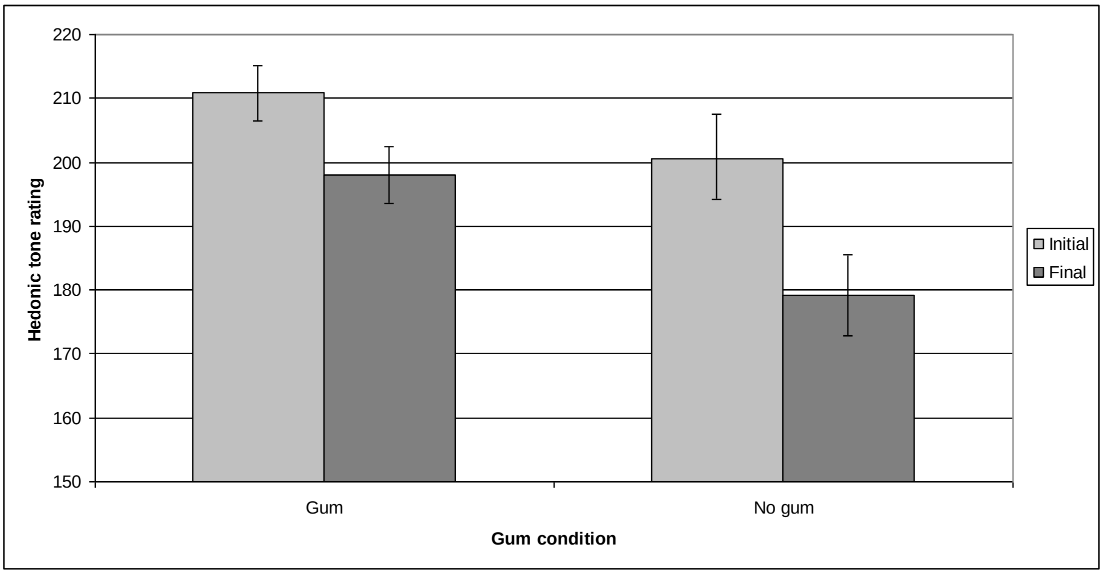
Hedonic tone fell significantly over the course of the study, $F(1, 96) = 29.15$, $p < .001$, *partial* $\eta^2 = .23$. Time had a significant effect on all components of hedonic tone, except self-centred-outward going.

6.3.3 Effect of gum and gum over time on mood

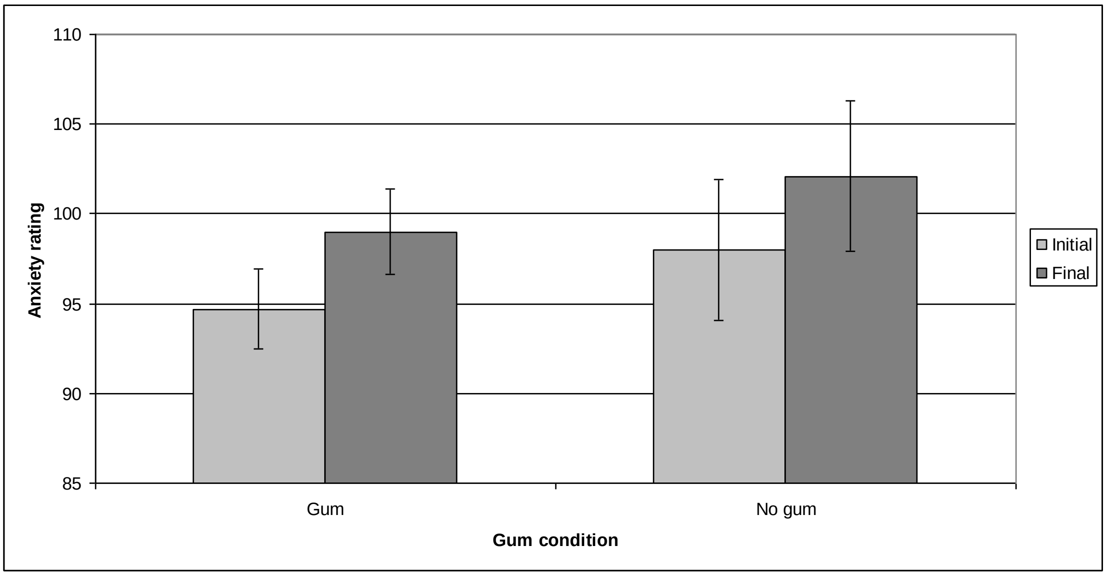
Alertness was higher in the chewing gum conditions, $F(1, 98) = 3.92$, $p = .05$, *partial* $\eta^2 = .04$; and this was the case for the items drowsy-alert ($p = .02$), muzzy-clear headed ($p = .007$), and lethargic-energetic ($p = .04$), but not on any other component items. Gum did not lead to a significant effect on hedonic tone. There was no effect on anxiety (see Figure 6-1). None of these effects were moderated by time or by habitual gum consumption.


290
270
250
230
210
190
170
150
Alertness rating
*
Initial
Final
Gum
No gum
Gum condition

A


220
210
200
190
180
170
160
150
Hedonic tone rating
Initial
Final
Gum
No gum
Gum condition

B



C

Figure 6-1: Effect of gum chewing on initial and final (A) alertness, (B) hedonic tone and (C) anxiety[51]

6.3.4 Effects of gum flavour and replacement

As summarised in Figure 6-2, alertness fell by slightly less in the gum with replacement condition than in the other conditions. However, conditions did not significantly moderate changes in alertness between the initial and final measurement, $F(3, 96) = .59$, $p > .05$, *partial* $\eta^2 = .02$. There was no main effect of condition either, $F(3, 96) = 1.61$, $p > .05$, *partial* $\eta^2 = .05$.

Anxiety fell slightly in the gum base condition, while it increased in the other conditions. However, there was no significant effect of condition on change in anxiety, $F(3, 94) = 1.13$, $p > .05$, *partial* $\eta^2 = .04$, nor did the conditions have a main effect on anxiety, $F(3, 94) = 0.25$, $p > .05$, *partial* $\eta^2 = .01$. However, for the item tense-calm, there was an interaction between gum condition and time ($p = .02$). Calmness increased in the spearmint conditions, fell in the gum base condition and remained the same in the no gum control.

Hedonic tone fell somewhat less in the gum with replacement condition, but again there was no main effect on hedonic tone, $F(3, 96) = 1.59$, $p > .05$, *partial* $\eta^2 = .05$, or significant effect of gum condition on change in hedonic tone, $F(3, 96) = 1.25$, $p > .05$, *partial* $\eta^2 = .04$.

Habitual gum consumption did not moderate any effect of flavour and replacement or any interaction between condition and time.

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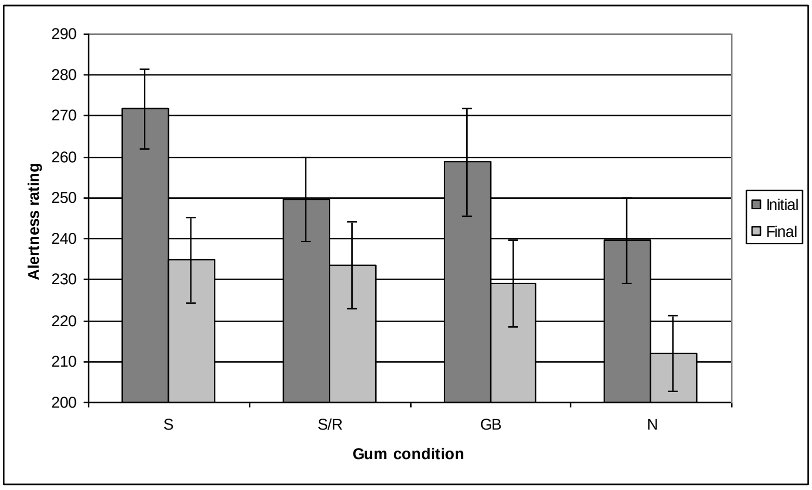
[51] Error bars represent standard error. Asterisk indicates significant difference between gum conditions ($p = .05$)



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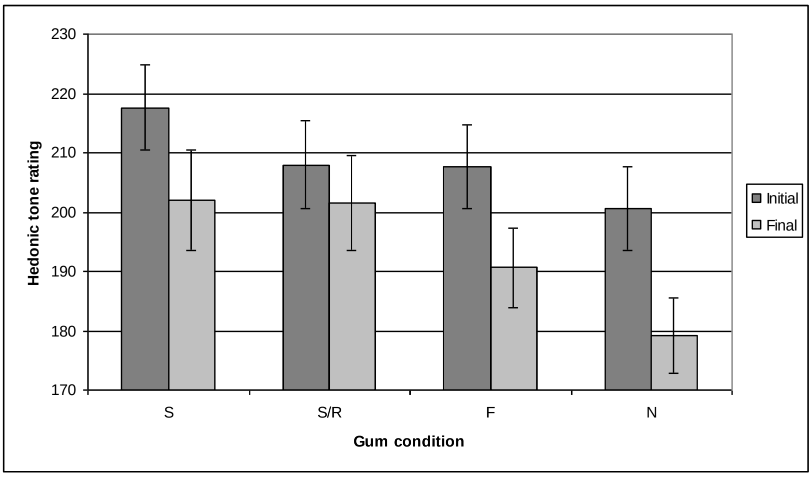

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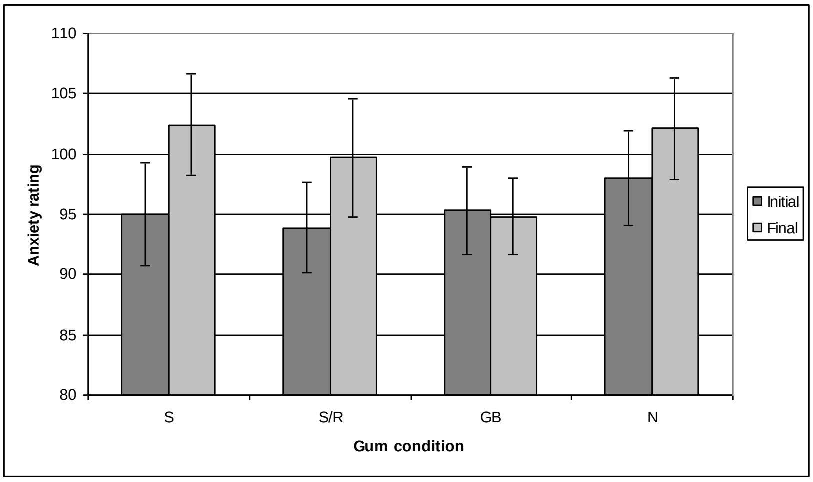

C

Figure 6-2: Effect of gum chewing and flavour on initial and final (A) alertness, (B) hedonic tone and (C) anxiety[52]

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[52] S = Spearmint gum without replacement, S/R = spearmint gum with replacement, GB = gum base, N = no gum. Error bars represent standard error

6.4 Discussion

6.4.1 Chewing gum and alertness

Chewing gum led to higher alertness in the absence of concurrent cognitive performance tasks, consistent with the findings that chewing led to greater refreshment (Yagyu et al., 1998) and higher physiological alertness (Johnson, Miles, et al., 2012). Although previous research has shown a more consistent effect of chewing gum on post-test alertness, and although alertness clearly fell over the course of this experiment, there was not an interaction between chewing gum and time. Looking at individual gum conditions, neither spearmint-flavoured gum nor gum base differed significantly from the no-gum control for alertness or change in alertness. Although alertness fell to a somewhat lesser degree for those who chewed spearmint gum with replacement than in the other conditions, this may be due to the coincidentally lower level of initial alertness for the spearmint with replacement condition. Since initial alertness was rated after the manipulation had begun, a limitation of this study is that it had no clear measure of individual differences in baseline mood.

6.4.2 Chewing gum and other aspects of mood

Hedonic tone and anxiety were not affected by gum. However, there was an interaction between gum condition and time for anxiety's tense-calm item. Initial calmness was similar in all conditions, and then fell in the gum base condition, increased slightly in the control and increased to a greater extent in the spearmint conditions, suggesting that spearmint flavour and the act of chewing may have different effects for this type of mood. The increasing level of calmness in the spearmint gum condition is consistent with the finding that spearmint gum leads to higher alpha activity (Masumoto et al., 1998).

6.4.3 Habitual gum consumption

Contrary to the relevant hypothesis, habitual gum consumption did not moderate any effects of gum or time on reported mood. This contrasts with the survey findings in Chapter 3 that habitual chewers are more likely to report that chewing gum is pleasurable and enhances positive mood. The lack of an effect may be due to the fact that many of the participants in this study had relatively low levels of habitual gum consumption; a moderating effect might be observed where a sample contains more participants with very high typical consumption.

6.4.4 Critique

Averaging the palatability ratings for spearmint with and without replacement, spearmint gum was rated as more palatable than gum base. However, palatability of gum rated at the end would probably show greater palatability ratings for the fresher gum being chewed in the replacement condition. The lack of a final measure of palatability is thus an oversight, although the fact that some participants did not replace their gum suggests that palatability may not fall greatly over the length of time used in this study. A possible counter-argument to this is that gum does indeed lose its flavour, and some participants do not replace the gum as they are simply ignoring it. It may thus have been more controlled to have participants in the replacement condition replace their gum at frequent, fixed intervals, in order to ensure that flavour was maintained. However, participants were given a reminder to keep chewing and, in the replacement condition, to replace the gum if they wished.

Another possible criticism of this study is that participants varied in what they read. This could be criticised as a lack of control, although Hodoba demonstrated effects of gum on sleepiness, even though participants could read, listen to music or converse. A key difference between Hodoba's research and the current study is that this study was much shorter. It would be interesting to see if stronger effects on alertness emerged over a period of one hour or longer. Indeed, this study differed from other experimental research in this thesis in that it simply required each participant to take part in a single 25 minute condition, as opposed to a longer testing period with chewing gum as a within-participants factor. A longer testing period may thus have shown different effects.

6.4.5 Conclusions

As was the case in studies 4 and 5, chewing gum led to higher alertness. Gum also led to a marginal increase in hedonic tone. Mint-flavoured gum did not have a stronger effect than gum base on these aspects of mood. There was evidence that gum base led to decreasing calmness, whereas calmness increased relative to the no-gum control for spearmint gum. Habitual gum consumption did not moderate mood or any of the observed changes in mood over time.

Given the widespread demonstration of an alerting effect, and some evidence for changing patterns in vigilance over time observed in Study 5, further research is required to establish what the underlying mechanism may be. The fact that self-reported data on subjective alertness is consistently affected while results from behavioural tasks have been variable implies that it may be necessary to investigate if demand characteristics may account for an apparent alerting effect. However, given previous findings that chewing gum can have effects on heart rate and brain activity, it will be informative to first consider if physiological variables may be associated with changes in mood and time-on-task trends in vigilance.

Chapter 7 Chewing gum and associated physiology during vigilance

7.1 Introduction

7.1.1 General introduction

Study 5 indicated that chewing gum shortened vigilance reaction time, but only after several performance sessions, and only towards the end of the vigilance task. This finding was consistent with time-on-task effects of chewing previously observed for both adults (L. Tucha & Simpson, 2011) and schoolchildren (Tänzer et al., 2009). Both studies indicated an enhancing effect of chewing gum, but only later in the task. Although most of the research on chewing gum and vigilance has tested the effect of chewing during task performance, the effects of chewing gum on cognitive performance have been shown to persist after chewing has ceased (e.g. Onyper et al., 2011; Sakamoto, Nakata, & Kagigi, 2009). Although a vigilance task was not used in these studies, it may be the case that chewing gum for a short period at the beginning of a lengthy task can attenuate a decline in vigilance, even when gum is no longer being chewed. Onyper et al. (2011) suggest that this ongoing enhancement in performance is due to an continuing effect of chewing on arousal, and L. Tucha and Simpson (2011) explained the time-on-task effect during chewing as being due to distraction by gum becoming less prominent and facilitating mechanisms (such as enhanced arousal) increasing as chewing and task performance continue. The plausibility of physiological arousal as a mechanism for effects of chewing gum can be tested by observing heart rate, as well as brain activity associated with arousal.

However, although arousal may be a candidate mechanism for explaining the effects of chewing gum on vigilance, the relationship between vigilance and arousal remains controversial. Furthermore, the physiological evidence for chewing gum's effect on arousal is mixed.

7.1.2 Vigilance, arousal and chewing gum

Vigilance reaction time lengthened in Study 4 and the second experimental session of Study 5. Although it has been suggested that such decrements in vigilance performance occur due to reduced arousal (Heilman, 1995), Warm, Parasuraman and Matthews (2008) have argued that vigilance tasks are stressful, which would imply that the decline in vigilance is due to heightened arousal instead. With regard to chewing gum and subjective indicators of arousal, gum has been found to increase reported alertness, but there is also some evidence that chewing gum is associated with reduced stress (Scholey et al., 2009; Smith, 2009a, 2009b). There is also mixed evidence regarding the effect of chewing on heart rate under experimental conditions (O. Tucha et al., 2004; Wang et al., 2009). Wang et al. was the only study on heart rate to examine if prior chewing had a continuing effect, and their results indicated an increase in heart rate. The lack of an effect on heart rate in Study 3, where participants were chewing over the course of the day, suggests that chewing gum may not have an extended effect on heart rate. Given the varied findings concerning gum and arousal, a positive effect of chewing gum on vigilance may be due to either gum increasing arousal after a vigilance task reduces arousal, or the converse: chewing gum reversing an increase in arousal induced by a vigilance task. By examining physiological arousal, this study may help to elucidate which account of vigilance and which putative mechanism of chewing gum is accurate.

Research on sustained attention (that has not involved gum) has indicated a fall in heart rate over time, suggesting that participants may become bored and experience reduced arousal during vigilance performance (Pattyn, Neyt, Henderickx, & Soetens, 2008). Participants reported engaging in other mental activities during the task, which refutes the idea that attention resources are engaged but become overstretched during vigilance. Furthermore, participants generally reported lower alertness compared to pre-test following the vigilance task, which was the last attention task performed in the batteries used in studies 4 and 5.

Chewing gum has been found to shorten the heart R-R interval (Shiba, Nitta, Sugita, & Iwasa, 2002), suggesting increased sympathetic nervous activity. However, Shiba et al.'s study did not require participants to perform an attention task, whereas two experiments by O. Tucha et al. (2004) which did involve attention tasks did not show an effect of gum on heart rate. Perhaps the finding concerning heart rate which is most relevant to this study is that current chewing leads to increased heartbeats per minute during performance of a digit vigilance task (Wilkinson et al., 2002), although the effect of the vigilance task itself was questionable, as heart rate was unchanged in the control groups (no chewing and making chewing movements). The vigilance task may not have had an effect in this case as it followed performance of other tasks in a battery, similar to previous experiments in this thesis.

Electroencephalographic measures generally show differential effects during sustained attention. For example, a decrease in an EEG measure of task engagement occurred over the course of performance of a 20-minute vigilance task (Berka et al., 2007). An aroused state is associated with increased beta activity and reduced alpha activity in EEG, while the opposite trends are associated with relaxation (Masumoto et al., 1999). An effect of chewing on alpha and beta waves has been demonstrated. Masumoto et al. (1998) found that alpha frequencies were higher at T3, F3 and F4 in a post-chewing recording than during the control. This implies greater relaxation, which may impair vigilance performance if arousal is reduced. Similarly, following chewing of gum with sucrose beta ratios of activity were lower at F4, and alpha was higher at T3 (Masumoto et al., 1999). However, ratios of beta activity at T3 increased following the chewing of flavourless gum. In another study the chewing of gum base with sucrose led to an increase in the ratio of alpha activity at T3 and F3 (Morinushi et al., 2000). Following chewing of flavoured gum, the ratio of alpha activity increased at F4, and beta increased at T3. The flavour used included a number of constituents, including peppermint and lavender. All of these three previous studies used linked ear lobes for reference electrodes.

Combining these findings, it seems that an arousing effect of the act of chewing in itself (evident in the increase in beta activity when chewing flavourless gum) is counteracted by flavour. This is similar to the finding that chewing spearmint gum increased calmness while gum base reduced calmness in Study 6. Given the finding that vigilance performance in itself is associated with reduced task engagement, it seems likely that chewing gum base (rather than mint flavoured gum), by increasing central nervous system arousal, should have the clearest effect on vigilance and associated neurophysiology.

7.1.3 Rationale and hypotheses

This experiment investigated the effect of chewing standard gum base on vigilance performance and heart rate, both during chewing and after chewing had ceased, as well as the effects of chewing on EEG after chewing had finished. By including a concurrent vigilance task to perform during and after chewing, the present research went further than previous EEG studies examining chewing gum effects, which did not examine cognition. Participants alternated between performing blocks of a vigilance task and receiving brief EEG recordings. Given that some of the findings on vigilance have been equivocal (e.g. there was a lack of a time-on-task trend in Study 4), a longer period of vigilance performance was used in the current study, with the aim of investigating if clearer effects would occur when vigilance performance was not interspersed with different tasks. The vigilance task was thus performed multiple times, instead of being performed following other attention tasks.

Subjective alertness was assessed, and was hypothesised to fall to a lesser extent in the chewing condition, consistent with the previous research. Given this fall in alertness, a reduction in arousal by vigilance performance was predicted, which in turn would be associated with lengthened reaction time and a lower response rate (fewer hits and fewer false alarms). It was further hypothesised that chewing gum during the first testing block would attenuate the decline in vigilance performance during this first block. This attenuation should continue over the subsequent blocks, although this effect should become less evident for the last block, as the arousing effect of gum wears off, consistent with the lack of an ongoing alerting effect of chewing observed in the NG group in Study 5. It was expected that this attenuation of the vigilance decrement would be associated with a more modest reduction in physiological arousal, which would be evident in higher heart rate, increased beta activity and reduced alpha activity in the gum condition.

In summary, vigilance performance was hypothesised to lead to a fall in alertness, physiological arousal, and performance, while chewing gum was hypothesised to attenuate these trends.

7.2 Study 7: Method

7.2.1 Design

Participants were randomly assigned to either a chewing or control condition. Participants in the chewing condition chewed during the vigilance task that followed baseline EEG.

7.2.2 Participants

Forty-eight participants were recruited, but eight participants' EEG data had to be excluded due to movement artefacts. Forty right-handed participants (thirty-two females, eight males) were included in the final study, with eighteen participants in the gum condition and twenty-two in the control. Mean age was 23.5 (range = 19-29). The majority of participants were students (N = 32); other participants were administrators ($N = 3$), researchers ($N = 3$) and other professions ($N = 2$). Participants were recruited through an online university notice board. Participants had normal or corrected-to-normal vision. They were paid £10 for participation. Exclusion criteria were the same as in previous studies.

7.2.3 Materials

Silver electrodes were placed at specific regions on the scalp (T3 and F7) according to the international 10/20 system. Additionally, a reference electrode (A1) was placed on the mastoid behind the left ear while the two earth electrodes were positioned on forehead and right arm. All the electrodes were connected to an electrode adaptor box (Cambridge Electronic Design CED1902, Cambridge, UK) followed by a pre-amplifier/amplifier (CED1902, Cambridge, UK) before the signal was digitized (CED1401 laboratory interface) and stored on a computer. ARBO ECG electrodes were used for the reference and earth electrodes. A piezo-electric pulse transducer (UFI, CA, USA) was used in conjunction with a CED 1401-*plus* laboratory interface to monitor heart rate monitor.

The standard gum base was the same used in Study 6. Repeated digits vigilance and mood tasks were the same as in previous studies, and were run on a laptop.

7.2.4 Procedure

Testing took place either in the late morning (start time at 10.00, 11.00 or 12.00) or the afternoon (start time 15.00 or 16.00), so that participants were not tested during periods of low circadian alertness. Participants were tested one at a time, and were requested not to eat for one hour before entering the lab, in order to avoid post-lunch type effects.

Participants signed a consent form and filled in a demographic questionnaire. They were then seated in a comfortable chair approximately 85cm from the laptop screen. Test electrode sites were cleaned with alcohol and exfoliated. A reference electrode was attached at the left mastoid. Test electrodes were then placed at T3 and F7, followed by an earth on the right forehead. The extra earth electrode was attached to the left wrist. The heart rate monitor was attached to the index finger of the left hand.

The stages of testing are summarised in Table 7-1 below. Following a familiarisation with the computer tasks, participants performed a baseline measure of mood and vigilance. The next vigilance task was performed with or without chewing gum, and was followed by two more vigilance tasks without chewing gum, to assess the effects of chewing after cessation of chewing. EEG recording followed performance of the vigilance task for the baseline session and each of the testing sessions. Immediately before EEG recording, subjects were asked to stay still with their eyes closed in order to eliminate visual cues, and to rest their heads back and remain as still as possible, in order to minimise muscle movement. A post-test assessment of mood followed the last EEG recording. Following familiarisation, heart rate was measured throughout testing. Participants in the chewing gum condition expectorated their gum immediately after finishing the vigilance task with chewing.

Table 7-1: Order and approximate timings of conditions

Task	EEG
Familiarisation vigilance task + mood (minutes 1-4)	(No EEG recording)
Baseline vigilance + mood (minutes 5-13)	Baseline EEG (minute 14)
Chewing/no-gum control vigilance (minutes 15-21)	EEG1 (minute 22)
Post-chewing vigilance 1 (minute 25-31)	EEG2 (minute 32)
Post-chewing vigilance 2 (minutes 33-39)	EEG3 (minute 40)
Post-test mood (minutes 41-42)	No EEG (End)

7.2.5 Analysis

Heart rate and EEG data were analysed using Spike 2, version 7.07. These data were visually inspected for artefacts, which were removed from the analysis. The two EEG frequency bands analysed were alpha, 8 to 13 Hz, and beta, 13 to 30 Hz.

Change-from-baseline data were analysed using ANOVA. The independent variables were chewing gum condition and time-on-task, and habitual gum consumption was also entered to test for interactions between experimental gum condition and habitual level of consumption. The dependent variables were mood, vigilance performance (hits, false alarms and reaction time), heart rate, EEG alpha power and EEG beta power.

7.3 Results

7.3.1 Effect of time

Time led to a highly significant reduction in alertness, $F(1, 36) = 72.73$, $p < .001$, *partial* $\eta^2 = .67$, including a significant effect on all component items of alertness.

Hedonic tone also fell between pre- and post-test assessment, $F(1, 36) = 19.93$, $p < .001$, *partial* $\eta^2 = .36$, and this effect was significant for all component items. However, anxiety did not differ between pre- and post-test assessment.

Across sessions, repeated digits hits fell significantly, $F(2, 76) = 3.51$, $p = .02$, *partial* $\eta^2 = .08$, as did false alarms, $F(2, 74) = 2.63$, $p = .04$, *partial* $\eta^2 = .07$, indicating a lower overall response rate. However, there was no significant effect on reaction time.

Heart rate was also significantly affected by time, $F(5, 160) = 14.48$, $p < .001$, *partial* $\eta^2 = .33$. Mean heart rate fell slightly across the EEG testing sessions, but was substantially reduced for the post-chewing vigilance tasks, compared to the chewing vigilance task. Neither alpha power nor beta power was significantly affected by time at either electrode site.

7.3.2 Gum consumption

Habitual chewing was classified as follows: twenty-one participants were regular chewers (Median pieces chewed per week = 10, range = 5-21), fifty-one were infrequent (Median = 1.6, range = 0.25-2.5) and five never chewed. There was no significant difference between experimental groups in mean number of pieces chewed per week.

Habitual gum consumption did not moderate the effects of gum on mood. Entering all post-baseline vigilance tasks in the same analysis, there was no interaction between habitual gum consumption and gum condition on vigilance performance, heart rate or EEG data.

7.3.3 Effect of gum and gum over time on reported mood and vigilance performance

Although there was no main effect of gum condition, it did lead to a significantly smaller reduction in alertness between baseline and post-test, $F(1, 36) = 7.51$, $p = .01$, *partial* $\eta^2 = .017$ (see Figure 7-1). Looking at the components of the alertness factor, there was a similar interaction between time and gum condition for drowsy-alert, muzzy-clear headed, mentally slow-quick witted, and incompetent-proficient, a marginally significant interaction for strong-feeble and attentive-dreamy, and no such interaction for coordinated-clumsy or lethargic-energetic. There was no main effect of gum condition for any of the items composing alertness.

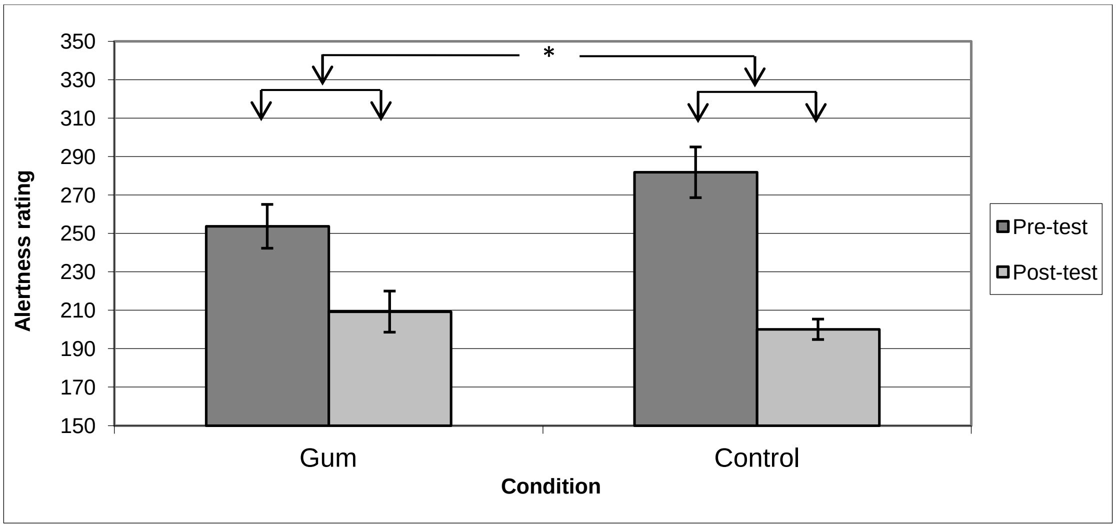


Figure 7-1: Effect of gum on change in alertness[53]

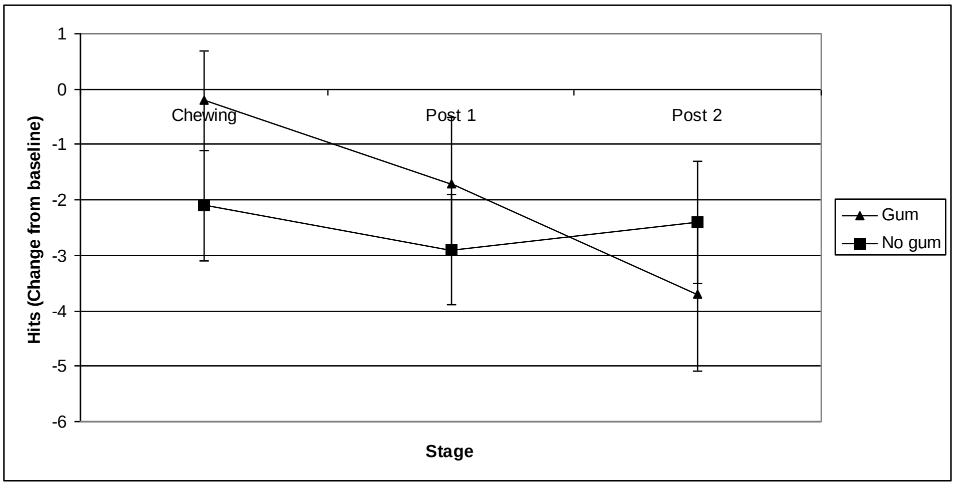
There was no main effect of gum on hedonic tone. Although a general fall in hedonic tone was attenuated somewhat by chewing gum, the interaction was not significant, $F(1, 36) = 3.18$, $p = .08$, *partial* $\eta^2 = .08$, although for the item contented-discontented in particular, discontentedness rose in the control condition ($p = .02$). Gum condition did not have an effect on anxiety. The mean anxiety and hedonic tone scores are reported in Table 7-2.

Table 7-2: Hedonic tone and anxiety for gum conditions at pre- and post-test assessment[54]

	Gum	No gum
Pre-test hedonic tone	223.6 (8.6)	226.8 (7.2)
Post-test hedonic tone	206.7 (9.2)	192.8 (8.0)
Pre-test anxiety	97.7 (4.3)	100.2 (4.6)
Post-test anxiety	101.0 (5.4)	93.2 (5.1)

There was an interaction between chewing gum and stage of testing on repeated digit hits, $F(2, 76) = 2.71$, $p = .04$, *partial* $\eta^2 = .07$ (see Figure 7-2). Hits were higher for the gum condition during chewing and at post 1, but were lower at post 2. Reaction time was marginally shortened in the gum condition, $F(1, 38) = 2.72$, $p = .053$, *partial* $\eta^2 = .07$. There were no other significant interactions, and although there were more false alarms in the gum condition this effect was not significant. Within task sessions there were no interactions between minute and gum condition.

[53] Error bars indicate standard error. Asterisk indicates significant difference in change in alertness ($p < .05$)
[54] Standard errors in brackets



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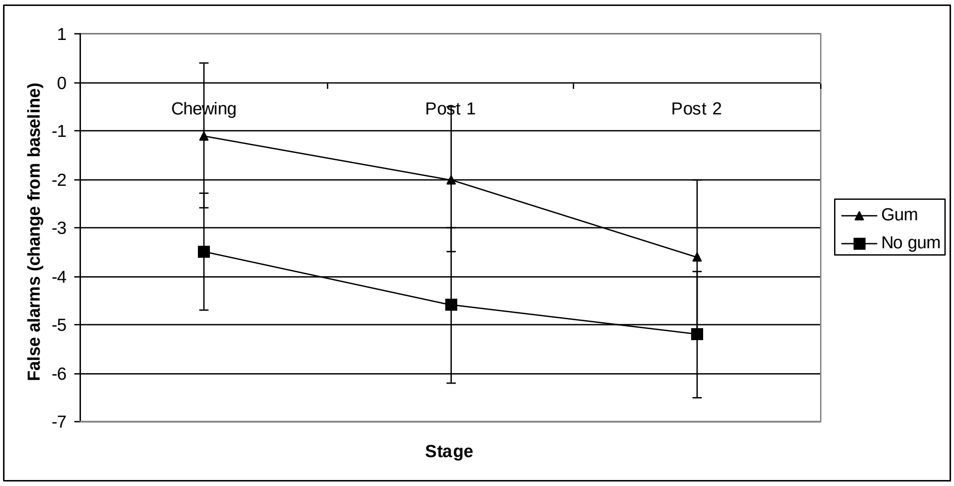

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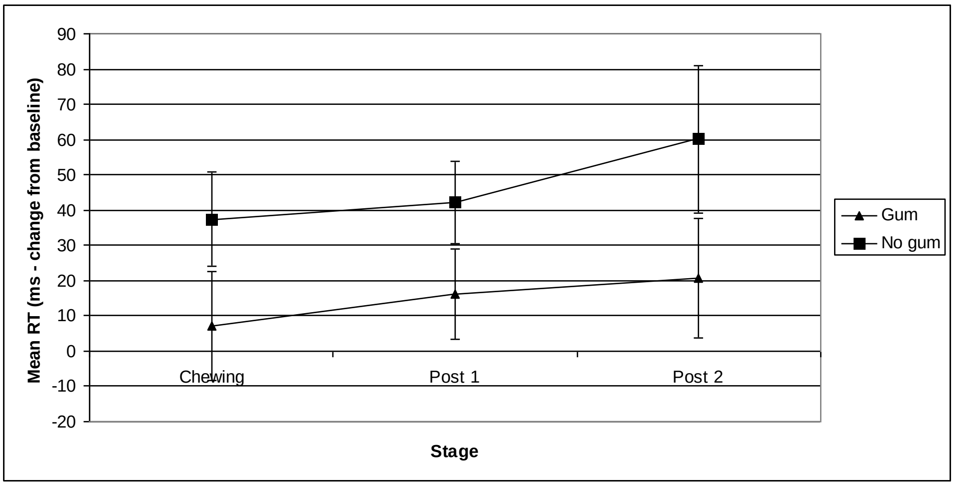

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Figure 7-2: Effect of gum across sessions on (A) hits, (B) false alarms and (C) mean reaction time for the repeated digits task[55]

[55] Change scores from pre-chewing baseline are used. Error bars indicate standard error

7.3.4 The effect of gum and gum over time on physiology

There was a significant interaction between gum condition and time of testing for heart rate, $F(1.91, 61.12) = 8.51$, $p = .001$, *partial* $\eta^2 = 0.21$, Greenhouse-Geisser adjusted. Gum led to a highly significant increase in heart rate during chewing, $F(1, 312) = 48.59$, $p < .001$, *partial* $\eta^2 = 0.67$, but there was a lack of a difference between conditions later in the experiment, although heart rate was somewhat lower for the gum condition during the post-chewing vigilance tasks (see Figure 7-3).

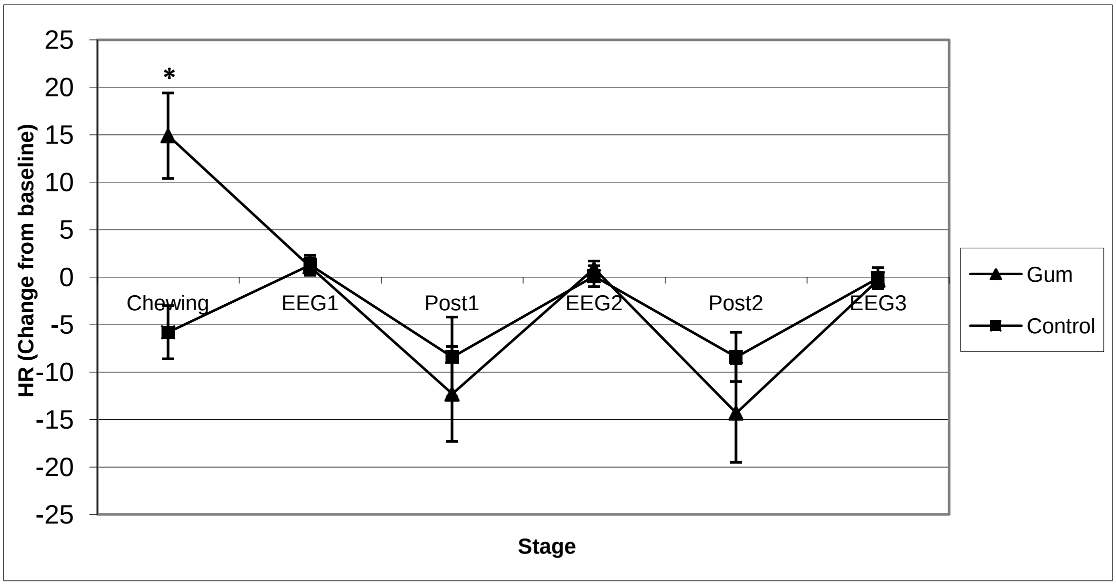
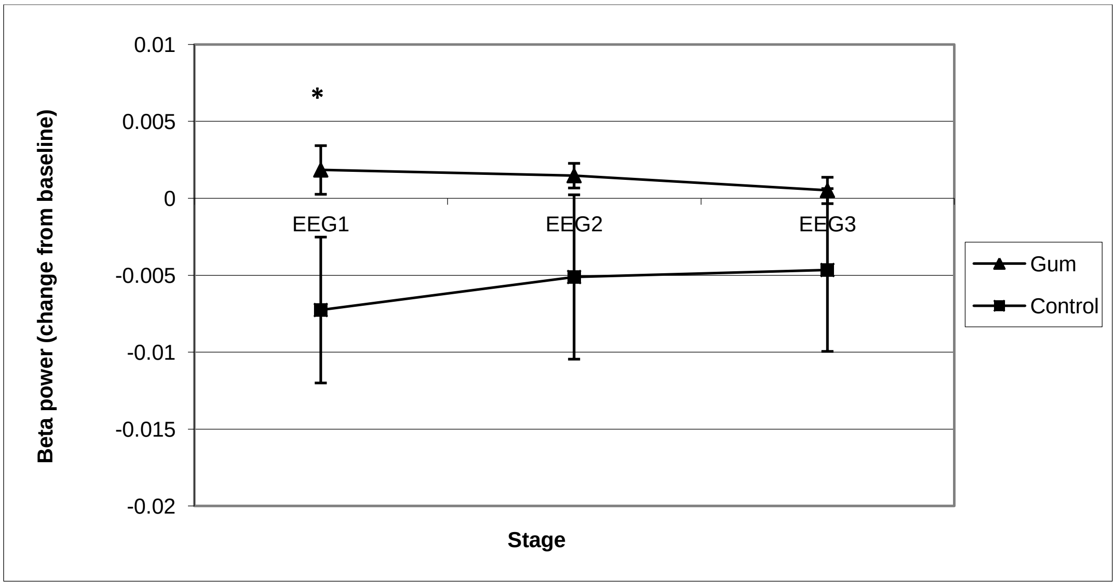


Figure 7-3: Effect of gum on heart rate during vigilance tasks and during EEG readings[56]

There were no statistically significant trends in the EEG data. However, chewing led to an overall increase in beta power at T3, $F(1, 28) = 2.1$, $p = .08$, *partial* $\eta^2 = 0.07$, and at F7, $F(1, 28) = 2.13$, $p = .08$, *partial* $\eta^2 = 0.07$ (see Figure 7-4). These effects were strongest during EEG1, both for T3, $F(1, 31) = 3.35$, $p = .04$, *partial* $\eta^2 = 0.1$, as well as for F7, $F(1, 31) = 4.68$, $p = .02$, *partial* $\eta^2 = 0.13$.

[56] Change scores from pre-chewing baseline are used. Error bars indicate standard error. Asterisk indicates significant difference ($p < .001$)



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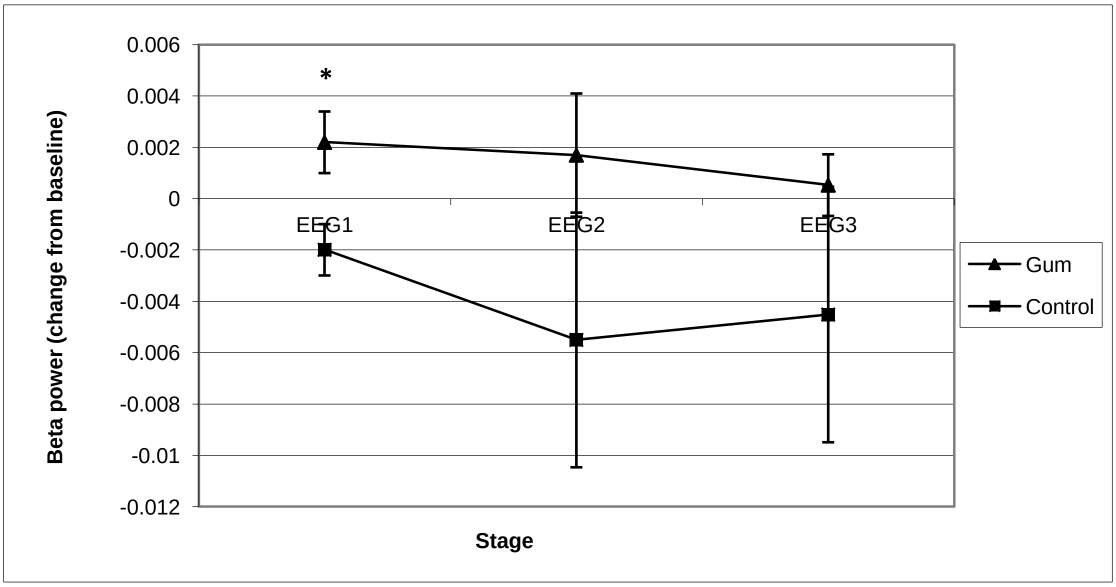


B

Figure 7-4: Effect of gum on beta power (A) at T3 and (B) at F7[57]

7.3.5 Physiology's association with alertness and vigilance

Examining correlations between change from baseline scores for heart rate during vigilance tasks and vigilance performance, there was a lack of a significant relationship between heart rate and vigilance. As beta power was higher just after chewing at both electrodes, these figures were also examined for a correlation with vigilance, but again there were no significant correlations.

[57] Change scores from baseline are used. Error bars indicate standard error. Asterisk indicates significant difference ($p < .05$)

Given the descriptive evidence that gum reduced heart rate for the later vigilance task, heart rate during the last vigilance task was tested for an association with post-test alertness, but there were no significant correlations.

7.4 Discussion

7.4.1 Changes over time

Alertness fell between baseline assessment and the end of testing, as did hedonic tone, similar to other studies in this thesis. Heart rate fell significantly in the post-chewing sessions compared to during the earlier vigilance tasks, and fell between baseline and the chewing session for the control group. In contrast, alpha and beta power were not affected by time performing the vigilance tasks. This suggests that repeated digits vigilance is associated with reduced arousal, but not in the central nervous system. It may be the case that there are differences in the effects of gum between a more boring task such as the one used here and more stressful vigilance tasks. In terms of the vigilance task itself, both false alarms and correct hits fell, suggesting a heightened detection-response threshold.

7.4.2 The effects of chewing gum

The gum condition interacted with time, such that gum led to a smaller fall in alertness. The smaller fall in alertness for the chewing condition is consistent with previous research. However, baseline alertness happened to be lower in the gum condition, before the gum manipulation, and it fell to a level similar to that of the control condition post-test. It is somewhat unclear if this interaction is simply due to this initial difference. One could argue that the task alone brought participants in the gum condition to a similar level of alertness as those in the control, although it is possible that alertness would have fallen even lower for participants in the gum condition if they had not chewed.

Gum led to initially higher correct hits and false alarms, although hits subsequently fell below the control condition. The gum condition was also associated with shortened vigilance reaction time in general, consistent with an alerting effect. The onset of this effect seems to be faster than that observed during Study 5; it may have been that going through the set up of the EEG and heart rate equipment led to fatigue in participants. The higher level of false alarms and correct hits suggest that gum leads to a reduced detection-response threshold.

In contrast to the lack of an effect on heart rate over the course of the day observed in Study 3, chewing gum led to a clear increase in heart rate during vigilance, consistent with the findings of Wilkinson et al. (2002). However, this increase only occurred during the act of chewing, and seemed to reverse post-chewing; it may explain any effects on vigilance that begin to reverse post-chewing, such as correct hits. The descriptive evidence that chewing gum reduced heart rate post-chewing would also be consistent with a calming effect of gum after chewing has ceased. The fact that the trend in heart rate began to reverse quickly, whereas the effect of gum on behavioural data was only attenuated in the post-chewing sessions, suggested that vigilance performance changes may lag behind rapid changes in heart rate. Beta power at F7 and T3 was higher immediately after chewing, although this was also less evident following subsequent testing sessions.

7.4.3 Critique

Despite the evidence for an effect of chewing gum on both heart rate and vigilance performance, there was not a clear association between heart rate and vigilance performance, even though heart rate was reduced over time by the act of completing the vigilance tasks. There was also a lack of an association between chewing gum and beta power. There may thus be factors other than a mediating effect of physiology for effects of chewing gum on vigilance, or perhaps factors which further moderate the extent to which physiological effects lead on to behavioural. On the other hand, it may simply be that psychological trends lag behind those physiological trends which cause them.

Performance with and without chewing gum was included in the chewing condition so that the effects of current chewing and prior chewing could be examined. Some previous research with EEG has required participants to chew gum for a short period of time (3-15 minutes). In contrast, other studies in this thesis that have looked at vigilance have required participants to chew gum for periods of time (approximately 25 minutes per battery) that were longer than the period of chewing used in this study (approximately 6 minutes); the effects on vigilance performance may have been stronger and persisted for longer after chewing had a longer period of chewing been employed. Another shortcoming of using a shorter period of chewing is that it reduces the comparability of chewing conditions between studies. It may have been better to have each participant perform two sets of 25-minute vigilance tasks, with those in the chewing condition chewing for the first 25-minutes task. This would preserve a similar length of chewing to other experimental studies while still allowing for current and prior chewing effects to be tested.

As a number of participants had to be excluded due to movement artefacts, the final sample size was somewhat underpowered. However, the use of a baseline condition allowed for individual differences to be controlled for.

The size of the change in vigilance performance over time may have been attenuated somewhat by the EEG recordings between vigilance tasks, which allowed participants to have a short break approximately every five minutes. These breaks were necessary in order to avoid artefacts in the EEG data. However, although changes in vigilance can occur quite rapidly, performance can recover very quickly if interrupted (Nachreiner & Hänecke, 1992). Trends in vigilance performance were observed over time in this study nonetheless, but continuous vigilance testing may lead to a larger decrement, upon which chewing may show a clearer effect.

The finding that chewing gum can enhance arousal during a vigilance task suggests that it may be used as a mean for maintaining vigilance and alertness in situations where vigilance must be sustained (e.g. in security or military settings). Given the apparent reduction in the detection-response threshold observed in this study, gum chewing may be of particular use where false alarms are less costly than failures to detect target stimuli. The enhancement of work performance reported in studies 2 and 3 suggests that the objective evidence for acute effects in the current chapter can lead to a noticeable benefit in an everyday setting. The increase in heart rate also adds to the evidence for an arousing effect of gum chewing provided by the rise in cortisol at 10.00 for the chewing condition in Study 3.

Previous discussion of time-on-task trends in chewing effects has suggested that an initial distracting effect (which should become less evident as chewing becomes more automatic) may be followed by enhanced arousal (which may persist after chewing has ceased). The major advantage of this study is that it allowed for the direct measurement of arousal, along with the measurement of post-chewing effects which occur after the distracting task of simultaneously chewing has finished, although a measure of distraction was not taken in the present research. It may be possible to assess distraction indirectly by look at the rate at which participants chew. Other mechanisms may be also at work in experiments such as this which could explain some of the variability in chewing effects on attention and mood. Demand characteristics and attitudes towards chewing gum in particular may be responsible for gum effects.

Chapter 8 Chewing gum effects and the role of demand characteristics and attitudes[58]

8.1 Introduction

8.1.1 The issue of demand characteristics

Notwithstanding the questionable moderation of a fall in alertness by chewing gum in the previous chapter, enhanced alertness has been demonstrated for chewing during cognitive performance in numerous previous studies. However, the evidence concerning chewing gum and biomarkers of alertness has been less consistent (e.g. Scholey et al., 2009; Smith, 2010 on cortisol). This could be due to differences in the timing of chewing and measurement between studies (consider how the quickening effect of gum on heart rate reversed after chewing ceased in Study 7 above). Similar to the inconsistent findings for subjective and physiological indicators of alertness, chewing gum has been found to reduce reported stress but increase cortisol in response to a social stressor (Gray et al., 2012). The findings that self-reported alertness and stress can be improved by chewing gum, whereas physiological variables associated with alertness and stress and objective measures of performance are more variable, suggests that demand characteristics may explain any observed effects of chewing gum on reported mood.

Unfortunately, a double- or even single-blind methodology has not been used in chewing gum research, as it is difficult to create a placebo condition. Consequently, there is a need to identify if demand characteristics can explain the observed improvements in reported alertness as well as variable findings concerning attention; differing demand characteristics in different studies may have led some researchers to find a positive effect of gum and others not. To this end, a procedure for manipulating demand characteristics was designed, where participants were either informed that the research aimed to find positive or negative effects of chewing gum, or an experimental aim was not mentioned.

The effect of differing demand characteristics should be observed over time, to see if they interact with time-on-task trends. Since causally related events are perceived as occurring closer together in time (Buehner & Humphreys, 2009), it can be

[58] This chapter is an extended version of Allen, A.P. & Smith, A.P. (2012). Demand characteristics, pre-test attitudes and time-on-task trends in the effects of chewing gum on attention and reported mood in healthy volunteers. *Appetite*, *59*(2), 349-356

hypothesised that participants who have a clearer belief that chewing gum will have an effect will also believe that this effect occurs more quickly. Faro (2010) got participants to complete a reaction time task, and gave all participants the feedback that their performance had improved over time (regardless of actual performance). Faro informed some participants that chewing gum causes greater alertness. Others were told that chewing gum can cause higher alertness, but that an improvement in performance could also be explained by practice effects. Faro found that, compared to participants who were also offered an alternative explanation for enhanced performance, participants who were only given chewing gum as a possible explanation for greater alertness (and consequently were more likely to see it as the cause of improved performance) reported that chewing gum led to an earlier onset of performance enhancement on the reaction time task. They were also quicker to indicate that they were starting to feel an effect of chewing gum during a subsequent short-term memory task. Although Faro's study only looked at self-report, it may be the case that if people assume that chewing gum is the key cause of improved mood or attention, then alertness or attention may actually improve more quickly, compared to a situation where people have no expectations with regards to the effects of gum. For example, the finding that vigilance performance only improved gradually in study 5 may have been due to the fact that a positive expectation for gum's effect was not mentioned to participants. By manipulating demand characteristics and measuring actual performance on attention tasks over time, this study will test for such an effect.

8.1.2 Rationale and hypotheses

The present research aimed to investigate the effects over time of chewing gum, prior attitudes towards gum and demand characteristics on attention, reported mood and changes in attitudes towards the effects of gum on attention, stress and mood. To investigate demand characteristics, we presented the research to some participants as anticipating a positive effect of chewing gum on mood and task performance, to others as anticipating negative effects, and did not mention a hypothesis to the third group. There were some positive effects on the selective attention tasks in studies 4 and 5, so in order to investigate if demand characteristics could account for such effects, the full battery of attention tasks was presented (rather than just the vigilance task, as was the case for Study 7).

It was predicted that the main effects of chewing gum would include a broader focus of attention, faster encoding of information for the selective attention tasks and higher reported alertness. Consistent with Orne's (1969) suggestion that participants will attempt to confirm the hypothesis they perceive the researcher to be testing, it was hypothesised that positive presentation of gum would lead to higher reported alertness and better performance on attention tasks than negative presentation. Furthermore, neutral presentation of gum should lead to effects on attention and mood that are more similar to those of positive presentation condition than those of negative presentation. This is because, even in the absence of explicit demand characteristics, the experimental context should provoke participants to become more motivated in an apparent intervention condition (performing tasks with chewing gum) than in an apparent control (doing so without chewing gum). It is likely that demand characteristics will have their strongest effect on mood compared to performance on attention tasks, as mood is self-reported and thus more easily changed in order to confirm the researcher's perceived hypothesis.

With regard to time-on-task, it was hypothesised that chewing gum would generally have a more positive effect on attention later in the attention tasks and particularly for vigilance. Although Study 7 did not indicate a significant within-task effect for vigilance, this may have been because of the shorter time spent chewing. This study was perhaps most similar to Study 4 in its procedure, although the addition of extra procedures to manipulate demand characteristics could possibly induce greater fatigue, which should lead to a time-on-task effect similar to that observed in Study 5. It was also predicted that the time-on-task trend would not be evident in the positive presentation group, who would show enhanced performance from the beginning due to the perception that gum should have an immediate effect, similar to the subjective effect observed by Faro (2010).

The hypotheses were as follows:

1. Chewing gum will have a positive effect on selective attention and alertness.
2. The effect of chewing gum on attention will be moderated by time-on-task.
3. Positive demand characteristics will lead participants to perform better on the attention tasks and report more positive mood than negative demand characteristics, and neutral demand characteristics will lead to a profile of results that are more similar to positive than negative demand characteristics.

4. Demand characteristics will interact with time-on-task, such that positive demand characteristics will lead to immediate positive effects, whereas neutral and negative demand characteristics will be associated with an enhancement over time.
5. Positive and negative demand characteristics will lead to corresponding changes in attitudes towards the effects of chewing gum.

8.2 Study 8: Method

8.2.1 Design

The independent measures factors were demand characteristics (manipulated through different presentations of chewing gum and its effects) and order of gum condition. The repeated measures factors were gum condition and time-on-task. This led to a 2 (gum condition) X 2 (order of gum condition) X 3 (demand characteristics condition) X 5 (time) mixed factorial ANOVA design. Participants were randomly assigned to an order of gum condition and a positive, negative or neutral demand characteristics condition.

8.2.2 Participants

Seventy-four healthy participants (sixty-eight females, six males) completed the study. Mean age was 19.4 (SD = 1.4). Twenty-five participants took part in each of the positive and negative presentation conditions, and twenty-four took part in the neutral condition. Thirty-eight participants began with the gum condition and thirty-six began with the no-gum control. Exclusion criteria were the same as in previous experiments. Participants were recruited through an online experimental sign-up system, and received either £10 or course credit for participating.

8.2.3 Materials

Mood and attention tasks and the choice of commercially available flavours of chewing gum were the same as in previous studies.

Attitudes towards gum were assessed at the beginning and end of testing with pen-and-paper questionnaires. A Likert scale of -3 (very negative) to +3 (very positive) was used to assess current attitudes regarding chewing gum’s effect on concentration and speed of mental processing (combined to form a measure of attitudes to “attention”), on mood and on stress (see Appendix 8.2). Age, gender and habitual level of gum consumption (number of pieces chewed per week) were assessed by pen-and-paper at the end of testing.

8.2.4 Procedure

Participants were randomly assigned to one of three gum presentation conditions (positive, negative or neutral). Given the need for participants not to be exposed to any stimuli from a different gum presentation condition, they were tested in groups of no more than two. Participants' attitudes towards chewing gum effects were assessed. Participants in the positive and negative presentation conditions were then given one of two information sheets which suggested that previous research had shown positive/negative effects of gum, and that the current experiment aimed to find these effects again:

(Positive demand characteristics)

Does chewing gum improve cognitive performance and mood?

Previous research has indicated that chewing gum improves cognitive performance (e.g. Smith, 2010) and mood (e.g. Scholey, 2009). This study aims to find out if these effects also exist with certain computer-based tasks.

(Negative demand characteristics)

Does chewing gum impair cognitive performance and mood?

Previous research has indicated that chewing gum impairs cognitive performance (e.g. Smith, 2009) and mood (e.g. Smith, 2010). This study aims to investigate if chewing gum also worsens performance and mood with certain computer-based tasks.

Participants in the neutral condition did not receive an information sheet.

Following a familiarisation with the tasks, all participants completed the mood and attention tasks with and without chewing gum. The gum conditions were completed one after the other, with a short pause of about one minute between sessions. Following the mood and attention tasks, attitudes towards gum were measured again, in order to see if the information sheet, condition scripts and procedure changed participants' attitudes, and participants were asked if they suspected that there were any additional aims to the experiment (see Appendix 8.3). One participant guessed the hypothesis; the corresponding data were removed. Participants were fully debriefed at the end of the procedure, and asked not to mention the nature of the study to their friends.

The verbal protocol used by the experimenter differed between demand characteristics conditions:

Positive/negative demand characteristics

(*While chewing gum in positive condition*) Cool, this info sheet is just to tell you more specifically what the study's about. (*Once the information sheet is read*) The first set of tasks is a familiarisation-the instructions'll appear on screen. Any further questions? (*Following familiarisation*) So, basically we're trying to find if chewing gum improves ("*has a negative effect on*" in negative condition) how you feel and performance on some simple tasks. (*Before chewing gum condition*) So for this set of tasks chew two pieces of gum at the same time, and just those two pieces, while doing the tasks. You can keep the rest of the pack as a thank-you (*The thank-you was mentioned before the gum condition for the positive condition only; otherwise mentioned at the end of the procedure*).

Neutral demand characteristics

The first set is a familiarisation-the instructions'll appear on screen. There're a few different tasks, but they'll load automatically. Any further questions? You can start whenever you're ready. (*Before chewing gum condition*) So for this set of tasks chew two pieces of gum at the same time, and just those two pieces, while doing the tasks.

8.2.5 Analysis

Mixed ANOVAs were used to analyse the data, with the independent variables being gum condition, time-on-task, demand characteristics and order of gum condition. The effects of the experimental factors on mood (alertness, anxiety and hedonic tone) and attention tasks (selective attention, simple reaction time and vigilance) were tested. Participants were randomly assigned to an order of gum condition and a positive, negative or neutral demand characteristics condition. Pre-test attitudes towards the effects of gum (attitudes concerning mood in the case of mood variables and attitudes concerning attention in the case of attention variables) and habitual gum consumption were also entered into subsequent ANOVAs; attitudes towards gum were dichotomised using a median split.

8.3 Results

8.3.1 Chewing gum data

The numbers of participants who selected each type of gum were as follows: Extra Cool Breeze (15), Extra Spearmint (12), Extra Peppermint (8), Extra Ice (7), Wrigley's Spearmint (6), Airwaves Green Mint (6), Airwaves Menthol & Eucalyptus (3), and Airwaves Cherry (3). Habitual chewing was classified as follows: twenty-three participants were regular chewers (Median pieces chewed per week = 7, range = 5-15), thirty were infrequent (Median = 2, range = 0.5-4.5) and seven never chewed. There was no significant difference in mean pieces chewed per week between demand characteristic conditions. Regular chewers had slower encoding of new information for categoric search in the gum condition (see Figure 8-1). Gum increased pre-test anxiety for infrequent chewers, but reduced it for non-chewers, although these simple effects were not themselves significant (see Figure 8-2).

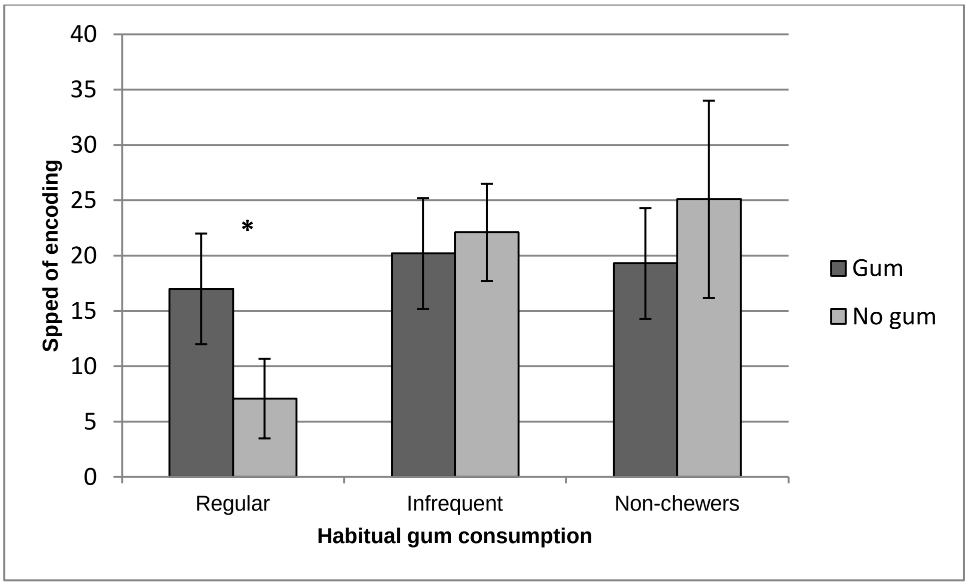


Figure 8-1: Effect of chewing gum and habitual gum consumption on categoric search speed of encoding[59]

[59] Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)

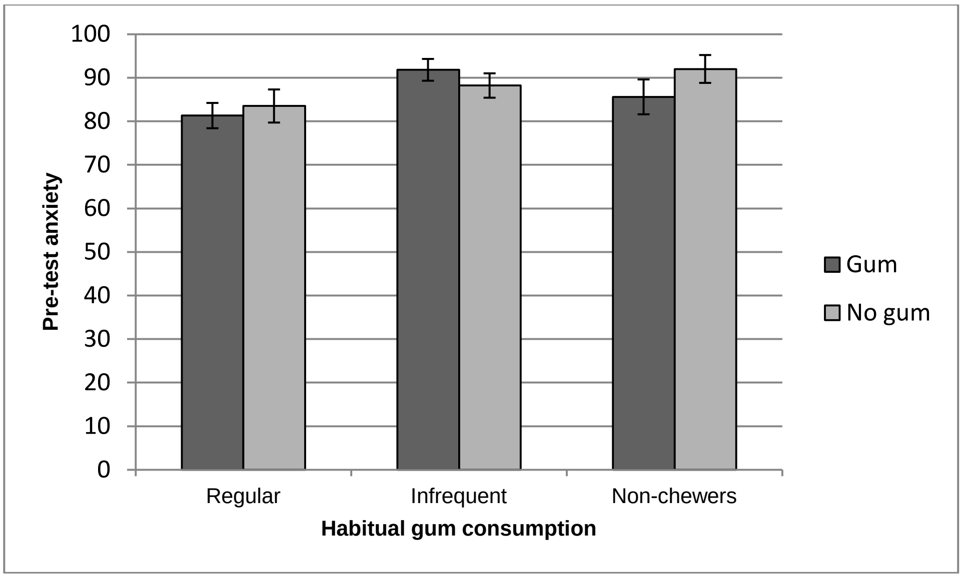


Figure 8-2: Effect of chewing gum and habitual gum consumption on pre-test anxiety[60]

8.3.2 Attitudes towards effects of gum

Attitudes assessed before the manipulation of demand characteristics were positive towards gum's effect on mood (M = 0.4, SD = 0.67), attention (M = 1, SD = 1.45), and stress (M = 0.5, SD = 1). Using one-sample t-tests, these values were all significantly greater than zero (p < .001). Those classified as having more positive pre-test expectancies for chewing gum by the median split gave a response of 1 or higher for mood and a response of 2 or higher for attention. There were no significant differences between the positive, neutral and negative presentation of gum groups in terms of pre-test attitudes towards gum. Compared to the neutral condition, negative presentation led to participants' attitudes becoming more negative for chewing gum's effect on mood (U = 98, r = -.18), stress (U = 94, r = -.2) and attention (U = 112.5, r = -.08). In comparison to the neutral condition, positive presentation actually led to less of an increase in positive attitudes for stress (U = 102, r = -.15) and mood (U = 105.5, r = -.13), although for attention positive presentation led to less of a reduction (U = 113.5, r = .07) (see Table 8-1 for mean pre-test and change scores). Using a Kruskal-Wallis test, the overall effect of presentation of gum was statistically non-significant for changes in attitude toward gum effects on mood, $H(2)$ = 1.14, p > .05, stress, $H(2)$ = 1.67, p > .05, and attention, $H(2)$ = 1.73, p > .05.

[60] Errors bars indicate standard error

Table 8-1: Mean pre-test scores and changes between pre- and post-test for attitude toward effects of gum for different presentations of chewing gum[61]

Presentation	Mood (pre-test)	Mood (change)	Attention (pre-test)	Attention (change)	Stress (pre-test)	Stress (change)
Positive	.27 (.15)	.12 (.2)	1 (.27)	-.48 (.5)	.42 (.19)	0 (.18)
Neutral	.5 (.17)	.4 (.27)	1 (.47)	-.6 (0.7)	.3 (.37)	.4 (.56)
Negative	.48 (.12)	-.04 (.22)	.96 (.31)	-1.28 (.5)	.72 (.18)	-.17 (.25)

8.3.3 Effect of time

Time-on-task led to a significant fall in alertness, $F(1, 67) = 115.4$, $p < .001$, *partial* $\eta^2 = .63$, and in hedonic tone, $F(1, 67) = 45.44$, $p < .001$, *partial* $\eta^2 = .4$. Time did not significantly affect anxiety.

For focused attention, time-on-task did not significantly affect accuracy or reaction time. Categoric search significantly differed across blocks, although it alternated between increasing and decreasing over the blocks. Simple reaction slowed significantly over the course of performance, $F(4, 272) = 28.19$, $p < .001$, *partial* $\eta^2 = .29$. For repeated digits, time-on-task led to a significant fall in hits, $F(4, 248) = 33.46$, $p < .001$, *partial* $\eta^2 = .35$, and lengthening of reaction time, (4, 248) = 6.58, $p < .001$, *partial* $\eta^2 = .1$, but did not affect false alarms.

8.3.4 Effect of gum and gum over time on reported mood

Reported alertness was higher in the gum condition, both at pre-test (Mean Change = 13.1, SEM = 4.8) and at post-test (Mean Change = 19.6, SEM = 3.8). Entering pre- and post-test data in the same analysis, this overall difference was highly significant, $F(1, 67) = 42.5$, $p < .001$, *partial* $\eta^2 = .39$. There was a significant main effect of gum for all items making up the alertness factor. Mean hedonic tone was higher at pre-test (Mean Change = 8.6, SEM = 3.9) and at post-test (Mean Change = 10.0, SEM = 3.1), $F(1, 67) = 16.23$, $p < .001$, *partial* $\eta^2 = .2$. For specific items comprising the hedonic tone factor, gum had a significant effect on interested-bored, withdrawn-sociable, and self-centred-outward going. However, gum did not significantly affect reported anxiety. See Table 8-2 for non-significant effects of gum.

[61] Standard errors are given in brackets

Table 8-2: Effects of gum on mood and attention[62]

Test	Mean Change
Pre-test anxiety	0.3 (1.2)
Post-test anxiety	1.1 (2.6)
Focussed attention long responses	0 (0.1)
Focussed attention errors	0.2 (1.2)
Focussed attention mean RT	-1.6 (2.9)
Categoric search speed of encoding	2 (2.2)
Categoric search spatial uncertainty	3.1 (4.8)
Categoric search place repetition	0.1 (2.1)
Categoric search long responses	-0.5 (0.4)
Categoric search errors	-0.9 (1.1)
Categoric search mean RT	0 (3.8)
Simple reaction time	-7.1 (4.8)
Repeated digits false alarms	0 (0.9)
Repeated digits RT	4.1 (6.8)

8.3.5 Effect of gum and gum over time on attention

For percent hits on the repeated digits task, a significant interaction between minute and gum condition was found, $F(4, 248) = 4.27$, $p = .004$, *partial* $\eta^2 = .06$ (see Figure 8-3). Contrary to the hypothesised interaction, performance was impaired by chewing gum later in the task: accuracy was significantly lower for the gum condition during the fourth minute, $F(1, 68) = 13.97$, $p < .001$, *partial* $\eta^2 = .17$.

[62] Standard errors are given in brackets

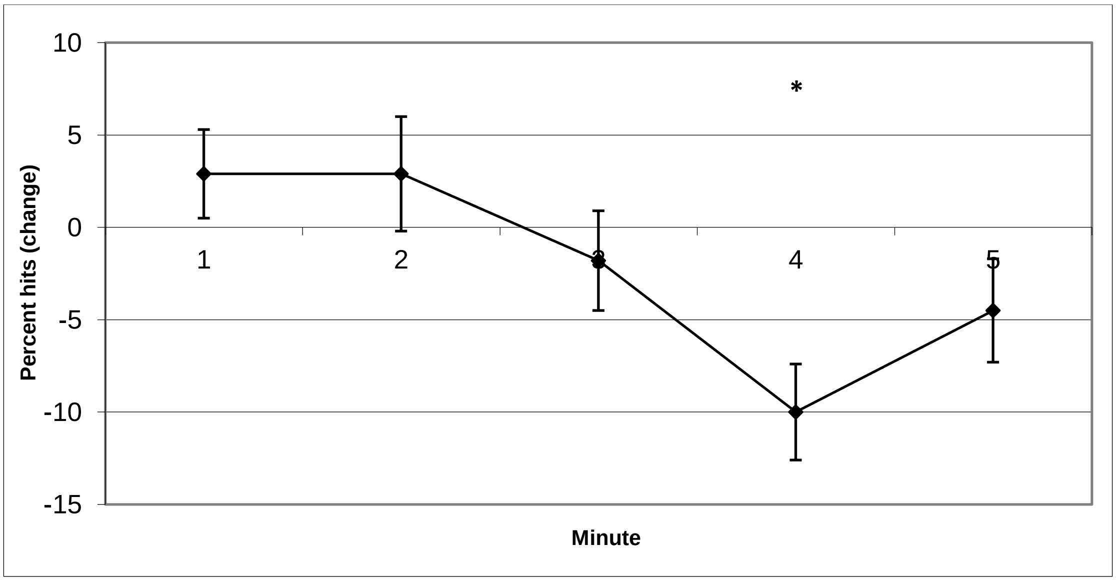


Figure 8-3: Change between gum and control condition on percent hits on the repeated digits task per minute[63]

For the focussed attention task, speed of encoding of information was faster for the gum condition (Mean Change = -5.8, SEM = 2.2), $F(1, 68) = 6.03$, $p = .02$, *partial* $\eta^2 = .08$, and breadth of attention was wider by gum (Mean Change = -8.9, SEM = 4.4), $F(1, 68) = 4.38$, $p = .04$, *partial* $\eta^2 = .06$. Gum also improved response organisation for the categoric search task, with the difference between compatible and incompatible target/response locations reduced by gum (Mean Change = -9.5, SEM = 2.6), $F(1, 68) = 13.05$, $p = .001$, *partial* $\eta^2 = .16$. There were no interactions between the effect of gum and order of gum conditions.

8.3.6 The effects of demand characteristics and attitudes towards gum

There was a significant interaction between demand characteristics and gum condition for overall reported alertness, $F(2, 67) = 3.18$, $p = .048$, *partial* $\eta^2 = .09$. This interaction was not further moderated by any other factors. Follow-up tests indicated that gum led to a highly significant increase in reported alertness following both positive presentation of gum, $F(1, 67) = 21.75$, $p < .001$, *partial* $\eta^2 = .25$, and neutral presentation, $F(1, 67) = 23.6$, $p < .001$, *partial* $\eta^2 = .26$, but not negative presentation, $F(1, 67) = 3.04$, $p = .09$, *partial* $\eta^2 = .04$ (see Figure 8-4). For specific items comprising the alertness factor, there was a significant moderating effect of

[63] Higher scores indicate more correct hits in the gum condition. Error bars represent standard error. Asterisk indicates significant difference ($p < .001$)

presentation of gum for drowsy-alert, mentally slow-quick witted, and incompetent-proficient.

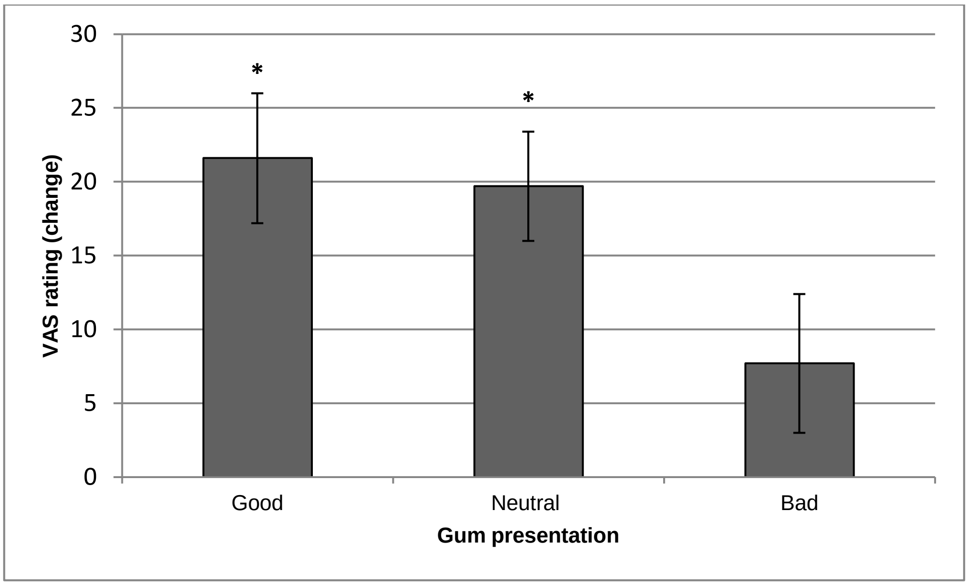


Figure 8-4: Chewing condition and alertness ratings for positive, neutral and negative presentation of chewing gum[64]

There was no interaction between gum and demand characteristics or pre-test attitudes to gum for anxiety or hedonic tone. None of the effects of gum on attention, including the time-on-task effect of gum on the repeated digits task, were moderated by demand characteristics or attitudes to gum.

8.4 Discussion

8.4.1 Chewing gum, mood and attention

Similar to previous studies, chewing gum enhanced alertness, although this was moderated by demand characteristics (see Section 8.4.3 below). In contrast to the findings of Scholey et al. (2009), but similar to previous experimental studies in this thesis and other previous research (Johnson et al., 2011; Smith, 2010) chewing gum did not have an effect on anxiety, although chewing gum did lead to an improvement in hedonic tone, similar to studies 4 and 5.

The current study replicated the previous findings (Smith, 2010) that chewing gum broadens the focus of attention and increases speed of encoding of information for a focussed attention task. These effects may be due to the enhancing effect on alertness reported in the research. Gum also enhanced response organisation, similar to Study 4.

[64] Error bars represent standard error. Asterisk indicates significant difference ($p < .001$)

8.4.2 Time-on-task trends

Time-on-task analysis (independent of gum condition) showed that alertness and hedonic tone fell over time. Simple reaction time lengthened, as did repeated digits reaction time, and repeated digits hits fell. The results also indicated that the effect of chewing gum on different aspects of attention can be moderated by time-on-task. However, chewing gum’s reduction of digit vigilance hits towards the end of testing on the repeated digits task contrasts with the higher rate of hits observed during chewing in Study 7. The test used in Study 7 was of similar length to the battery used here, but it may be the case that the vigilance task used in the present study was not long enough to indicate the effects shown in Study 7, which employed multiple trials of the repeated digits task, rather than a variety of attention tasks. Similarly, earlier studies in this thesis and Smith (2010) which used a variety of tasks recorded a positive time-on-task effect on vigilance only after a longer overall period of testing than that used in the current study. It may be that the reduction in hits is due to the fact that the fourth and fifth minute of the task is still in the earlier, detrimental phase of a time-on-task trend, even though participants had been performing attention tasks for some time before the vigilance task began. As chewing and task performance continue, the act of chewing while performing the task may become more automatic, and the impairment in performance will dissipate. With regard to whether or not selective attention tasks must be performed before vigilance, a key difference between the selection attention tasks and the vigilance task is that the selective attention tasks require the participant to make a response before continuing to the next trial, whereas this is not the case for vigilance. The selective attention tasks appearing before the vigilance task may thus have motor activity effects similar to the chewing of gum, as a button must be pressed every second or so. The order in which the attention tasks are completed is thus of interest.

Neither the main effects of gum nor the time-on-task effects of gum were moderated by the order of gum conditions. If there were clear effects of gum after chewing, one would expect that those who completed the control condition shortly after the chewing condition would show comparable performance and mood during the control. The absence of these interactions suggests that the effects of gum do not persist for long after chewing.

8.4.3 Chewing gum and demand characteristics

Consistent with much of the literature, gum enhanced alertness. However, this effect of gum was moderated by demand characteristics. Neutral presentation of chewing gum led to a strong effect of chewing gum on reported alertness, comparable to that caused by positive presentation. This suggests that giving chewing gum to participants may induce demand characteristics for self-report data, even if chewing gum is not presented in a positive light. As Orne (1969) has pointed out, participants (particularly those taking part in a crossover design) will often notice the difference between a control condition and experimental condition by themselves, and improve performance during the experimental condition. Nonetheless, despite the interaction between demand characteristics and reported alertness, given the very strong main effect of chewing gum on reported alertness, it is likely that gum has a genuine alerting effect caused by some other mechanism (e.g. the provision of glucose to relevant brain areas suggested by Stephens & Tunney, 2004a), and this alerting effect may simply be exaggerated by demand characteristics. The fact that hedonic tone was not moderated by demand characteristics also suggests that participants were not altering a reported response purely to please the researcher, as one would expect participants in the positive demand characteristics condition to report improved hedonic tone in such a case. Analysis of the sub-components of the alertness rating indicated that the main effect of gum was significant for all sub-components of the alertness factor, including drowsy-alert, lethargic-energetic and muzzy-clear headed. In comparison, although the interaction between gum and demand characteristics was also significant for drowsy-alert, it was strongest for the item incompetent-proficient, suggesting that demand characteristics may have a stronger effect on perceived ability to maintain alertness and attention, rather than a "gut" feeling of subjective alertness, fatigue or sleepiness, which is clearly affected by chewing gum. The finding that feelings of incompetence were reduced by gum is relevant to the clear findings of improved perceived performance throughout Chapter 4, which suggests that future interventions or surveys assessing this outcome may need to carefully control for demand characteristics.

A moderating effect of demand characteristics or pre-test attitudes was not observed in the case of any of the other outcomes. This suggests that the enhancement of speed of encoding seen here and in earlier chapters is not simply due to demand characteristics. It also suggests that previous studies' less consistent findings on chewing gum and cognitive performance and some aspects of mood cannot simply be explained by differences in demand characteristics.

The time-on-task effects on vigilance and focussed attention were not moderated by demand characteristics. These findings contrast with Faro's (2010) findings regarding the perceived timing of an effect, where participants reported a quicker effect of gum when gum was the only potential explanation of enhanced alertness provided. This difference in findings may be due to the fact that we measured actual performance, rather than performance assessed by self-report.

8.4.4 Attitudes and demand characteristics

There was a lack of a significant effect of gum presentation on changes in reported attitudes regarding gum and mood. This highlights the difference between being exposed to a positive presentation of chewing gum and developing a more/less positive attitude towards chewing gum, and suggests that the previous studies did not alter participants' attitudes towards the effect of gum. As previous research may have inadvertently presented chewing gum in a positive light, the key aim of this study was not necessarily to change participants' attitudes, but rather to manipulate presentation of chewing gum and assess what effects (or lack thereof) this would have on attitudes to gum (as well as effects on attention and reported mood). There are different possibilities as to why this gap between demand characteristics and subsequent attitudes emerged. Participants may have interpreted "mood" here as referring to levels of happiness (future research could specifically enquire about attitudes to alertness). Perhaps participants were prepared to indicate that the chewing gum increased their current alertness at the end of testing, consistent with Orne's suggestion that participants will try to confirm the researcher's perceived hypothesis, but were reluctant to indicate a change in attitude, as they did not want it to appear as if their attitudes would be so easily influenced by the experimental procedure. Demand characteristics may not have a homogenous effect across participants; some participants may act so as to confirm a perceived hypothesis, others to disconfirm it, while others may ignore demand characteristics (Weber & Cook, 1972). The variety of different responses to demand characteristics could have dampened their moderating effect on stated attitudes regarding chewing gum effects.

The finding that pre-manipulation attitudes towards gum and stress were positive is consistent with attitudes of survey respondents in Study 1, as well as previous research in which 56% of frequent chewers and 42% of less regular chewers reported using chewing gum in their daily lives as a means of reducing stress (Zibell & Madansky, 2009). It is interesting that participants in the positive presentation condition did not report a change in the attitude that chewing gum reduces stress, while those in a neutral condition reported a slight increase in this attitude. Further research could address whether reported stress is affected by demand characteristics, perhaps using an intervention method, as this has shown robust effects on reported chronic stress (Smith et al., 2012; Zibell & Madansky, 2009).

8.4.5 Summary

In summary, this study indicates that chewing gum enhances alertness, hedonic tone, and selective attention. There is also an interaction between gum and time-on-task for vigilance. The effect on alertness is moderated by demand characteristics, but there are no other interactions between gum and demand characteristics. Given that the ambiguity in previous findings on attention cuts across various aspects of attention which were not moderated by demand characteristics or time-on-task, the current study cannot account for much of the variability in the findings on attention to date. None of the studies in this thesis described thus far controlled for rate of chewing or the order in which the attention tasks were presented: this may help to explain variability in chewing gum effects on attention.

Chapter 9 Rate of gum chewing, task order, attention and mood

9.1 Introduction

9.1.1 Rate and force of chewing

The experimental work in this thesis has indicated that chewing gum attenuates a fall in alertness during cognitive performance, but the effects of chewing gum on attention tasks have been less consistent, similar to findings from previous research on this topic (see Section 2.3.1). As highlighted in Section 2.6.2, the level of motor activity involved in gum chewing may moderate any effects on attention. The previous studies all involved participants chewing at their own pace; a possible confound is thus that different participants may chew at different paces and with different degrees of force, leading to different levels of chewing effects.

Rickman et al. (2012) suggested that greater physical resistance to chewing should lead to increased cerebral activity, which should aid cognitive performance; there may also be a positive correlation between rate of chewing and cerebral activity. Rickman et al. manipulated the degree of chewing force by having participants either chew one piece of gum or four during performance of a memory task, and measured participants' rate of chewing. Increased chewing resistance was not associated with better memory performance. Similarly, asking participants to chew vigorously versus asking them to chew at a constant and natural pace did not moderate gum's effect on serial recall (Kozlov, Hughes, & Jones, 2012). However, more vigorous chewing may be more likely to have an effect for tasks requiring sustained attention over time.

A possible reason for these observed null effects on aspects of attention is that, although chewing may affect levels of arousal, chewing gum during a cognitive task may also lead to distraction (Onyper, 2011). Consequently, it is important to measure both the amount of chewing which has occurred before the task, which should lead to arousal, and the current rate of chewing during the task, which can lead to distraction as well as arousal.

Participants who are chewing gum automatically should show less variation in their rate of chewing, whereas participants who experience chewing as a distraction from the task may chew less over time to reduce the level of distraction. It is thus possible that difficulty in maintaining chewing and attention performance at the same time will be visible in greater variability in chewing. If variability occurs within specific tasks, then within-task time-on-task effects on attention should also be moderated by changes in the rate of chewing.

Rickman et al. pointed out that they did not measure resistance to chewing. The current study used the approach of having participants rate the hardness of their chewing, rather than manipulating the amount of gum chewed. Rickman et al. also observed that chewing rate did not vary between their chewing resistance conditions; however, there may be an association between individuals' pace of chewing and how hard they feel they are chewing the gum. The lack of an association between rate of chewing and resistance to chewing in Rickman et al. may have been due to the fact that the rate of chewing did not differ much over the course of participation. More substantial variation should be observed between participants; Rickman et al. used a within-participants design. In contrast, Tasaka et al. (2008) measured rate of chewing and observed substantial variation between the fastest and slowest chewers (1.4 versus 0.76 cycles per second). The low variation in rate of chewing in Rickman et al may also be related to the fact that participants were only required to chew for two minutes at a time, with two minute breaks in between. Tasaka et al. measured rate of chewing over a ten minute period, so longer periods of continuous chewing may lead to greater variability in rates of chewing, with chewing slowing down as tasks continue. The sets of attention tasks used so far in this thesis generally last at least twenty-five minutes, which could lead to even greater variation than that observed in Tasaka et al.

As well as allowing for the measurement of chewing rate, filming participants has the added benefit of ensuring compliance with the chewing instructions. Given that this is likely to enhance compliance, if the rate of chewing falls even when participants are being filmed then it is likely that chewing also slowed during previous studies of comparable length where participants were not directly monitored during performance.

9.1.2 Task order

The studies of this thesis which have used the selective attention, simple reaction time and vigilance tasks have presented the participants with the tasks in one fixed order: two tasks with predictable onset target stimuli (the selective attention tasks) have been followed by two tasks involving target stimuli with unpredictable onsets (the simple reaction time and vigilance tasks), so it is not possible to say whether the effects of chewing gum on specific tasks (e.g. speed of encoding for selective attention) are due to gum affecting performance on the task itself or simply due to changes in the effect of gum over time, regardless of the type of task. It is thus necessary to manipulate the order in which the tasks are presented, in order to clarify this issue.

Previous research has indicated that task order does not moderate the effects of current chewing gum (Onyper et al., 2011), although Onyper et al. tested different aspects of cognitive performance than those that have been examined in this thesis. Furthermore, Onyper et al. did not assess rate of chewing, and any effects of task order may be related to changes in the rate of chewing over time or in response to different types of task. For example, one participant during the pilot phase of testing (see Section 9.2) reported chewing in rhythm to the predictable onset of stimuli during the selective attention tasks.

9.1.3 Rationale and hypotheses

By observing the rate of chewing, this study will allow for the assessment of any relationship between the level of chewing activity and observed effects on attention. Given that the length of testing is longer than that used by Rickman et al. or Tasaka et al., it is probable that rate of chewing will fall over the course of testing. Given that greater chewing activity should facilitate greater cerebral activation and physiological arousal, it is likely that a greater intensity of chewing will be associated with an enhancement of attention. The positive effect of prior chewing on attention should be greater than that of current chewing. This is because prior chewing and current chewing will lead to arousal, but prior chewing will not have the distracting effect of current chewing.

Variability in rate of chewing will be assessed. Given the possible association of variable rates of chewing with dual-task interference, it is likely that greater variability will be associated with poorer performance.

The order in which tasks are presented will be varied, so that it can be ascertained whether any observed effects are specific to the type of task being performed, or are simply related to time spent performing and chewing. Given previous findings that chewing gum can have a more positive effect on attention later in a period of chewing and task performance (e.g. on vigilance in Study 5), if task order has an effect it is likely that performance will be facilitated by chewing gum for whichever task is presented later in the battery.

The hypotheses were as follows:

1. The rate of chewing will fall over the course of the testing session.
2. A higher current rate and hardness of chewing will have a greater facilitating effect on attention.
3. The level of prior chewing will have a stronger facilitating effect on attention than the level of current chewing.
4. Performance on attention tasks will be worse for participants with greater within-task variability in their rate of chewing.
5. Chewing gum will have a greater facilitating effect for a given task when it is presented later in the experiment.

Before the main experiment was conducted, pilot work was conducted to ensure that measuring the rate of chewing by observation had good inter-rater reliability and that participants' rate of chewing would vary sufficiently to allow for useful analysis.

9.2 Pilot I

To test the inter-rater reliability of measuring chewing by observation, five participants chewed gum constantly while completing one set of mood and attention tasks, the number of chews per minute were counted and a second researcher was asked to independently count the number of chews per minute for these same videos. The following instructions were giving for rating the speed of chewing:

> *Watch the videos closely. For each minute, note the number of times the participant chewed. You're looking for a telltale downward stroke of the jaw; swallowing without chewing, moving the gum about in the mouth without bringing the teeth down or just licking one's lips don't count. (Although obviously, someone could chew while seemingly swishing the gum about in his/her mouth).*
>
> *Be careful to count each chew, regardless of the pace of chewing. Count the chewing right up until the end (the last "minute" will be something like 20 or 40 seconds, just give the total number of chews for this).*

Some videos have the participant talking to me – if you observe any chews during this, count them. Don't confuse talking with chewing!!

Make sure to keep an eye on the clock towards the end of each minute, so you don't end up running over to the next and losing count.

The intra-class correlation (single measures) between the author's and the second researcher's ratings was .996, suggesting excellent inter-rater reliability.

9.3 Pilot II

In order to gain an estimate of variability in the rate of chewing, eleven participants completed the full procedure (see Section 9.4.4). The number of times each participant chewed was divided by the total number of seconds the task lasted. This was multiplied by 30 to simplify comparability between variability in this data and that observed by Rickman et al.

9.3.1 Pilot II results

The mean chewing rate per 30 seconds was calculated between participants for pre-test mood, M = 22.9, SEM = 2.7, focussed attention, M = 18.1, SEM = 3.5, categoric search, M = 15.9, SEM = 3.2, simple reaction time, M = 16.5, SEM = 3.6, repeated digits, M = 10.8, SEM = 2.5, and post-test mood, M = 16.3, SEM = 3.1. Participants also differed in their rating of how hard they chewed the gum, M = 5.1, SEM = 0.5. This suggests that participants vary in the speed and force with which they chew, suggesting that a useful analysis of the effects of chewing at different speeds and degrees of hardness can be carried out. It also seems that participants chew most quickly during the first task (the pre-test mood rating), before slowing down for the remainder of the testing session.

A standard error of chewing for each participant was calculated by dividing the standard deviation of the number of chews for the time blocks/minutes for each attention task by the square root of the number of time blocks. The standard errors for each task were: focussed attention, M (Mean standard error) = 2.2, SEM (of standard error) = 0.3; categoric search, M = 2.2, SEM = 0.3; simple reaction time, M = 1.6, SEM = 0.2; repeated digits, M = 1.9, SEM = 0.4. The standard errors of these standard error scores were large enough (relative to the mean standard errors) to suggest that participants do differ in their degree of variability in chewing rate within given tasks.

9.4 Study 9: Method

9.4.1 Design

This experiment examined factors that could potentially moderate the effects of gum on attention and mood. The repeated measures factors were gum condition and time-on-task. Similar to previous studies, gum condition was included as a crossover variable to test if any effects of gum would carry over to a no-gum condition (for those who completed the gum condition first). The between-subjects factors were rate of chewing during tasks, level of chewing prior to tasks, habitual level of chewing, order of gum conditions and order of attention tasks. Order of attention tasks was either (a). selective attention tasks (predictable stimulus onset), simple reaction time and repeated digits (unpredictable stimulus onset) or (b). simple reaction time, repeated digits and selective attention tasks.

9.4.2 Participants

Fifty-six participants (forty-two female, fourteen male) completed the study (mean age = 19.6, range = 18-24). They were recruited through an online experimental management system, and were mostly psychology students at the School of Psychology. Exclusion criteria were the same as in previous studies.

9.4.3 Materials

Wrigley’s Extra: Peppermint, Spearmint, Cool Breeze and Ice were used as available flavours. Mood and attention tasks were the same as those used in previous studies. A questionnaire on attitudes towards gum was also used. This was the same as that used in the previous study, apart from the inclusion of a specific question concerning gum’s effect on alertness. An 11-point Likert scale was used for rating how hard participants were chewing the gum. Participants were filmed using a LabTech webcam.

9.4.4 Procedure

As only one participant could be filmed at a time, participants were tested one at a time. Participants were tested at 9.00, 11.00 or 15.00. They were requested not to chew any gum for one hour before participation, and to consume as much caffeine as they usually would in the morning. Once informed consent was obtained attitudes towards chewing gum were assessed. Following a familiarisation, participants completed the mood and attention tasks twice; they were instructed to chew two pieces of gum constantly at their own pace during one of these testing sessions, and not to chew during the other. Participants selected a packet of gum just before the chewing condition, and rated palatability of the gum before beginning the tasks for the chewing session. They were filmed throughout the chewing session, and were not informed of when they were being filmed. In order to assess the rate of chewing during each task, notes were taken of which periods of the footage corresponded to which tasks and minutes/blocks of tasks. Participants were asked to rate the current palatability of the gum and indicate how hard they had been chewing immediately after the gum condition. Following completion of both conditions, participants rated their attitudes towards gum again. They were fully debriefed.

9.4.5 Analysis

The footage was divided into the mood tasks, blocks for the selective attention tasks and minutes for the unpredictable onset tasks, as well as gaps between tasks. Each piece of footage was rated twice, and the intra-class correlation (single measures) was .996, suggesting excellent test-retest reliability for the video rating. The mean of the two scores for each section of the footage was used as the final result.

To test the effects of the gum condition, factorial ANOVAs were used, similar to previous experiments, with the added factor of task order. Multiple regressions were used to test if the rate of chewing and prior amount of chewing could predict changes in attention and mood between gum and no-gum conditions. Variability of rate of chewing for each attention task was derived by taking the standard error of rate of chewing for the relevant task's blocks or minutes.

9.5 Results

9.5.1 Chewing gum data and attitudes to chewing gum

The numbers of participants who selected each type of gum were as follows: Extra Spearmint (22), Extra Ice (21), Extra Cool Breeze (10), and Extra Peppermint (3). The palatability rating of the gum was higher at the start of testing (M = 1.75; SD = 1.2) compared to the end (M = 0.4; SD = 1.4). Habitual chewing was classified as follows: twenty participants were regular chewers (Median pieces chewed per week = 7, range = 5-21), fifty-one were infrequent (Median = 1.5, range = 0.2-3) and eight never chewed. Regular chewers had higher post-test hedonic tone in the gum condition (see Figure 9-1), as well as faster reaction time (see Figure 9-2).

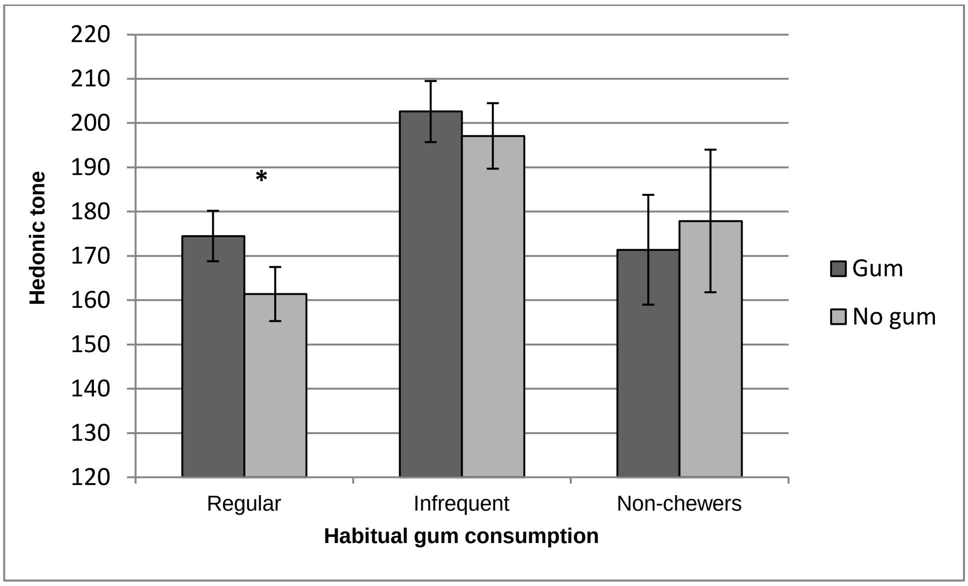


Figure 9-1: Effect of gum condition and habitual gum consumption on post-test hedonic tone.[65]

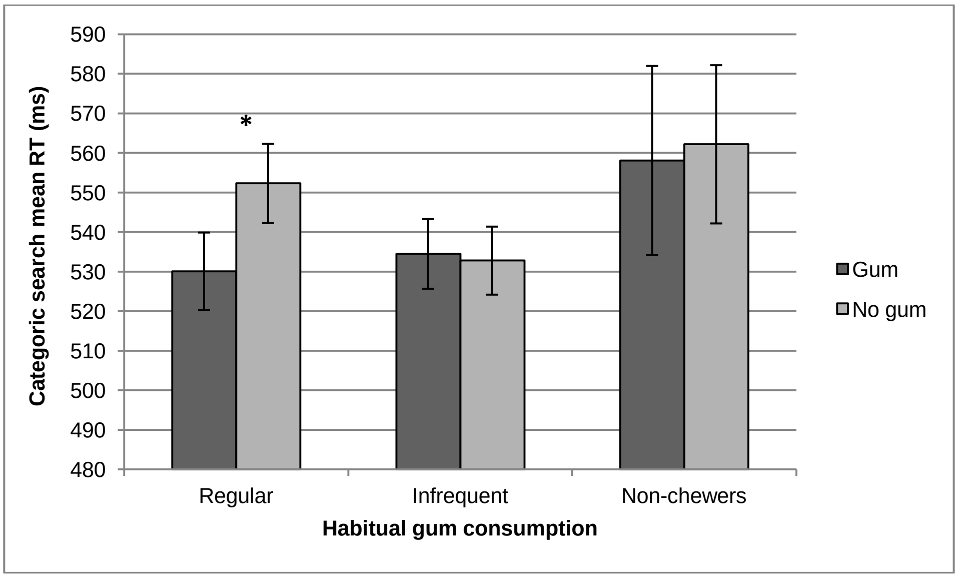


Figure 9-2: Effect of gum condition and habitual gum consumption on categoric search reaction time[47]

Those classified as having more positive pre-test attitudes for chewing gum by the median split gave a response of 1 or higher for mood, alertness and attention. Attitudes assessed before the manipulation of demand characteristics were positive towards gum's effect on mood (M = 0.4, SD = 0.7), attention (M = 0.8, SD = 1), alertness (M = 0.5, SD = 0.8) and stress (M = 0.8, SD = 0.8) (p's $< .001$). Using

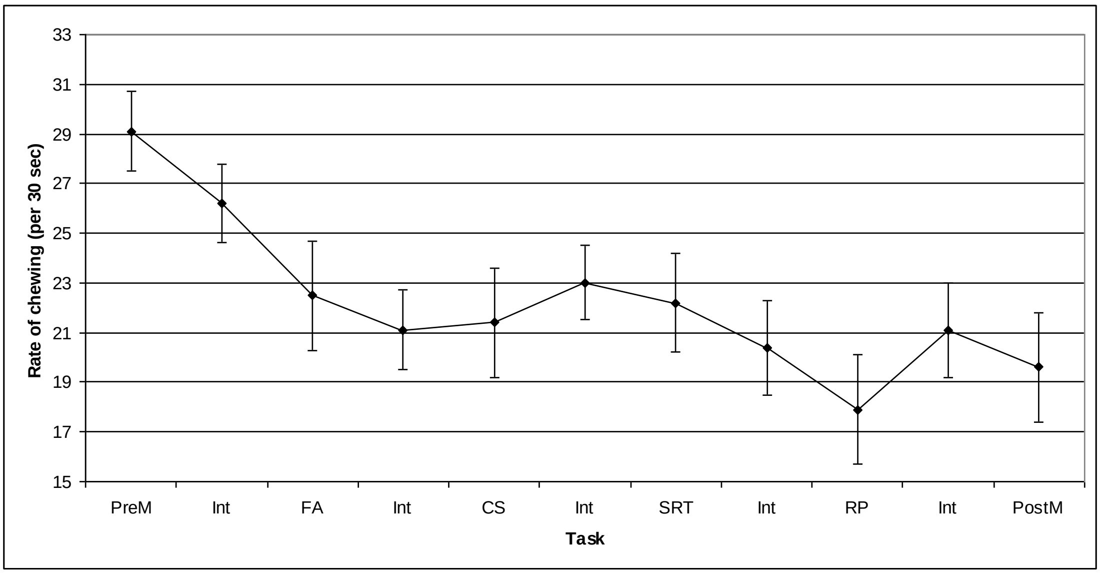
[65] Error bars indicate standard error. Asterisk indicates significant effect ($p < .05$)

paired-samples t-tests, none of these changes in attitudes were statistically significant, indicating that the experiment as a whole did not alter participant's attitudes. Rate of chewing and variability in chewing rate were not significantly correlated with pre-test attitudes to gum's effect on attention or mood during the attention tasks or mood tasks respectively.

9.5.2 Rate and hardness of chewing

There was a significant positively correlation between hardness of chewing and rate of chewing for pre-test mood (r = .4, p = .003), focussed attention (r = .46, p < .001), categoric search (r = .42, p = .001), simple reaction time (r = .42, p = .002), repeated digits vigilance (r = .49, p < .001) and post-test mood (r = .34, p = .01).

Looking at the mean rate of chewing during tasks and intervals between tasks, there was a highly significant effect of time-on-task, $F(5.85, 315.65) = 9.44$, $p < .001$, *partial* $\eta^2 = .15$ (Greenhouse-Geisser adjusted), with a clear reduction in the rate of chewing shortly after the start of the experiment (see Figure 9-3). Excluding the pre-test mood and following interval (as these occurred before the task order manipulation was implemented), there was also a significant interaction between time-on-task and order of tasks, $F(5.27, 284.62) = 2.57$, $p = .03$, *partial* $\eta^2 = .05$. When the vigilance task was the last attention task presented, it was associated with slower chewing than any other task. This was not the case when the unpredictable stimulus onset tasks came first, where simple reaction time was considerably shortened.



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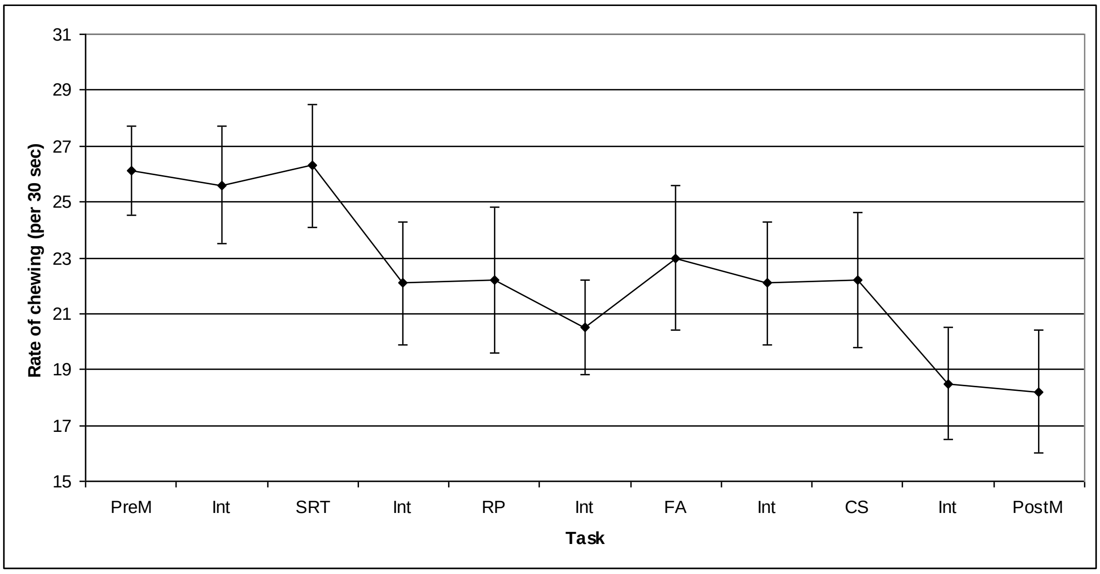

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Figure 9-3: Mean rate of chewing for (A) predictable stimulus onset tasks first and (B) unpredictable stimulus onset tasks first[66]

Within tasks, the rate of chewing fell during the simple reaction time task, $F(2, 108) = 3.99$, $p = .02$, *partial* $\eta^2 = .07$, with the rate of chewing falling after the first minute, although such a trend was not observed for the other attention tasks. There was no interaction between the order in which tasks were presented and the rate of chewing within any of the attention tasks.

Habitual gum consumption was not correlated with variability in chewing rate, nor was it associated with faster or slowing chewing, for any of the tasks.

9.5.3 The effects of rate and hardness of chewing on mood and attention

Rate of chewing was associated with lengthened simple reaction time (Beta = 0.42, $p = -.04$) (see Figure 9-4). Neither current rate of chewing nor prior chewing predicted other aspects of attention, or pre- or post-test mood.

[66] Tasks are listed in the order in which they were presented depending on task order condition. PreM = pre-test mood, Int = intervals following tasks, FA = focussed attention, CS = categoric search, SRT = simple reaction time, RP = repeated digits vigilance, PostM = post-test mood

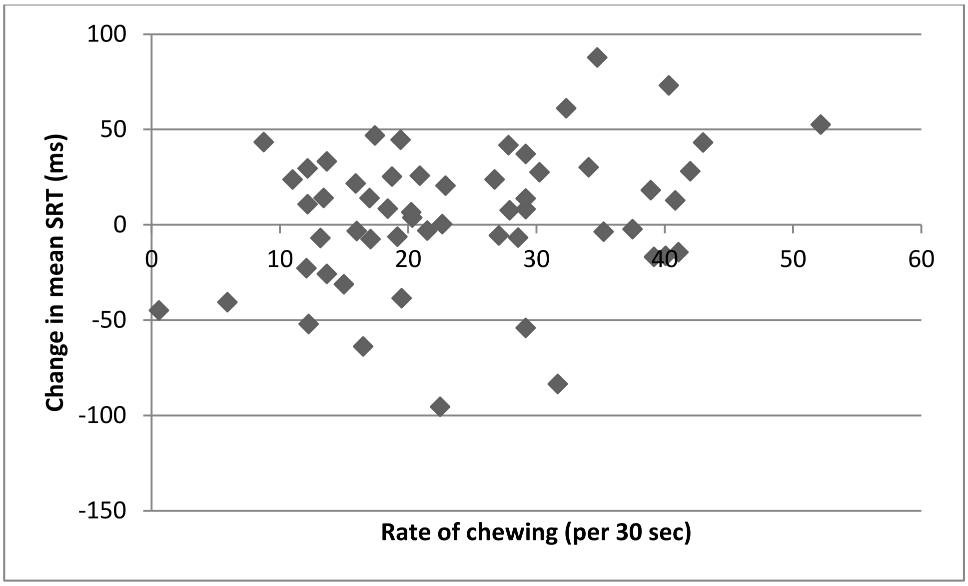


Figure 9-4: Association between rate of chewing and change in mean simple reaction time between gum conditions

The variability of rate of chewing did not predict performance on any of the attention tasks.

Harder chewing was significantly associated with faster encoding of new information on the categoric search task (Beta = -0.27, p = 0.4) (see Figure 9-5).

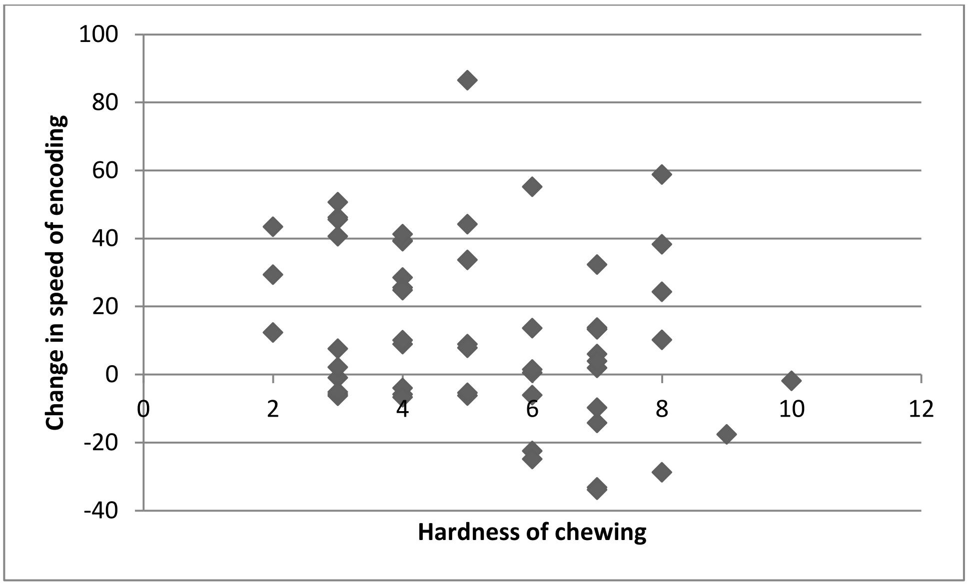


Figure 9-5: Association between hardness of chewing and change in categoric search speed of encoding

9.5.4 Task order

The effects of gum were not moderated by task order, which suggests that any observed effects were due to the nature of the task, rather than their placement within a battery. Task order did not have a main effect on any of the attention tasks or on mood.

9.5.5 The main effects of gum

Post-test alertness was significantly higher in the gum condition, $F(1, 51) = 43.97$, $p < .001$, *partial* $\eta^2 = .46$ (mean change = 25.5, SEM = 3.8). For the components of the alertness factor, gum had a highly significant positive effect on drowsy-alert and mentally slow-quick witted ($p < .001$), as well as on muzzy-clear headed ($p = .005$), coordinated-clumsy ($p = .01$), lethargic-energetic ($p = .001$). Post-test hedonic tone was significantly higher in the gum condition, $F(1, 52) = 7.29$, $p = .01$, *partial* $\eta^2 = .12$ (mean change = 6.4, SEM = 2.4). Pre-test anxiety was lower in the gum condition, $F(1, 50) = 6.52$, $p = .01$, *partial* $\eta^2 = .12$.

There were no main effects of chewing gum for the focussed attention task. For the categoric search task, gum led to a significant shortening of mean reaction time, $F(1, 52) = 7.22$, $p = .01$, *partial* $\eta^2 = .12$ (mean change = - 7.6, SEM = 4), but significantly slower speed of encoding, $F(1, 48) = 32.94$, $p < .001$, *partial* $\eta^2 = .41$ (mean change = 11.6, SEM = 3.2). In contrast to previous studies, gum lengthened simple reaction time, $F(1, 48) = 4.32$, $p = .04$, *partial* $\eta^2 = .08$ (mean change = 6, SEM = 4).

Table 9-1 reports aspects of attention and mood which were not significantly affected by gum or an interaction between gum and another factor.

Table 9-1: Effect of gum on attention and mood[67]

Test	Mean change
Breadth of attention	3.2 (4.9)
Focussed attention long responses	-0.2 (0.2)
Focussed attention percent correct	0.1 (0.4)
Categoric search errors	-0.4 (0.5)
Categoric search spatial uncertainty (ms)	-10.3 (5.7)
Categoric search place repetition (ms)	1.6 (2.7)
Categoric search long responses	0 (0.2)
Post-test anxiety	-0.9 (1.3)

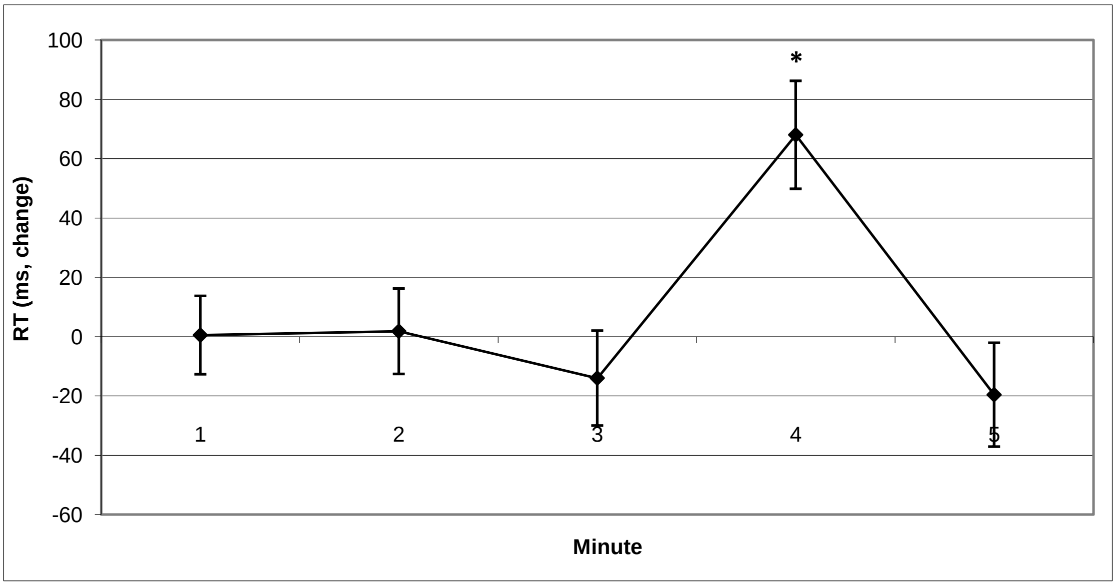
[67] Standard errors in brackets

9.5.6 Order of gum conditions

There were significant interactions (at $p < .05$) between gum condition and the order of gum condition for focussed attention speed of encoding and number of errors, for categoric search reaction time, for repeated digits false alarms and correct hits, for simple reaction time and for pre-test alertness and hedonic tone. With the exception of simple reaction time and repeated digits false alarms, performance and mood were improved by gum when it came before the control condition. However, the only interaction observed here that had been observed in a previous study (Study 4) was the reduction in focussed attention errors when the gum condition came first.

9.5.7 Time-on-task trends

There was a significant interaction between gum condition and time-on-task for repeated digits reaction time, $F(4, 204) = 5.16$, $p = .001$, *partial* $\eta^2 = .09$. Chewing gum lengthened reaction time during the fourth minute, $F(1, 54) = 13.91$, $p < .001$, *partial* $\eta^2 = .21$. Time-on-task also moderated the gum effect on false alarms, $F(4, 204) = 2.45$, $p = .048$, *partial* $\eta^2 = .05$; chewing gum also reduced the number of false alarms during the final minute of the task, $F(1, 54) = 13.69$, $p = .001$, *partial* $\eta^2 = .2$ (see Figure 9-6). The main effect of time was to lengthen reaction time and reduce both correct hits and false alarms, and these effects were highly significant ($p < .001$).



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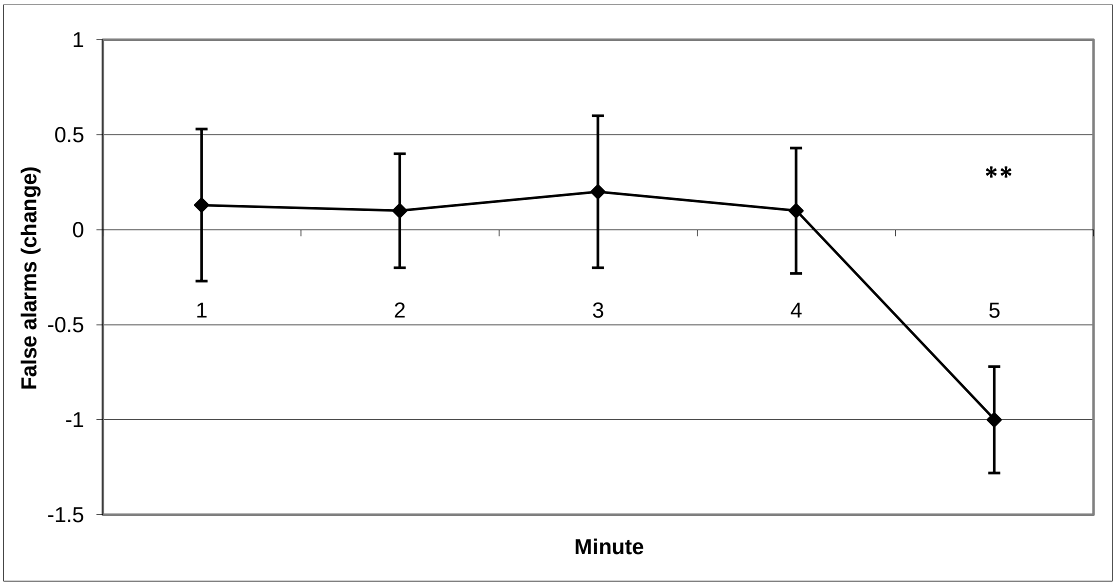

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Figure 9-6: Effect of gum over time on repeated digits (A) reaction time and (B) false alarms[68]

The overall reductions in alertness and hedonic tone between pre- and post-test assessment were highly significant (p < .001), although this was not the case for anxiety. There was a significant interaction between chewing gum and time-on-task for alertness, $F(1, 50) = 21.01$, $p < .001$, *partial* $\eta^2 = .3$. The gum condition led to a greater increase in alertness at post-test, compared to pre-test (see Figure 9-7).

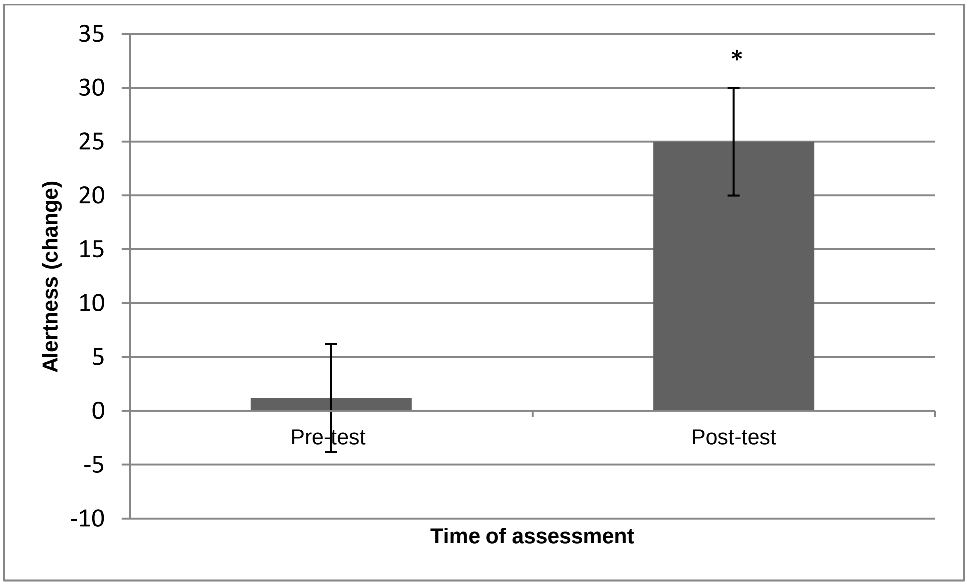

Figure 9-7: Effect of gum on pre- and post-test alertness[69]

[68] Error bars indicate standard error. * indicates p < .001, ** indicates p = .001
[69] Error bars represent standard error. Asterisk indicates significant effect (p < .001)

9.6 Discussion

9.6.1 Effects of gum condition and timing

Chewing gum increased post-test hedonic tone and, as has been consistently shown elsewhere, post-test alertness. As alertness generally fell during the attention tasks, it would seem that chewing gum attenuates a reduction in alertness caused by the testing procedure. Unlike the findings from previous experimental studies, pre-test anxiety was lower in the gum condition.

With regard to the attention tasks, much of the results were inconsistent with previous experiments in this thesis. Chewing gum slowed categoric search encoding (which gum quickened in Study 5), vigilance reaction time (which gum shortened in Studies 5 and 7), and simple reaction time (which was not significantly affected by gum in any of the previous chapters). The different (generally more negative) effects of gum on attention observed here suggest that the process of being filmed alters the effect of gum on attention in some way, perhaps by heightening the level of distraction, which may arise from feeling self-conscious at being filmed.

There was a pervasive interaction between gum condition and gum order for attention tasks, with gum being associated with better performance when it came first; this trend suggests a lack of carryover effects on attention between sessions. However, it is also curious in that one might expect gum to have a more beneficial effect when it is chewed during the second session, given that participants' alertness might be more depleted at that point; it may be that the depletion after that period of testing is simply not that severe to show a beneficial effect of subjective alertness. These interactions need to be interpreted with caution, as it is possible that such interactions may be due to general effects of timing of session rather than a true interaction between timing and the effects of chewing gum (see Section 5.4).

For the repeated digits task, chewing gum lengthened reaction time in the fourth minute, but reduced false alarms in the last minute. These effects occurred in the later stages of the task, which is when reaction time generally began to lengthen and false alarms generally began to fall, regardless of gum condition. This would suggest that chewing gum was exaggerating the effects of vigilance performance over time, rather than reversing such effects (as was the case in Study 7). There was no difference between gum conditions in time-on-task trends for performance on the simple reaction time task.

Similar to the previous experiment, participants indicated positive attitudes towards the effects of gum at the start of the experiment, and the changes in attitudes between pre- and post-test were not statistically significant. An addition to future research could be to assess expectancy towards gum effects after each attention task; this would allow for a more direct evaluation of the hypothesis that a more positive attitude towards gum will lead to a belief that a positive effect of chewing gum will be apparent sooner.

9.6.2 Rate of chewing over time

The rate of chewing fell quickly following the initial mood ratings. This suggests that the chewing during the attention tasks may have been somewhat slower than in previous studies (such as those in the context-dependent memory literature) which required participants to chew for shorter periods such as two minutes. However, one possible reason why the rate of chewing fell significantly was that participants did not replace their chewing gum. Palatability rating of the gum fell, so it seems plausible that participants had less incentive to continue chewing. However, it is probably that the initial fall in the rate of chewing observed here occurred before many people would tend to replace their gum. The evidence to support this comes from Study 6, where many participants either did not replace their gum pellets or only replaced them once over the 25 minutes of chewing, and from Study 1, where most participants reported typically spending more than 5 minutes chewing a piece of gum. Given the possible connection between flavour and rate of chewing, it is also of interest whether rate of chewing will change over time for flavourless gum; if a reduction in rate of chewing is primarily due to a loss of flavour, then chewing may start off at a moderate pace and remain at the same speed when people chew flavourless gum.

The rate of chewing varied over the course of the simple reaction time task, but there was no time-on-task trend in gum effects on simple reaction time. Conversely, although the rate of chewing did not vary significantly over the course of the repeated digits task, time-on-task trends were evident between gum conditions. This suggests a clear dissociation between changes over time in performance and changes in the rate of chewing. Interactions between gum conditions and time-on-task could instead be related to properties of the tasks and changes in how chewing at a given rate affects performance at different times.

9.6.3 Rate of chewing, hardness of chewing, prior chewing, attention and alertness

Consistent with the hypothesis that harder chewing would lead to a greater enhancement of attention, harder chewing was associated with fewer long responses and faster encoding of new information in the categoric search task. Faster chewing was associated with lengthened simple reaction time; this is contrary to the hypothesis, although it is also consistent with the finding that the gum condition was associated with lengthened simple reaction time overall. A higher rate of chewing was also associated with lengthened focused attention reaction time. It may be the case that faster chewing led to more distraction from the attention task, although future research could address this more explicitly, perhaps with a measure of subjective distraction.

In contrast to the effect on simple and focused attention reaction time, neither rate of chewing nor prior chewing were associated with any other aspects of attention or mood. One might have speculated that the lack of a clear linear relationship between rate of chewing and changes in attention and mood might be due to interference stemming from an increase in both arousal and distraction. However, the fact that prior chewing (which would only lead to increased arousal) also showed a lack of an association with these outcomes suggests that such an explanation will not suffice, particularly given the evidence that chewing can lead to continued arousal after the act of chewing has ceased (as indicated by the EEG results in Study 7), albeit for a short period of time. The lack of a linear relationship between speed of chewing and most measured outcomes would suggest that there is not a linear relationship between the outcomes in question and the motor activity of chewing; this suggests that there is some other aspect of the gum condition that may alter attention and mood. The difference in results for simple reaction time tasks and the other attention tasks may be due to the other tasks' greater level of complexity. Replication of these findings with other tasks of varying difficulty may clarify this.

The high positive correlation between rate of chewing and self-rated hardness of chewing contrasts with the lack of a relationship between rate of chewing and chewing resistance (manipulated via the amount of gum chewed) observed by Rickman et al. Future research could assess hardness of chewing following each task; this would allow for the evaluation of whether hardness changes over time, if any such changes are related to changes in rate of chewing, and if they may have differing effects on attention over time.

Although participants did vary in their rate of chewing, this variation was not predictive of worse performance. It may be that measuring variability across block/minutes is too coarse a method of investigating variability in chewing. A better measure of dual-task interference may be to measure variability in rate of chewing across target stimuli and associated responses, and the extent to which chewing is synchronised with target stimuli onset where the timing of onset is predictable. Alternatively, participants could be required to time their chewing to the onset of stimuli; this could possibly reduce dual-task interference, as the movement of the jaw and fingers could be thought of as a single response.

9.6.4 Gum and task order

Similar to the findings of Onyper et al, task order did not moderate any effects of chewing gum on attention or mood. This null effect was observed even though task order did moderate trends in the rate of chewing. This suggests that chewing gum effects are related to the characteristics of the tasks themselves, rather than the order in which they have been presented previously and associated changes in the rate of chewing. The tasks in the current study were grouped based on whether the stimuli had predictable or unpredictable onsets; it is possible that different effects may be observed if testing uses other orderings of tasks not observed here, although this would run the risk of an underpowered study.

9.6.5 Effect of gum and habitual chewing

The findings of this study indicate that regular chewers had quickened categoric search reaction time, whereas the first experimental session of Study 5 indicated that non-chewers had slowed categoric search reaction time. Taken together, these effects suggest that greater habitual chewing is associated with a more positive effect of gum on this aspect of selective attention. Habitual gum consumption also had a moderating effect on hedonic tone, although given that the other moderating effects of habitual gum consumption have been inconsistent throughout the experimental studies of this thesis, such effects should be treated with caution.

9.6.6 Conclusions and critique

In summary, this study replicated the consistent finding that chewing gum enhances post-test alertness, and indicated effects on attention that were inconsistent with much the previous experimental findings from this thesis. The rate of chewing slowed noticeably after the first few minutes of testing, and slowed during the simple reaction time task. The rate and hardness of chewing were associated with different levels of performance change between a gum and a control condition, but only for simple reaction time and categoric search respectively. The other effects of gum seen here (increased alertness and hedonic tone, lengthened simple reaction time and shortened categoric search reaction time) were not exaggerated by hardness of chewing, chewing rate, amount of prior chewing or variability in chewing rate. Time-on-task effects were also observed for tasks during which rate of chewing did not vary, indicating that such effects are not due to within-task changes in rate of chewing. This study's key novel findings are thus that intensity of chewing and variability in speed of chewing are limited in their explanatory power for the effect of chewing gum on attention and mood, and that task order does not moderate effects of chewing gum.

An aspect of the procedure which could have been controlled better was time of day at which testing occurred. Some participants began testing in the morning whereas others began at 15.00. The circadian fall in cortisol levels may have moderated any effects of gum, and as Study 3 indicated that the effect of gum on cortisol is restricted to the morning, it is plausible that chewing gum may have had differing effects when testing occurred at different times.

A possible weakness with the questionnaires assessing attitudes, which were also used in Study 8, is that they were phrased in terms of the general effect of gum (e.g. "Do you think that chewing gum has an effect on mood?"); this may have led to participants differing in the extent to which they used their own experience during the experiment in rating these items. Future research could phrase such a question in terms of gum's effect for the participant during the experiment, which should encourage all participants to map the question onto current mood ratings and performance on experimental tasks.

The fact that participants knew they were being filmed probably meant that there was a higher rate of compliance than in previous studies where no filming occurred. In the latter type of study, some participants have chewed very little. Indeed, although participants were not filmed in the experimental studies of this thesis, the presence of the researcher in the room may have enhanced compliance compared to the intervention research described in Chapter 4. It is possible that the fall in rate of chewing observed here, rather than indicating the robustness of a fall in the rate of chewing, may instead indicate that filming participants leads them to chew quicker during the first task (pre-test mood), when they are more self-conscious of being filmed, before slowing down to a natural pace as they habituate to being observed in this manner. Covert filming could resolve this question; it is also of interest if attention effects would be more similar to previous studies under such conditions. Any future experimental research investigating the effects of chewing behaviour in depth should also measure suitable physiological measures, given the clear effect on heart rate observed during chewing in Study 7.

Chapter 10 General discussion

10.1 Summary and critique

10.1.1 Brief overview

The most robust effect observed in this thesis was the reduction of fatigue induced by cognitive tasks, as indicated in an attenuated fall between pre- and post-test alertness. Survey evidence indicated a reduction in anxiety once potential confounding factors were controlled for, although the experimental research overall did not indicate an anxiety-reducing effect. Anxiety was reduced by one intervention, whereas stress was reduced as a result of the other.

The intervention research also indicated a clear positive effect of gum on reported performance during the workday. Consistent with the alerting effect, there was some evidence that chewing gum enhanced speed of encoding for selective attention. Chewing gum was also associated with time-on-task trends in vigilance, but these varied according to how long gum was chewed for and how long performance had to be maintained prior to the vigilance task; a facilitating effect of gum over time was more likely to be seen following longer periods of performance (e.g. during ES2 of Study 5).

10.1.2 General consumption of chewing gum

Similar to earlier survey findings, a substantial proportion of survey respondents chewed gum. Survey respondents also expressed generally positive attitudes about the effects of gum. Some participants cited stress reduction and concentration as reasons why they chewed gum, with some participants giving both reasons.

The pre-test attitudes in the experiments that assessed attitudes towards effects of gum were generally positive, similar to the corresponding survey findings. The participants in the interventions and experiments reported a level of habitual gum consumption which was comparable to that of the respondents to the survey research. Around half of the survey respondents reported typically chewing gum for 5-30 minutes at a time, and experiments typically required participants to chew gum for a period of approximately 25 minutes per session. More participants reported chewing gum during the late morning and afternoon than in the early morning and in the evening/night. Correspondingly, the intervention research in studies 2 and 3 required participants to chew during the workday, and the experimental work in the subsequent chapters took place in the morning and afternoon (Study 5 ran somewhat later than other experiments for some participants, who started at 18.00). Mint flavours were both popular according to the survey findings and frequently chosen in the intervention and experimental research. Taking these facts together, the intervention and experimental research used chewing gum manipulations that were comparable to chewing gum consumption patterns in daily life.

10.1.3 Chewing gum and alertness

The experiments described have given robust evidence that alertness falls during attention tasks, and have supported previous findings that chewing gum can increase alertness pre- and post-test (e.g. Smith, 2010) and prevent alertness from falling to the same extent it does in a control condition (e.g. Johnson et al., 2011). However, after chewing ceases the persistence of the effect is limited: in Study 5, when gum was chewed for the first session but not the second, the alerting effect of gum was restricted to the first session only.

Chewing when one is not engaged in a cognitively demanding task also had an effect on alertness, although the effect was somewhat smaller than when attention tasks were performed. It is possible that gum may be chewed in a different way when one is performing attention tasks compared to when one is sitting quietly, but the vigour of chewing is unlikely to explain differences in alertness, given the lack of a moderating effect of rate of chewing in Study 9. The fact that chewing gum can enhance alertness under conditions of attention suggests it could be a useful method of sustaining alertness in occupational conditions (e.g. security work at night). Table 10-1 summarises the effects of chewing gum on reported alertness. For ease of comparison between studies, gum and no-gum conditions are represented separately, regardless of whether gum was manipulated between or within participants.

Table 10-1: Chewing gum and alertness[70]

		Gum	No gum	Effect size[71]
Study 4	Pre-test	235.9 (50.8)	224.8 (57.6)	0.2 (54.2)
	Post-test*	214.4 (48)	203.3 (47.4)	0.23 (47.7)
Study 5 (ES1)	Pre-test	223.4 (50.9)	204.8 (59.6)	0.34 (55.5)
	Post-test*	209.4 (50.9)	177.6 (60.9)	0.57 (56.2)
Study 5 (ES2)	Pre-test**	225.8 (54.1)	192.6 (55.8)	0.6 (55.5)
	Post-test†	214.6 (46.4)	168.4 (55.1)	0.91 (50.8)
Study 6[72]	Initial[73]	260.1 (55.9)	239.6 (52.4)	0.37 (55.1)
	Final	232.4 (52)	211.9 (46.3)	0.4 (50.7)
Study 7	Pre-test	253.7 (49.8)	281.8 (60.4)	-0.55 (55.6)
	Post-test	209.3 (46.4)	200.1 (24.5)	0.25 (36.6)
Study 8	Pre-test*	226.4 (39.1)	213.2 (44.7)	0.32 (41.9)
	Post-test†	206.3 (41.4)	186.7 (35.3)	0.51 (38.4)
Study 9	Pre-test	242.9 (50.8)	237.5 (54.9)	0.1 (52.9)
	Post-test†	221.3(52.6)	197.8 (57.1)	0.43 (54.9)

10.1.4 Effects of chewing gum on attention and performance

Chewing gum improved speed of encoding for selective attention. The removal of fatigue by chewing gum may account for an enhancement of speed of encoding. However, speed of encoding was not enhanced during the last study; it is possible that being filmed while chewing may alter the effects of chewing gum on attention. Further support for this idea is indicated by the fact that chewing lengthened simple reaction time for Study 9, although this was not the case for the other experiments.

Chewing gum effects on vigilance differ over time. Study 5 showed a shortening of reaction time, but only in the second experimental session. Study 4, which involved two experimental sessions but no baseline testing session beforehand, did not indicate such an effect. This suggests that such time-on-task effects are only apparent when fatigued. Although it did not indicate within-task trends, chewing gum during Study 7

[70] Mean reported alertness scores. Standard deviations in brackets. * indicates $p < .05$, ** indicates $p = .001$, † indicates $p < .001$

[71] Effect size is based on the difference between the gum and no-gum condition divided by the pooled standard deviation (in cases where gum was manipulated between participants. Pooled standard deviation given in brackets)

[72] The gum condition includes all gum conditions

[73] Described as “initial” and “final” mood as there were no tests of attention

led to a clear pattern of results associated with increased arousal, with reaction time shortened and both correct hits and false alarms increased. This effect was strong during chewing, but began to fade away over subsequent vigilance tests, similar to the transient alerting effect shown over multiple testing sessions in Study 5. Although Study 7 did not involve completing batteries of attention tasks before completing the vigilance task, participants were required to remain still for about twenty minutes while having electrodes attached before beginning the vigilance tasks, so participants may have already been somewhat tired when they began to perform the vigilance tasks, similar to Study 5. The last two experiments indicated different effects of gum towards the end of a repeated digits task. Correct hits were reduced by gum towards the end of the task in Study 8. In Study 9, gum lengthened reaction time towards the end of the task. Given participants had not been performing for as long as in studies 5 and 7 while completing these tasks, it is possible that a distracting effect was still stronger than a reduction in fatigue, as suggested by L. Tucha and Simpson (2011). Indeed, comparing no-gum conditions across studies, post-test alertness (which was rated immediately after the vigilance task) for the experimental session 2 of Study 5 (Mean = 168.4, SEM = 6.9) was lower than for Study 8 (M = 186.7, SEM = 4.1) or Study 9 (M = 198.8, SEM =10, for those participants who completed the vigilance task last). Given that alertness was lower in Study 5, an alerting effect would have a greater potential for improving vigilance.

Both intervention studies in Chapter 4 revealed a positive effect of gum on reported performance, in terms of experiencing fewer cognitive problems and being less behind with work. The consistency of this finding in interventions may be partly due to gum being chewed over a long period of time. This would be consistent with a greater attention-enhancing effect of chewing gum over longer periods of time in experimental research.

The effects of chewing gum on selective attention, simple reaction time and vigilance are summarised in Tables 10-2 to 10-5.

Table 10-2: Chewing gum and categoric search[74]

		Gum	No gum	Effect size
Speed of encoding	Study 4	19.8 (23.7)	20.8 (25.5)	-0.04 (24.6)
	Study 5 (ES1)*	6.2 (27.2)	16.3 (28)	-0.37 (27.6)
	Study 5 (ES2)	13.8 (28.8)	14.8 (27.9)	-0.04 (28.4)
	Study 8	20.2 (23)	18.2 (23.8)	0.09 (23.4)
	Study 9†	17.7 (20.4)	4.8 (19)	0.65 (19.7)
Spatial uncertainty	Study 4	98.6 (29.8)	95.6 (27.5)	0.1 (28.7)
	Study 5 (ES1)	101.9 (36.1)	95.8 (37.7)	0.17 (36.9)
	Study 5 (ES2)	90.2 (25.2)	83.4 (37.2)	0.21 (31.7)
	Study 8	111.1 (30.3)	108 (36.1)	0.09 (33.2)
	Study 9	105.9 (36.1)	116.3 (39.9)	-0.27 (38)
Response organisation	Study 4*	26.3 (14)	33.4 (18.1)	-0.44 (16.1)
	Study 5 (ES1)	26.7 (17.4)	29.5 (19.2)	-0.15 (18.3)
	Study 5 (ES2)	30.2 (18)	29.6 (18.1)	0.03 (18)
	Study 8†	25.9 (17)	35.3 (21.3)	- 0.49 (19.2)
	Study 9	27.5 (19)	26.9 (19)	0.03 (19)
Place repetition	Study 4	18.1 (21)	18.1 (19.9)	0 (20.5)
	Study 5 (ES1)	19 (18.5)	18.1 (21.4)	0.05 (19.9)
	Study 5 (ES2)	11.8 (22.6)	12.3 (23.4)	-0.02 (23)
	Study 8	15.2 (15.3)	15.1 (18.3)	0.01 (16.8)
	Study 9	15.6 (19.1)	14 (21.8)	0.08 (20.5)
Errors	Study 4	28.1 (13.8)	29.1 (14.5)	-0.07 (14.2)
	Study 5 (ES1)*	14.2 (10.1)	18.4 (14)	-0.35 (12.1)
	Study 5 (ES2)	17 (12)	25.1 (32.5)	-0.33 (24.5)
	Study 8	23 (13.2)	23.9 (12.9)	-0.07 (13.1)
	Study 9	11.2 (5.9)	11.8 (6.9)	-0.09 (6.4)
Long responses	Study 4*	2.2 (3.1)	2.9 (3.6)	-0.21 (3.4)
	Study 5 (ES1)	4.5 (10.1)	5.7 (8.2)	-0.13 (9.2)
	Study 5 (ES2)	3.9 (4.6)	5.9 (10.3)	-0.25 (8)
	Study 8	3.6 (4.3)	4 (4.4)	-0.09 (4.4)

[74] Standard deviations in brackets (pooled standard deviation for effect size). * indicates $p < .05$, ** indicates $p = .001$, † indicates $p < .001$

	Study 9	1.7 (2.2)	1.9 (2.7)	0.08 (2.5)
Reaction time	Study 4	487.2 (45.5)	487.7 (50)	-0.01 (47.8)
	Study 5 (ES1)	503.6 (52.1)	502.1 (46.4)	0.03 (49.4)
	Study 5 (ES2)	493.8 (45.8)	490.7 (50.1)	0.06 (48)
	Study 8	499.9 (42.3)	500 (46.3)	0 (44.3)
	Study 9	536.3 (48.8)	544 (47.5)	-0.16 (48.2)

Table 10-3: Chewing gum and focussed attention[75]

		Gum	No gum	Effect size
Speed of encoding	Study 4	25.6 (21.6)	28.9 (19.8)	-0.16 (20.7)
	Study 5 (ES1)	15.5 (27.9)	22.9 (27.1)	-0.27 (27.5)
	Study 5 (ES2)	21.6 (32)	22.1 (26.8)	-0.02 (29.6)
	Study 8*	20 (21.3)	25.8 (23.8)	-0.26 (22.6)
	Study 9	25.5 (20.7)	24.4 (19.5)	0.05 (20.1)
Breadth of attention	Study 4	21.7 (34.7)	24.1 (30.1)	-0.07 (32.4)
	Study 5 (ES1)	14.1 (31.5)	15.7 (28.8)	-0.05 (30.2)
	Study 5 (ES2)†	19 (29.9)	-0.9 (29.5)	0.67 (29.7)
	Study 8*	8.1 (26.7)	16.9 (35.4)	-0.28 (31.1)
	Study 9	19 (35.3)	25.8 (40.4)	-0.18 (37.9)
Errors	Study 4	23.5 (9)	25.5 (12.6)	-0.19 (10.8)
	Study 5 (ES1)	14.7 (13.7)	16.7 (11)	-0.16 (12.4)
	Study 5 (ES2)	17.6 (13.3)	22.1 (16.6)	-0.3 (15)
	Study 8	20.4 (12)	20.2 (13.8)	0.02 (12.9)
	Study 9	10.2 (8.4)	10.1 (7.8)	0.01 (8.1)
Long responses	Study 4	0.6 (1.5)	0.7 (1.4)	-0.07 (1.5)
	Study 5 (ES1)	1.1 (2.5)	2 (4.3)	-0.25 (3.6)
	Study 5 (ES2)	0.9 (1.7)	1.5 (2.4)	-0.42 (1.43)
	Study 8	0.5 (0.9)	0.5 (0.9)	0 (0.9)
	Study 9	0.3 (0.6)	0.4 (1.6)	0.09 (1.1)
Reaction time	Study 4	384.2 (35.4)	386.7 (43.5)	-0.06 (39.5)
	Study 5 (ES1)	403.9 (39.7)	401.2 (43.2)	0.07 (41.5)
	Study 5 (ES2)	404.3 (40.5)	388.1 (36.3)	0.42 (38.5)
	Study 8	395.1 (38.7)	396.8 (34.9)	-0.05 (36.8)
	Study 9	397.2 (40)	397 (38.8)	0.01 (39.4)

[75] Standard deviations in brackets (pooled standard deviation for effect size). * indicates $p < .05$, ** indicates $p = .001$, † indicates $p < .001$

Table 10-4: Chewing gum and simple reaction time[76]

	Gum	No gum	Effect size
Study 4	344.5 (52.5)	353.4 (61.4)	-0.16 (57.1)
Study 5 (ES1)	366.8 (61.8)	378.8 (61.9)	-0.19 (61.8)
Study 5 (ES2)	385.3 (70)	385.6 (64.4)	0 (67.3)
Study 8	351.5 (46.5)	358.6 (50.9)	-0.15 (48.7)
Study 9	334.6 (46.6)	329.3 (52.2)	0.11 (49.4)

[76] Standard deviations in brackets (pooled standard deviation for effect size)

Table 10-5: Chewing gum and repeated digits vigilance[77]

		Gum	No gum	Effect size
Reaction time	Study 4	678.4 (89.1)	682.1 (82.3)	-0.04 (85.7)
	Study 5 (ES1)	689.2 (87.1)	694.7 (81.5)	-0.07 (84.3)
	Study 5 (ES2)	701.8 (81.7)	706.8 (75.3)	-0.06 (78.5)
	Study 7[78]	750.9 (84.4)	779.9 (76.4)	-0.36 (80.3)
	Study 8	701.9 (85.2)	695.9 (81.1)	0.07 (83.2)
	Study 9	709 (77.6)	702.7 (89.1)	0.08 (83.4)
Correct hits	Study 4	28.1 (7.4)	27.9 (6.3)	0.03 (6.9)
	Study 5 (ES1)	28.6 (7.4)	26.3 (7)	0.32 (7.2)
	Study 5 (ES2)	26.4 (6.9)	27.8 (6.8)	-0.2 (6.9)
	Study 7	28.6 (5.7)	26.8 (6.3)	0.3 (6)
	Study 8	28 (6.2)	29.1 (6.1)	-0.18 (6.2)
	Study 9	30.3 (4.7)	29.8 (5.4)	0.1 (5.1)
False alarms	Study 4	20 (9.2)	20.3 (12.3)	-0.03 (10.9)
	Study 5 (ES1)	16.6 (7.2)	19.1 (10.7)	-0.27 (9.2)
	Study 5 (ES2)	16.9 (7)	19.3 (10.6)	-0.27 (8.8)
	Study 7	18.6 (6.8)	17.7 (6)	0.14 (6.4)
	Study 8	20.7 (10)	20.5 (10.2)	0.02 (10.1)
	Study 9	19.2 (6.3)	21.1 (13.3)	-0.19 (9.8)

10.1.5 Chewing gum, mood, stress and anxiety

The first intervention (Study 2) indicated an effect on stress but not anxiety, whereas the converse was true for the second intervention (Study 3). The effects of chewing over a single workday observed here were thus not as strong or consistent as those indicated by a two week intervention (Smith et al., 2012). Gum chewing was associated neither with stress nor with anxiety for students in Study 1a, although chewing gum was associated with lower anxiety for the survey of workers in Study 1b. The observed effect in Study 1b is likely to be more reliable, as a greater number of covariates were controlled for. It may thus be the case that gum has an effect on anxiety over the course of a single day.

[77] Standard deviations in brackets (pooled standard deviation for effect size)
[78] Effect of current chewing

However, anxiety was generally not significantly affected during the experimental studies. Unlike some cognitive performance tasks in previous research (e.g. Scholey et al., 2009), the attention tasks used in this thesis were not designed to be anxiety-inducing, so it is quite possible that anxiety was not affected for these tasks as it was at floor level. See Table 10-6 for a summary of the findings on stress and anxiety.

Table 10-6: Chewing gum, stress and anxiety[79]

		Gum	No gum	Effect size
Study 2[80]	Baseline	5.1 (2.7)	4.6 (2.3)	0.2 (2.5)
	Testing day	3 (2.4)	2.6 (2.3)	0.17 (2.4)
Study 3	Testing days	1.7 (1.7)	2.2 (2)	- 0.26 (1.9)
Study 4[81]	Pre-test	86.1 (17)	85.4 (14.5)	0.04 (15.8)
	Post-test	86.1 (15.2)	85.8 (17.3)	0.02 (16.3)
Study 5 (ES1)	Pre-test	86 (16.1)	83.1 (18.2)	0.17 (17.2)
	Post-test	84.6 (16.3)	86.6 (18.3)	-0.12 (17.4)
Study 5 (ES2)	Pre-test	85.1 (17.4)	84.2 (16.9)	0.05 (17.1)
	Post-test	85.9 (16.3)	83.9 (17.5)	0.12 (16.9)
Study 6	Initial	94.7 (19.3)	98 (19.3)	-0.17 (19.3)
	Final	99 (20.9)	102.1 (20.8)	-0.15 (20.9)
Study 7	Initial	97.7 (19.3)	100.2 (20.6)	-0.12 (20)
	Post-test	101 (24)	93.2 (22.8)	0.33 (23.3)
Study 8	Pre-test	87.4 (14.8)	87.1 (15.6)	0.02 (15.2)
	Post-test	87.2 (23.2)	86.1 (16.9)	0.05 (20.1)
Study 9	Pre-test	89.7 (16.8)	92.7 (19.2)	0.17 (18)
	Post-test	90.4 (18)	91.3 (19.6)	0.05 (18.8)

10.1.6 Mechanisms for chewing gum effects

Chewing gum was clearly associated with short-term changes in psychophysiology. A substantial increase in heart rate by gum was observed during vigilance performance under experimental conditions. Beta activity was also enhanced by chewing gum base, and unlike heart rate this effect persisted after chewing had ceased. This suggests that physiological arousal can account for chewing gum effects on vigilance such as shortened reaction time, with arousal in the central nervous system accounting for any effects that persist following chewing. The fact that gum base demonstrated these effects suggests that the arousing effect is attributable to the act of chewing itself, rather than being dependent on mint flavour, which actually seemed to have a relaxing effect in Study 6. It is likely that the short-term effects of

[79] Standard deviations in brackets (pooled standard deviation for effect size)
[80] Anxiety scores from Studies 2 and 3 taken from HAD scores derived using principal components analysis
[81] Anxiety scores from Studies 4 to 9 taken from visual analogue scales

chewing are thus due to the motor activity of chewing during otherwise sedentary activity. The fact that heart rate began to decline following the chewing session in Study 7 seems consistent with a subsequent reduction in the stress response. However, the lack of a clear association between physiological and psychological data in Study 7 indicates that further research on this topic is warranted.

There was less clear evidence for psychophysiological effects of gum during intervention research. Despite previous findings that a chewing gum intervention can reduce reported stress, there was no substantial reduction in cortisol during a chewing gum intervention. In fact, cortisol was heightened at 10am. This is similar to a short-term increase in cortisol observed by Smith (2010), and is consistent with the alerting effect of gum, although fatigue was not reduced in the intervention studies. A reduction in cortisol may be observable over longer intervention studies, such as the two-week method used by Smith et al. Unlike the clear short-term effect observed under experimental conditions in Study 7, heart rate was not affected by gum during the intervention study.

Given that arousal during gum chewing was associated with faster vigilance performance, and that this was observed for gum base rather than flavoured gum, one might conclude that it is the motor activity of chewing that leads to its effects on attention. However, a faster rate of chewing did not seem to lead to differences in attention task performance in Study 9, even though rate of chewing was also highly correlated with reported hardness of chewing. It may be that chewing has a general effect of removing fatigue (e.g. by maintaining a minimal amount of movement of facial muscles, or perhaps some internal mechanism for avoiding choking when there is something in the mouth) which does not follow a pattern of linear enhancement when a greater amount of chewing takes place. Changes in the rate of salivation may also moderate effects on attention and fatigue, perhaps through effects on thirst (Stephens & Edelstyn, 2011) or through physiological preparation for feeding.

Demand characteristics moderated reported alertness in Study 8. Given the strong main effect of gum on certain aspects of alertness (see Section 8.4.3), combined with the clear effect of chewing gum on heart rate in Study 7, it seems that demand characteristics exaggerate an actual effect of gum on experienced arousal and performance, rather than creating an experimental artefact. Neither attention nor time-on-task trends in attention were moderated by demand characteristics, suggesting that demand characteristics are not a plausible mechanism for the inconsistent findings concerning chewing gum and attention. Pre-test attitudes had limited effects on attention and mood. One would expect demand characteristics to have more of an effect on reported mood than pre-test attitudes, as attitudes may refer to thoughts about how chewing gum affects attention and mood in a general sense, whereas demand characteristics may prompt participants to confirm the experimenter's hypotheses. This prompt could motivate them to work harder at a task, or to report that they have been affected during the experiment.

10.2 Future research

Unanswered questions remain concerning the effects of chewing gum on psychophysiology. Although cortisol increased during the morning of the one-day intervention, it may be the case that cortisol levels are reduced by chewing gum during longer interventions, consistent with the clearer findings on stress from past intervention research. Additionally, alternative psychophysiological measures might provide further insight into the effects of gum chewing. Heart rate variability could be a more useful marker of the stress response than overall heart rate. EEG measures could investigate the effects of chewing gum on alpha and beta power in the right hemisphere. The right hemisphere has been shown to be more active during relatively easy vigilance processing, although for more difficult vigilance tasks activation is bilateral (Helton et al., 2010); as maintaining vigilance becomes increasingly difficult over time, the left hemisphere may be recruited to a greater extent later in a vigilance task, and chewing gum may moderate this process. The study of neurotransmitters may also shed further light on the brain's response to chewing gum, and how this might in turn affect cognitive performance and mood.

Although the effect of gum on physiology is likely due to the movement associated with chewing, this was not examined directly in this thesis. If such a mechanism explains physiological effects, then the effect of gum should be dependent upon the extent to which people are otherwise physically inactive. Neuroimaging studies have required participants to remain still, although this is not necessarily the case for research not employing such imaging methods. Participants in Study 7 had to remain as still as possible in order to avoid movement artefacts, but participants in the other studies in this thesis were able to move about in their seats. Unfortunately, as physiology was not assessed in the experimental studies allowing movement it is not possible to directly compare physiological effects of gum between experimental studies. Future research could address this gap. Although the requirement to remain still may sacrifice some ecological validity, it could give a definitive answer to whether gum chewing as a motor activity can be responsible for psychophysiological effects. Intervention research could also take total exercise and movement into account; it may be that the removal of fatigue by gum is greater for those workers with more sedentary jobs.

Applications of the consistent finding that chewing gum can enhance alertness over time are numerous, and given the clear reporting of better work performance in the intervention research, research in more applied settings could perhaps provide greater insight into how chewing gum may affect tasks requiring attention to be sustained over time. In Chapter 3's survey, "while driving" was one reason offered for chewing gum under the "other" option. It would be of interest to see if chewing gum can enhance and sustain driver performance, particularly where the driver is already fatigued or sleepy. Smith (2010) has suggested that simulations of activities such as driving could be used in this context.

Individual differences in personality factors may moderate some effects of chewing gum on mood and attention. In the memory literature, Stephens and Edelstyn (2011) found that chewing gum improved spatial span for introverts; they suggested this could be due to introverts finding the testing more stressful, with gum reducing the stress that could impair performance. On the other hand, the survey by Smith (2009a) indicated that extroverts were more likely to chew gum. Study 1b did not find that those with higher habitual gum consumption differed in terms of extraversion, although they had lower emotional stability and conscientiousness. Personality factors may thus play a different role in chewing consumption and its effects over different time courses. Future research on acute effects of gum on introverts versus extroverts would have to take account of how different tasks may be perceived. For example, the Trier social stress test (used by Sketchley-Kaye et al., 2011) should be associated with greater differences between extroverts and introverts than attention tasks like the ones used in this thesis's experimental studies, given that the TSST contains a greater element of social evaluation.

Given the moderating effect of demand characteristics on alertness, future research investigating the effects of gum on mood could better control for demand characteristics. A method for blinding participants based on research on caffeine by Silverman, Evans, Strain and Griffiths (1992) may be possible. The procedure would require participants to be told that they are taking part in an experiment that is investigating the effects of different food additives, and that chewing gum is the method of delivery of this additive. As participants are led to believe that they may be in either an experimental group or a placebo group, they no longer have an incentive to perform better or report improved mood in the chewing gum condition. Such a method could also be useful for other aspects of nutritional research where blinding is difficult. Notwithstanding further ethical issues around deception, if the researcher(s) working with participants believe that a variable of interest is an additive in chewing gum, it would also be possible to do a double-blind version of this method. Although participants in Study 8 were asked if they thought any other hypotheses were being examined, future research should also probe participants in greater depth for the extent to which they think they know the research hypothesis, perhaps using a scale such as the Perceived Awareness of the Research Hypothesis (Rubin, Paolini, & Crisp, 2010).

In addition to better control for demand characteristics, future research could screen participants more explicitly for any medical conditions or psychiatric problems, particularly in research assessing effects on stress. Time of awakening and chronotype should also be measured, especially in studies examining cortisol, where diurnal trends need to be borne in mind. As there is some evidence that different flavours may be associated with different brain activity (Morinushi et al., 2000), it would be useful to control for flavour. Given the evidence base for chewing gum has mostly focused on mint, it would be worthwhile using this flavour in investigating mechanisms in greater depth, although given the fact that people may differ in how acceptable they find different flavours (Scholey et al., 2009), different strengths of mint should be available, and people who dislike mint can be excluded from participation.

Although the possible moderating effect of gender was examined in the studies 1 and 2, the remainder of the research in this thesis did not, as only a minority of the participants in the remaining studies were male. Although previous research has, for example, indicated equivalent cortisol reactivity in males and females (Gray et al. 2012), future experimental research could include comparable numbers of males and females to examine possible moderating effects of gender on chewing gum effects and the mechanisms which may drive them. Where such differences exist, they may have dampened the effect of any research employing samples of males and females.

10.3 Conclusions

In summary, the research described in this thesis has demonstrated that chewing gum can have an alerting effect, including when it is chewed without concurrent performance tasks. This effect is clearest when alertness has already fallen, and as such may best be described as a removal of tiredness rather than a stimulant effect. This removal of tiredness may help to account for the fact that chewing gum consistently enhanced reported work performance in the intervention research. Chewing gum was associated with an attenuation of the lengthening of reaction time and increase in detection-response threshold for vigilance, but this effect was more reliable when participants were fatigued, similar to the alerting effect. In contrast to the robust alerting effect, the evidence for an effect of chewing gum on stress and anxiety was more equivocal.

Physiological effects of gum include a strong rise in heart rate while chewing and an increase in beta power in brain activity; these trends could help to explain alerting and vigilance effects. Cortisol increased during the morning for participants who chewed; this is also consistent with an alerting effect. Demand characteristics can moderate the effect of gum on alertness, but they are not a plausible mechanism for effects on attention. Rate of chewing does not account for mood or attention effects. Of the mechanisms examined, it thus seems that the physiological effects of chewing may explain psychological effects. Future research may probe these mechanisms in greater depth, as well as examining applications of chewing gum effects.

References

Ader, R. (1980). Psychosomatic and psychoimmunologic research. *Psychosomatic Medicine*, *42*(3), 307-321.

Ahlberg, J., Rantala, M., Savolainen, A., Suvinen, T., Nissinen, M., Sarna, S., et al. (2002). Reported bruxism and stress experience. *Community Dentistry and Oral Epidemiology, 30*(6), 405-408.

Allen, K. L., Galvis, D., & Katz, R. V. (2006). Evaluation of CDs and chewing gum in teaching dental anatomy. *New York State Dental Journal*, *72*(4), 30-33.

Allen, K. L., Norman, R. G., & Katz, R. V. (2008). The effect of chewing gum on learning as measured by test performance. *Nutrition Bulletin, 33*(2), 102-107.

Baker, J. R., Bezance, J. B., Zellaby, E., & Aggleton, J. P. (2004). Chewing gum can produce context-dependent effects upon memory. *Appetite, 43*(2), 207-210.

Berka, C., Levendowski, D. J., Lumicao, M. N., Yau, A., Davis, G., Zivkovic, V., et al. (2007). EEG correlates of task engagent and mental workload in vigilance, learning, and memory tasks. *Aviation, Space, and Environmental Medicine, 78*, B231-B244.

Brice, C. F., & Smith, A. (2002). Factors associated with caffeine consumption. *International Journal of Food Sciences and Nutrition, 53*(1), 55-64.

Britt, D. M., Cohen, L. M., Collins, F. L., & Cohen, M. L. (2001). Cigarette smoking and chewing gum: Response to a laboratory-induced stressor. *Health Psychology*, *20*(5), 361-368.

Britt, D. M., Collins, F. L., & Cohen, L. M. (1999). Cigarette smoking and chewing-gum use among college students. *Journal of Applied Biobehavioral Research, 4*(2), 85-90.

Broadbent, D. E., Broadbent, M. H. P., & Jones, J. L. (1986). Performance correlates of self-reported cognitive failure and obsessionality. *British Journal of Clinical Psychology, 25*(4), 285-299.

Broadbent, D. E., Broadbent, M. H. P., & Jones, J. L. (1989). Time of day as an instrument for the analysis of attention. *European Journal of Cognitive Psychology*, *1*, 69-94.

Buchner, A., Erdfelder, E., & Faul, F. (1997). How to use G*Power, from http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/how_to_use_gpower.html. (Retrieved 15th November 2012).

Buehner, M. J., & Humphreys, G. R. (2009). Causal binding of actions to their effects. *Psychological Science, 20*(10), 1221-1228.

Choi, B., Schnall, P. L., Yang, H., Dobson, M., Landsbergis, P., Israel, L., et al. (2010). Sedentary work, low physical job demand, and obesity in US workers. *American Journal of Industrial Medicine, 53*(11), 1088-1101.

Clow, A. (2001). The physiology of stress. In F. Jones & J. Bright (eds.) *Stress: Myth, theory and research* (pp. 47-61). Essex, UK: Pearson.

Cosco, T. D., Doyle, F., Ward, M., & McGee, H. (2012). Latent structure of the Hospital Anxiety And Depression Scale: A 10-year systematic review. *Journal of Psychosomatic Research, 72*(3), 180-184.

Deshpande, A., & Jadad, A. R. (2008). The impact of polyol-containing chewing gums on dental caries: A systematic review of original randomized controlled trials and observational studies. *Journal of the American Dental Association, 139*(12), 1602-1614.

Dickerson, S. S. & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*(3), 355-391.
Ehlert, J., & Campbell, U. (2012). Acute psychosocial stress: Does the emotional stress correspond with the physiological responses? *Psychoneuroendocrinology*, *37*(8), 1111-1134.
Ekuni, D., Tomofuji, T., Takeuchi, N., & Morita, M. (2012). Gum chewing modulates heart rate variability under noise stress. *Acta Orthodontologica Scandinavica*, *70*(6), 491-496.
Farella, M., Bakke, M., Michelotti, A., Marotta, G., & Martina, R. (1999). Cardiovascular responses in humans to experimental chewing of gums of different consistencies. *Archives of Oral Biology*, *44*(10), 835-842.
Faro, D. (2010). Changing the future by reshaping the past: The influence of causal belief on estimates of time to onset. *Journal of Consumer Research, 37*(2), 279-291.
Field, A. (2009). *Discovering statistics using SPSS (Third edition)*. London: Sage.
Fisher, S. (1986). *Stress & strategy*. London: Lawrence Erlbaum.
Fries, E., Dettenborn, E., & Kirschbaum, C. (2009). The cortisol awakening response: Facts and future directions. *International Journal of Psychophysiology, 72*(1), 67-73.
Gerber, M., Kellmann, M., Hartmann, T., & Pühse, U. (2010). Do exercise and fitness buffer against stress among Swiss police and emergency response service officers? *Psychology of Sport and Exercise, 11*(4), 286-294.
Gómez, F. M., Giralt, M. T., Sainz, B., Arrúe, A., Prieto, M., & García-Vallejo, P. (1999). A possible attenuation of stress-induced increases in striatal dopamine metabolism by the expression of non-functional masticatory activity in the rat. *European Journal of Oral Sciences, 107*(6), 461-467.
Gray, G., Miles, C., Wilson, N., Jenks, R., Cox, M., & Johnson, A. J. (2012). The contrasting physiological and subjective effects of chewing gum on social stress. *Appetite, 58*(2), 554-558.
Gruen, R. J. (1993). Stress and depression: Towards the development of integrative models. In L. Goldberger and S. Breznitz (Eds.), *Handbook of stress: Theoretical and clinical aspects* (pp. 550-569). New York: The Free Press.
Heilman, K. M. (1995). Attentional asymmetries. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 217-234). Cambridge, MA: MIT Press.
Hellhammer, D. H., Kirschbaum, C., & Belkien, L. (1987). Measurement of salivary cortisol under psychological stimulation. In J. Hingtgen, D. H. Hellhammer, G. Huppmann (Eds.), *Advanced methods in psychobiology* (pp. 281-289). Toronto, Canada: C. J. Hogrefe, Inc.
Helton, W. S., Dember, W. N., Warm, J. S., & Matthews, G. (1999). Optimism, pessimism, and false failure feedback: Effects on vigilance performance. *Current Psychology, 18*(4), 311-325.
Helton, W. S., Hollander, T. D., Warm, J. S., Tripp, L. D., Parsons, K., Matthews, G., et al. (2007). The abbreviated vigilance task and cerebral hemodynamics. *Journal of Clinical and Experimental Neuropsychology, 29*(5), 545-552.
Helton, W. S., Warm, J. S., Tripp, L. D., Matthews, G., Parasuraman, R., & Hancock, P. A. (2010). Cerebral lateralisation of vigilance: A function of task difficulty. *Neuropsychologia, 48*(6), 1683-1688.
Hewlett, P., & Smith, A. P. (2007). Effect of repeated doses of caffeine on performance and alertness: New data and secondary analyses. *Human Psychopharmacology: Clinical and Experimental, 22*(6), 339-350.

Hillyard, S. A. (1999). Electrophysiology, electric and magnetic evoked fields. In R. A. Wilson & F. C. Keil (Eds.), *MIT encyclopedia of the cognitive sciences* (pp. 262-264). Cambridge, MA: MIT press.

Hirano, Y., Obata, T., Kashikura, K., Nonaka, H., Tachibana, A., Ikehira, H., et al. (2008). Effects of chewing in working memory processing. *Neuroscience Letters, 436*(2), 189-192.

Hodoba, D. (1999). Chewing can relieve sleepiness in a night of sleep deprivation. *Sleep Research Online, 2*(4), 101-105.

Hollingworth, H. L. (1939). Chewing as a technique of relaxation. *Science, 90*, 385-387.

HSE (2012).Stress-related and psychological disorders in Great Britain. Retrieved from http://www.hse.gov.uk/statistics/causdis/stress/index.htm, 13/4/2013.

Huppert, F. A. (2009). A new approach to reducing disorder and improving well-being. *Perspectives on Psychological Science, 4*(1), 108-111.

Johnson, A. J., Jenks, R., Miles, C., Albert, M., & Cox, M. (2011). Chewing gum moderates multi-task induced shifts in stress, mood, and alertness. A re-examination. *Appetite, 56*(2), 408-411.

Johnson, A. J., & Miles, C. (2008). Chewing gum and context dependent memory: The independent roles of chewing gum and mint flavour. *British Journal of Psychology, 99*(2), 293-306.

Johnson, A. J., Miles, C., Haddrell, B., Harrison, E., Osborne, L., Wilson, N., et al. (2012). The effect of chewing gum on physiological and self-rated measures of alertness and daytime sleepiness. *Physiology & Behavior, 105*(3), 815-820.

Johnson, A. J., Muneem, M., & Miles, C. (2012). Chewing gum benefits sustained attention in the absense of task degradation. *Nutritional Neuroscience*. DOI: 10.1179/1476830512Y.0000000041.

Johnston, C. A., Tyler, C., Stansberry, S. A., Moreno, J. P., & Foreyt, J. P. (2012). Brief report: Gum chewing affects standardized math scores in adolescents. *Journal of Adolescence, 35*(2), 455-459.

Kamiya, K., Fumoto, M., Kikuchi, H., Sekiyama, T., Umino, M., & Arita, H. (2009). Gum chewing evokes activation of ventral prefrontal cortex and suppression of nocioceptive responses: Involvement of brain serotonergic system. *European Journal of Pain, 13*(Supplement 1), S262-S263.

Kirschbaum, C. K., Pirke, K. M., Hellhammer, D. H. (1993). The Trier Social Stress Test: A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*, 76-81.

Kleber, E. W., Kleber, G., & Hans, O. (1999). *Differentieller Leistungstest-KG (DL-KG)*. Göttingen, Germany: Hogrefe.

Kozlov, M. D., Hughes, R. W., & Jones, D. M. (2012). Gummed-up memory: Chewing gum impairs short-term recall. *The Quarterly Journal of Experimental Psychology*, 65(3), 501-513.

Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science, 197*(4305), 792-795.

Labbe, D., Gilbert, F., Antille, N., & Martin, N. (2009). Sensory determinants of refreshing. *Food Quality and Preference, 20*(2), 100-109.

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and Cognition, 65*(3), 209-237.

Masumoto, Y., Morinushi, T., Kawasaki, H., Ogura, T., & Takigawa, M. (1999). Effects of three principal constituents in chewing gum on

electroencephalographic activity. *Psychiatry and Clinical Neurosciences, 53*(1), 17-23.
Masumoto, Y., Morinushi, T., Kawasaki, H., & Takigawa, M. (1998). Spectral analysis of changes in electroencephalographic activity after the chewing of gum. *Psychiatry and Clinical Neurosciences, 52*(6), 587-592.
Matthews, G., Warm, J. S., Reinerman, L. E., Langheim, L. K., & Saxby, D. J. (2010). Task engagement, attention, and executive control. In A. Gruszka, G. Matthews & B. Szymura (Eds.), *Handbook of individual differences in cognition: Attention, memory and executive control* (pp. 205-230). New York: Springer.
Miles, C., Charig, R., & Eva, H. (2008). Chewing gum as context: Effects in long-term memory. *Journal of Behavioral and Neuroscience Research, 6*(2), 1-5.
Miles, C., & Johnson, A. J. (2010). Switching between chewing-gum and no-gum at learning and retrieval does not accentuate error production in free recall. *Journal of Behavioral and Neuroscience Research, 8*(2), 9-19.
Morgan, K., Johnson, A. J. & Miles, C. (2013). Chewing gum moderates the vigilance decrement. *British Journal of Psychology*. DOI: 10.1111/bjop.12025.
Morinushi, T., Masumoto, Y., Kawasaki, H., & Morikuni, M. (2000). Effect on electroencephalogram of chewing flavoured gum. *Psychiatry and Clinical Neurosciences, 54*(6), 645-651.
Motowildo, S. J., Packard, J. S., Manning, M. R. (1986).Occupational stress: Its causes and consequences for occupational performance. *Journal of Applied Psychology*, *71*(4), 618-629.
Nachreiner, F., & Hänecke, K. (1992). Vigilance. In A. P. Smith & D. M. Jones (Eds.), *Handbook of human performance volume three: State and trait* (pp. 261-288). London: Academic Press.
Onozuka, M., Fujita, M., Watanabe, K., Hirano, Y., Niwa, M., Nishiyama, K., et al. (2003). Age-related changes in brain regional activity during chewing: A functional magnetic resonance imaging study. *Journal of Dental Research, 82*(8), 657-660.
Onyper, S. V., Carr, T. L., Farrar, J. S., & Floyd, B. R. (2011). Cognitive advantages of chewing gum: Now you see them, now you don't. *Appetite, 57*(2), 321-328.
Orne, M. T. (1969). Demand characteristics and the concept of quasi-controls. In R. Rosenthal & R. Rosnow (Eds.), *Artifact in behavioral research* (pp. 143-179). New York: Academic Press.
Overman, A. A., Sun, J., Golding, A. C., & Prevost, D. (2009). Chewing gum does not induce context-dependent memory when flavor is held constant. *Appetite, 53*(2), 253-255.
Pattyn, N., Neyt, X., Henderickx, D., & Soetens, E. (2008). Psychophysiological investigation of vigilance decrement: Boredom or cognitive fatigue? *Physiology & Behavior*, *93*(1-2), 369-378.
Pawlow, L. A., & Jones, G. E. (2002). The impact of abbreviated progressive muscle relaxation on salivary cortisol. *Biological Psychology*, *60*(1), 1-16.
Princeton Review, & Wrigley (2005). *Study habits survey*. New York: Princeton Review.
Rabkin, J. G. (1993). Stress and psychiatric disorders. In L. Goldberger and S. Breznitz (Eds.) *Handbook of stress: Theoretical and clinical aspects* (pp. 566-584). New York: The Free Press.
Ray, C., Weir, W. R. C., Phillips, S., & Cullen, S. (1983). Development of a measure of symptoms in chronic fatigue syndrome: The profile of fatigue-related symptoms. *Psychology & Health*, *7*(1), 27-43.

Read, G. F., Fahmy, D. R., & Walker, R. F. (1977). Determination of cortisol in human plasma by radioimmunoassay. *Annals of Clinical Biochemistry, 14*(6), 343-349.

Rickman, S., Johnson, A. J., & Miles, C. (2012). The impact of chewing gum resistance on immediate free recall. *British Journal of Psychology*. DOI:10.1111/j.2044-8295.2012.02124.x.

Robertson, I. H., & Manly, T. (1997). Oops! The sustained attention for response test. *Neuropsychologia*, *35*(6), 747-758.

Rubin, M., Paolini, S., Crisp, R. J. (2010). A processing fluency explanation of bias against immigrants. *Journal of Experimental Social Psychology*, *46*(1), 21-28.

Sakamoto, K., Nakata, H., Honda, Y., & Kakigi, R. (2009). The effect of mastication on human motor preparation processing: A study with CNV and MRCP. *Neuroscience Research, 64*(3), 259-266.

Sakamoto, K., Nakata, H., & Kikigi, R. (2009). The effect of mastication on human cognitive processing: A study using event-related potentials. *Clinical Neurophysiology, 120*(1), 41-50.

Scholey, A. (2003). Chewing and learning. In H. E. E. P. Staff (Ed.), *The benefits of chewing* (pp. 30-37). New York: Health Education Enterprises, Inc.

Scholey, A. (2004). Further issues regarding the possible modulation of cognitive function by the chewing of gum: Response to Stephens and Tunney (2004) and Tucha et al. (2004). *Appetite, 43*(2), 221-223.

Scholey, A., Haskell, C., Robertson, B., Kennedy, D., Milne, A., & Wetherell, M. (2009). Chewing gum alleviates negative mood and reduces cortisol during acute laboratory psychological stress. *Physiology & Behavior, 97*(3-4), 304-312.

Schultheiss, O. C. (2013). Effects of sugarless chewing gum as a stimulant on progesterone, cortisol and testosterone concentrations assessed in saliva. *International Journal of Psychophysiology, 87*(1), 111-114.

Shiba, Y., Nitta, E., Sugita, M., & Iwasa, Y. (2002). Evaluation of mastication-induced change in sympatho-vagal balance through spectral analysis of heart rate variability. *Journal of Oral Rehabilitation, 29*, 956-960.

Silverman, K. Evans, S. M., Strain, E. C. & Griffiths, R. R. (1992). Withdrawal syndrome after the double-blind cessation of caffeine consumption. *The New England Journal of Medicine*, 327, 1109-1114.

Sketchley-Kaye, K., Jenks, R., Miles, C., & Johnson, A. J. (2011). Chewing gum modifies state anxiety and alertness under conditions of social stress. *Nutritional Neuroscience, 14*(6), 237-242.

Smith, A. P. (2009a). Chewing gum, stress and health. *Stress & Health*, *25*(5), 445-451.

Smith, A. P. (2009b). Effects of caffeine in chewing gum on mood and attention. *Human Psychopharmacology: Clinical and Experimental, 24*(3), 239-247.

Smith, A. P. (2009c). Effects of chewing gum on mood, learning, memory and performance of an intelligence test. *Nutritional Neuroscience, 12*(2), 81-88.

Smith, A. P. (2010). Effects of chewing gum on cognition function, mood and physiology in stressed and non-stressed volunteers. *Nutritional Neuroscience, 13*(1), 7-16.

Smith, A. P. (2012). Effects of chewing gum on stress and health: A replication and investigation of dose-response. *Stress & Health*. DOI: 10.1002/smi.2430.

Smith, A. P., & Boden, C. (2012). Effects of chewing menthol gum on the alertness of healthy volunteers and those with an upper respitory tract illness. *Stress & Health*. DOI: 10.1002/smi.2437.

Smith, A. P., Chaplin, K., & Wadsworth, E. (2012). Chewing gum, occupational stress, work performance and wellbeing. An intervention study. *Appetite, 58*(3), 1083-1086.
Smith, A. P., Johal, S. S., Wadsworth, E., Davey-Smith, G., & Peters, T. (2000). *The scale of occupational stress: The Bristol stress and health at work study*. Norwich, UK: HSE Books.
Smith, A. P., Kendrick, A. M., Maben, A. L., & Salmon, J. (1994). Effects of breakfast and caffeine on performance, mood and cardiovascular functioning. *Appetite*, *22*(1), 39-55.
Smith, A. P., Sutherland, D., & Christopher, G. (2005). Effects of repeated doses of caffeine on mood and performance of alert and fatigued volunteers. *Journal of Psychopharmacology*, *19*(6), 620-626.
Smith, A. P., & Woods, M. (2012). Effects of chewing gum on the stress and work of university students. *Appetite*, *58*(3), 1037-1040.
Spielberger, C. D. (1983). *Manual for the State-Trait Anxiety Inventory (STAI)*. Palo Alto, California: Consulting Psychologists Press.
Spikman, J., & Van Zomeren, E. (2010). Assessment of attention. In J. M. Gurd, U. Kischka & J. C. Marshall (Eds.), *The handbook of clinical neuropsychology* (pp. 81-96). New York: Oxford University Press.
Stephens, R., & Edelstyn, N. M. J. (2011). Do individual differences moderate the cognitive benefits of chewing gum? *Psychology*, *2*(8), 834-840.
Stephens, R., & Tunney, R. J. (2004a). Role of glucose in chewing gum-related facilitation of cognitive function. *Appetite, 43*(2), 211-213.
Stephens, R., & Tunney, R. J. (2004b). How does chewing gum affect cognitive function? *Appetite, 43*(2), 217-218.
Steptoe, A., Wardle, J., Cui, W., Bellisle, F., Zotti, A. M., Baranyai, R., et al. (2002). Trends in smoking, diet, physical exercise, and attitudes toward health in European university students from 13 countries, 1990-2000. *Preventive Medicine*, *35*(2), 97-104.
Suh, H. J., Kim, S. Y., Chang, U. J., & Kim, J. M. (2008). Anti-stress effects of chewing gum prepared with yeast hydrolysate. *European Food Research and Technology*, *227*(2), 331–336.
Tahara, Y., Sakurai, K., & Ando, T. (2007). Influence of chewing and clenching on salivary cortisol levels as an indicator of stress. *Journal of Prosthodontics, 16*(2), 129-135.
Tänzer, U., von Fintel, A., & Eikermann, T. (2009). Chewing gum and concentration performance. *Psychological Reports*, *105*(2), 372-374.
Tasaka, A., Tahara, Y., Sugiyama, T., & Sakurai, K. (2008). Influence of chewing rate on salivary stress hormone levels. *The Journal of the Japanese Prosthodontic Society, 52*(4), 482-487.
Teff, K. L. (2010). Cephalic phase polypeptide responses to liquid and solid stimuli in humans. *Physiology & Behavior*, *99*(3), 317-323.
Teff, K. L., & Townsend, R. R. (2004). Prolonged mild hyperglycemia induces vagally mediated compensatory increase in C-peptide secretion in humans. *Journal of Clinical Endocrinology & Metabolism, 89*(11), 5606-5613.
Teruhisa, U., Ryoji, H., Taisuke, I., Tatsuya, A. Fumihiro, M. Tatsuo, T. (1981). Use of saliva for monitoring unbound free cortisol levels in serum. *Clinica Chimica Acta*, *110*(2), 245-253.
Torney, L. K., Johnson, A. J., & Miles, C. (2009). Chewing gum and impasse-induced self-reported stress. *Appetite, 53*(3), 414-417.

Tucha, L., & Koerts, J. (2012). Chewing gum and cognition: An overview. *Neuroscience & Medicine*, *3*(3), 243-250.
Tucha, L., & Simpson, W. (2011). The role of time on task performance in modifying the effects of gum chewing on attention. *Appetite, 56*(2), 299-301.
Tucha, L., Simpson, W., Evans, L., Birrel, L., Sontag, T. A., Lange, K. W., et al. (2010). Detrimental effects of gum chewing on vigilance in children with attention deficit hyperactivity disorder. *Appetite, 55*(3), 679-684.
Tucha, O., Mecklinger, L., Maier, K., Hammerl, M., & Lange, K. W. (2004). Chewing gum differentially affects aspects of attention in healthy subjects. *Appetite*, *42*(3), 327-329.
Tunn, S., Müllman, H., Barth, J., Derendorf, H. & Krieg, M. (1992). Simultaneous measurement of cortisol in serum and saliva after different forms of cortisol administration. *Clinical Chemistry 38*(8), 1491-1494.
Van Anders, S.M. (2010). Chewing gum has large effects on salivary testosterone, estradiol, and secretory immunoglobulin A assays in women and men. *Psychoneuroendocrinology*, *35*(2), 305-309.
Van Zomeren, A. H., & Brouwer, W. H. (1994). *Clinical neuropsychology of attention.* New York: Oxford University Press.
Wang, X., Gitelman, D., & Parrish, T. (2009). Effects of chewing gum on working memory and stress. *NeuroImage, 47*(Supplement 1), S145-S145.
Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance requires hard mental work and is stressful. *Human factors*, *50*(3), 433-441.
Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070.
Weber, S. J., & Cook, T. D. (1972). Subject effects in laboratory research: An examination of subject roles, demand characteristics, and valid inference. *Psychological Bulletin*, *77*(4), 273-295.
Weijenberg, R. A. F., Scherder, E. J. A., & Lobbezoo, F. (2011). Mastication for the mind-The relationship between mastication and cognition in ageing and dementia. *Neuroscience & Biobehavioral Reviews*, *35*(3), 483-497.
WHO. (2003). *Tobacco & health in the developing world*. Brussels, Belgium.
Wilkinson, L., Scholey, A., & Wesnes, K. (2002). Chewing gum selectively improves aspects of memory in healthy volunteers. *Appetite, 38*(3), 235-236.
Yagyu, T., Kondakor, I., Kochi, K., Koenig, T., Lehman, D., Kinoshita, T., et al. (1998). Smell and taste of chewing gum affect frequency domain EEG source locations. *International Journal of Neuroscience, 93*(3-4), 205-216.
Young, E. A., Abelson, J., & Lightman, S. L. (2004). Cortisol pulsatility and its role in stress regulation and health. *Frontiers in Neuroendocrinology*, *25*(2), 69-76.
Yu, H., Chen, X. Liu, J., Zhou, X. (2013). Gum chewing inhibits the sensory processing and the propogation of stress-related information in a brain network. *PLoS ONE*, *8*(4), e57111.
Zibell, S., & Madansky, E. (2009). Impact of chewing gum on stress levels: Online self-perception research study. *Current Medical Research and Opinion, 25*(6), 1491-1500.
Zigmond, A. S., & Snaith, R. P. (1983). The Hospital Anxiety and Depression Scale. *Acta Psychiatrica Scandinavica, 67*(6), 361-370.
Zimmerman, P., & Fimm, B. (1993). *A computerized neuropsychological assessment of attention deficits*. Herzogenrath, Germany: PsyTest.
Zimmerman, P., & Fimm, B. (2001). *A computerized neuropsychological assessment of attention deficits. Version 1.7*. Herzogenrath, Germany: PsyTest.

Zoladz, P. R., Raudenbush, B. (2005). Cognitive enhancement through stimulation of the chemical senses. *North American Journal of Psychology*, *7*(1), 125-140.

Appendices

Appendix 3.1: Study 1a survey

This survey includes questions about chewing gum consumption, smoking, anxiety, depression, cognitive problems, stress, fatigue and attitudes towards chewing gum. Please answer the following questions as honestly as possible. If you do not wish to answer any particular questions, please feel free to leave them blank.

Key code 2010-xxx

1. Age _________

2. Gender _________

Do you think that chewing gum is pleasurable or unpleasant? (-*3 = very unpleasant, 0 = neither pleasurable nor unpleasant, +3 = very pleasurable*)

-3 -2 -1 0 +1 +2 +3

Do you chew gum? Yes □ No □ (If no, please skip questions 3- 9 below)

3. What time of day do you chew gum?

8.00-10.00 □
10.00-12.00 □
12.00-14.00 □
14.00-16.00 □
16.00-18.00 □
18.00-20.00 □
20.00-22.00 □
22.00-24.00 □
24.00-8.00 □

4. Do you chew gum every day/nearly every day? Yes □ No □

5. Approximately how many pieces of gum do you chew in a week?

____

6. When you chew a piece of gum, on average how long would you chew it for?

Less than 1 minute □
1-5 minutes □
5-30 minutes □
More than 30 minutes □

7. Please tick all the flavours of gum that you chew.

Airwaves Cherry □
Airwaves Black Mint □
Airwaves Green Mint □
Airwaves Menthol & Eucalyptus □
Wrigley's Extra Spearmint □
Wrigley's Extra Peppermint □
Wrigley's Extra Cool Breeze □
Wrigley's Extra Ice □
Wrigley's Extra Fusion □
Orbit Spearmint □
Orbit Peppermint □
Orbit Complete □
Hubba Bubba □
Wrigley's Juicy Fruit □
Wrigley's Spearmint □
Wrigley's Double Mint □
Wrigley's 5 □

Other(s) (please specify)

____

8. Do you have a preferred flavour? ______________________________

9. Why do you chew gum? (Please tick all that apply)

Freshen breath □
Flavour □
Dental health □
Appearance/to look cool □
Concentration □
No particular reason □
Substitute for sweets □

Other reason(s) (please specify)

____

____

10. Do you think that chewing gum has an effect on mood? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

11. Do you believe that chewing gum has an effect on concentration? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

12. Do you think that chewing gum has an effect on stress? (-*3 =strong increase in stress, 0 = no effect, +3 = strong reduction in stress*)

-3 -2 -1 0 +1 +2 +3

13. Do you believe that chewing gum has an effect on speed of mental processing? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

14. Do you think that chewing gum is generally rude/ill-mannered in most social situations? (-*3 = not at all rude, 0 = moderately rude, +3 = highly rude*)

-3 -2 -1 0 +1 +2 +3

15. Do you currently smoke? Yes □ No □

16. If yes, how may cigarettes do you smoke per week? ________

17. In general, how stressful do you find your life?

Not at all stressful	Mildly stressful	Moderately stressful	Very stressful	Extremely stressful
□**0**	□**1**	□**2**	□**3**	□**4**

18. Below is a list of problems which may or may not apply to you. For each problem, please say to what extent you generally experience this. Do not think for too long before answering but give your immediate reaction. Please be careful not to miss out any of the items. Give your answer by circling any number from 1 to 7 to the right of the item, where;

1 = not at all, 4= moderately and 7 = extremely

		not at all			Moderately			extremely
A	Feeling physically tired even when taking things easy	1	2	3	4	5	6	7
B	Your limbs feeling heavy	1	2	3	4	5	6	7
C	Not having the physical energy to do anything	1	2	3	4	5	6	7
D	Difficulty standing for long	1	2	3	4	5	6	7
F	Muscles feel weak even after resting	1	2	3	4	5	6	7
G	The slightest exercise making you physically tired	1	2	3	4	5	6	7
H	Feeling physically drained	1	2	3	4	5	6	7
I	Feeling physically tired even after a good night's sleep	1	2	3	4	5	6	7
J	Having to stop doing something, that was easy in itself, because it made you tired	1	2	3	4	5	6	7
K	Muscles feeling weak after slight exercise	1	2	3	4	5	6	7
L	Feeling mentally tired even after a good night's sleep	1	2	3	4	5	6	7
M	The slightest effort making you mentally tired	1	2	3	4	5	6	7

19. Please read each item and then tick the box next to the reply that comes closest to how you generally feel. Try to give your first reaction. This will probably be more accurate than spending a long time thinking about an answer. Please answer all questions, and tick only ONE BOX per question.

a) I feel tense or wound up

Most of the time ☐0
A lot of the time ☐1
From time to time, occasionally ☐2
Not at all ☐3

b) I feel as if I am slowed down

Nearly all the time ☐0
Very often ☐1
Sometimes ☐2
Not at all ☐3

c) I still enjoy the things I used to enjoy

Definitely as much ☐0
Not quite so much ☐1
Only a little ☐2
Hardly at all ☐3

d) I get a sort of frightened feeling like "butterflies" in the stomach

Not at all ☐0
Occasionally ☐1
Quite often ☐2
Very often ☐3

e) I get a sort of frightened feeling as if something awful is about to happen

Very definitely and quite badly ☐0
Yes, but not too badly ☐1
A little, but it doesn't worry me ☐2
Not at all ☐3

f) I have lost interest in my appearance

Definitely ☐0
I don't take as much care as I should ☐1
I may not take quite as much care ☐2
I take just as much care as ever ☐3

g) I can laugh and see the funny side of things

As much as I always could ☐0
Not quite so much now ☐1
Definitely not so much now ☐2
Not at all ☐3

h) I feel restless, as if I have to be on the move

Very much indeed ☐0
Quite a lot ☐1
Not very much ☐2
Not at all ☐3

i) Worrying thoughts go through my head

A great deal of the time ☐0
A lot of the time ☐1
From time to time but not too often ☐2
Only occasionally ☐3

j) I look forward with enjoyment to things

As much as I ever did ☐0
Rather less than I used to ☐1
Definitely less than I used to ☐2
Hardly at all ☐3

k) I feel cheerful

Not at all ☐0
Not often ☐1
Sometimes ☐2

l) I get sudden feelings of panic

Very often indeed ☐0
Quite often ☐1
Not very often ☐2

Most of the time ☐3

Not at all ☐3

m) I can sit at ease and feel relaxed

Definitely ☐0
Usually ☐1
Not often ☐2
Not at all ☐3

n) I can enjoy a good book or radio or TV programme

Often ☐0
Sometimes ☐1
Not often ☐2
Very seldom ☐3

Appendix 3.2: Additional items for study 1b

Personality

I consider myself to be outgoing (For example: Talkative, comfortable with myself, confident in social situations)

Disagree strongly 1 2 3 4 5 6 7 8 9 10 Agree strongly

I feel that I have an agreeable nature (For example: I feel sympathy toward people in need, I like being kind to people, I'm co-operative)

Disagree strongly 1 2 3 4 5 6 7 8 9 10 Agree strongly

I feel that I am a conscientious person (For example: I am always prepared, I make plans and stick to them, I pay attention to details)

Disagree strongly 1 2 3 4 5 6 7 8 9 10 Agree strongly

I feel that I can get on well with others (For example: I'm usually relaxed around others, I tend not to get jealous, I accept people as they are)

Disagree strongly 1 2 3 4 5 6 7 8 9 10 Agree strongly

I feel that I am open to new ideas (For example: I enjoy philosophical discussion, I like to be imaginative, I like to be creative)

Disagree strongly 1 2 3 4 5 6 7 8 9 10 Agree strongly

Job characteristics

Please answer the following questions in relation to your current job.

Do you work at night?

(1) Never/almost never
(2) Seldom
(3) Sometimes
(4) Often

Do you do shift work?

(1)
(2)
(3)
(4)

Do you have to work long or unsociable hours?

(1)
(2)
(3)
(4)

Do you have to be "on call" for work?

(1)
(2)
(3)
(4)

Do you have unpredictable working hours?

(1)
(2)
(3)
(4)

Does your job ever expose you to breathing fumes, dusts or other potentially harmful substances?

(1)
(2)
(3)
(4)

Does your job ever require you to handle or touch potentially harmful substances or materials?

(1)
(2)
(3)
(4)

Do you ever have work tasks that leave you with a ringing in your ears or a temporary feeling of deafness?

(1)
(2)
(3)
(4)

Do you work in an environment where the level of background noise disturbs your concentration?

(1)
(2)
(3)
(4)

Health related behaviours

In this section, we are interested in finding out about how you live your life. In particular, we are interested in how much (or little) you drink or smoke.

Do you smoke cigarettes now (i.e. NOT cigars/pipe)?

(1) Yes
(2) No

How many cigarettes do you smoke per day?

MANUFACTURED

HANDROLLED

On average how often do you drink during the week, that is weekdays.

(1) Never
(2) 1-2 days
(3) 3 days

(4) 4 days

How many units do you drink during an average week? (1 unit
= half a pint of beer/glass of wine/1 measure of spirits)

UNITS

On average how often do you drink at the weekends?

(1) Never
(2) 1-2 days
(3) All 3 days

How many units do you drink on an average weekend?

UNITS

Do you drink tea?

(1) Yes
(2) No

If yes, what type of tea do you usually drink?

(1) Caffeinated
(2) Fruit/Herbal
(3) Decaffeinated
(4) Other

On average, how many cups of tea do you drink per day?

Do you drink coffee?

(1) Yes
(2) No

If yes, what type of coffee do you usually drink?

(1) Caffeinated
(2) Decaffeinated
(3) Other

On average, how many cups of coffee do you drink per day?

The next section is about snacks and meals

How often do you have a snack between meals?

(1) Never
(2) Less than once a week
(3) Once or twice a week
(4) Most days (3-6)
(5) Every day

Appendix 4.1: Study 2 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning the effects of chewing gum on attention, reaction time, stress and mood. There will be a familiarisation session on a day before the testing day which should last about one hour.

On the testing day, you should attend in the morning before work begins to complete a group of tasks, which should take about forty-five minutes to complete. During the working day you may be required to chew a packet of chewing gum. It is up to you at what time(s) during the working day to chew the gum, although you are encouraged to chew at any time at which you may feel stressed. Please try to eat and drink the amount that you would usually eat and drink on a normal working day. If you are not required to chew gum, please **avoid** chewing gum during the working day. It is possible that chewing gum over the course of the day may lead to tiredness/discomfort of the jaw or to reductions in level of hunger or thirst. Following work, you will then return to complete the same group of tasks. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve completing tasks which assess attention, reaction time, stress and mood. I understand that it may also involve chewing gum during some tasks and/or a packet of chewing gum during the working day.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment.

I understand that I will **not** be eligible to participate if I do not work full-time, if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw and/or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. At the end of the testing day, my responses will be made anonymous, so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ____________________________________(NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:
(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 4.2: Questions on occupational performance

Generally, do you find that you have problems of memory (e.g. forgetting where you put things), attention (e.g. failures of concentration), or action (e.g. doing the wrong thing)?

Not at all	Rarely	Occasionally	Quite frequently	Very frequently
☐ **0**	☐ **1**	☐ **2**	☐ **3**	☐ **4**

Generally, how frequently do you find that you don’t get as much work done as you would like?

Not at all	Rarely	Occasionally	Quite frequently	Very frequently
☐ **0**	☐ **1**	☐ **2**	☐ **3**	☐ **4**

Appendix 4.3: Ingredients of chewing gum

Airwaves Black Mint: Isomalt, sorbitol, maltitol syrup, mannitol, aspartame, acesulfame K, gum base, flavourings, gum arabic, maltodextrin, modified starch, carnauba wax, E171, BHA, E133, E160a, E141, E100.

Airwaves Green Mint: Isomalt, sorbitol, maltitol syrup, mannitol, aspartame, acesulfame K, gum base, flavourings, gum arabic, maltodextrin, modified starch, carnauba wax, E171, BHA, E133, E160a, E141, E100.

Airwaves Cherry: Isomalt, sorbitol, maltitol syrup, mannitol, aspartame, acesulfame K, gum base, flavourings, gum arabic, maltodextrin, modified starch, soybean lecithin, carnauba wax, E129, BHA, E160a, E133, E153.

Airwaves Menthol & Eucalyptus: Isomalt, sorbitol, maltitol syrup, mannitol, aspartame, acesulfame K, gum base, flavourings, gum arabic, maltodextrin, E171, modified starch, soybean lecithin, carnauba wax, E133, BHA, E160A.

Wrigley's Extra Cool Breeze: Sorbitol, maltitol, maltitol syrup, aspartame, mannitol, acesulfame K, gum base, humectant glycerine, gum arabic, calcium carbonate, flavourings, E171, soybean lecithin, carnauba wax, BHA.

Wrigley's Extra Spearmint: Isomalt, sorbitol, mannitol, aspartame, acesulfame K, gum base, flavourings, humectant glycerine, gum arabic, E171, carnauba wax, BHA.

Wrigley's Extra Peppermint: Sorbitol, maltitol, maltitol syrup, mannitol, aspartame, acesulfame K, gum base, humectant glycerine, gum arabic, flavourings, calcium carbonate, E171, soybean lecithin, carnauba wax, BHA.

Wrigley's Extra Ice: Sorbitol, xylitol, aspartame, mannitol, acesulfame K, gum base, gum arabic, humectant glycerine, flavourings, calcium phosphates, E171, soybean lecithin, sodium hydrogen carbonate, carnauba wax, BHA, E133.

Wrigley's Spearmint: Sugar, gum base, glucose syrup, flavourings, humecant glycerine, soybean lecithin, BHA.

Appendix 4.4: Study 2 debriefing sheet

Debriefing Form: The effects of chewing gum on mood, stress and cognitive function: morning, working day and evening

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum affects mood, stress and performance on thinking tasks if it has been chewed during the day.

Participants are asked to chew gum or avoid chewing gum during the day and to complete tasks and questionnaires with and without chewing gum so that a clear comparison can be made between the effects of chewing gum and not chewing gum. The tests you completed measured simple reaction time, mood, stress, sustained attention, focused attention and visual search skills.

You may withdraw your data without explanation. However, you may only do so until the data have been anonymised, which will happen at the end of the day.

If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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If you have any ethical concerns about this research, you may wish to contact:

Psychology Ethics Committee Secretary

Email: psychethics@cf.ac.uk
Phone: +44 (0)29 208 74007
Fax: +44 (0)29 2087 4858
Address: Psychology Ethics Committee Secretary

Cardiff University

Tower Building

Park Place

Cardiff

CF10 3AT

Appendix 4.5: Study 3 consent form

School of Psychology, Cardiff University
Consent Form - Anonymous data

After signing up, you will be asked to come to 63 Park Place to participate in this study concerning the effects of consumption habits on psychology and physiology. You will be asked to provide saliva samples at regular intervals (using the test tubes provided), so that stress hormones can be measured. These samples will be stored in a locked room with limited access. Heart rate will be measured using a monitor which you will wear throughout the working day. During the familiarisation day, you will have a chance to get used to the procedure for the working day intervention. There will then be two testing days (which will be at least one week apart).

You will be provided with a diary for recording what you consume, at what time you consume it and how you generally feel. During one day you will be required to chew a full packet of gum. You are requested NOT to eat for one hour before the after-work testing session. Please try to eat and drink the amount that you would usually eat and drink on a normal working day. However, during the testing days please AVOID alcoholic drink or chewing gum other than the provided gum. It is possible that chewing over the course of the day may lead to tiredness/discomfort of the jaw or reductions in level of hunger or thirst.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve completing tasks which assess well-being, as well as providing saliva samples and heart rate measurements.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment, and that I am free to withdraw my data, including saliva and heart rate data, but only up until the data is anonymised, which will happen at the end of the last testing day. I understand that I will NOT be eligible to participate if I do not work full-time, if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw and/or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis (including analysis of heart rate and saliva data). At the end of the last testing day, my responses will be made anonymous (i.e. the link between my name and my study number will be deleted), so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely. I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ____________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:
(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 4.6: Intervention diary

<u>Consumption diary</u>

Reminders: Please do not drink any alcohol or consume any chewing gum other than the gum provided. Please finish the packet of gum provided by the end of the workday.
Please do not eat anything for one hour before the final testing session.
DON'T FORGET: Please also provide a saliva sample in the appropriately labelled test tube each time you fill in a set of questions.

10am *(note: questions repeated for each hour of testing)*

Below is a list of descriptions which may or may not apply to you. For each description, please say to what extent you are experiencing this at the appropriate time listed. Do not think for too long before answering but give your immediate reaction. Please be careful not to miss out any of the items. Give your answer by circling any number from 1 to 7 below the item, where;

1 = not at all, 4 = moderately and 7 = extremely

Please also provide a saliva sample in the appropriately labelled tube each time you fill in a set of questions below.

1. Feeling anxious.
   1 2 3 4 5 6 7
2. Feeling depressed.
   1 2 3 4 5 6 7
3. Feeling stressed.
   1 2 3 4 5 6 7
4. Feeling mentally fatigued.
   1 2 3 4 5 6 7
5. Feeling physically fatigued.
   1 2 3 4 5 6 7
6. Not having the physical energy to do anything.
   1 2 3 4 5 6 7
7. Having problems of memory, attention or action.
   1 2 3 4 5 6 7
8. Not getting as much work done as you would like.
   1 2 3 4 5 6 7

9. Have you had anything to eat in the last hour? If so indicate what you've eaten

Yes: ________________

No:

10. How many caffeinated drinks have you had in the last hour (enter number):

Coffee:
Tea:
Cola:
Other:

If you marked other, what other(s) type of caffeinated drink did you have?

____

11. How many pieces of gum have you chewed in the last hour? (*note: this question was included for gum condition only)*

Number of pieces:

Appendix 4.7: Study 3 debriefing sheet

Debriefing Form: The effects of chewing gum on stress, fatigue and physiology: morning, working day and evening

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum affects well-being and physiological measures of stress and arousal over the course of the workday. Our previous research has indicated a stress- and fatigue-reducing effect of gum, but we only measured these outcomes at the end of the day, and did not include physiological measures. This research is partly funded by the Wrigley Science Institute.

Participants are asked to chew gum or avoid chewing gum during the different testing days and to complete questionnaires with and without chewing gum so that a clear comparison can be made between the effects of chewing gum and not chewing gum. The saliva samples will be assessed for levels of cortisol (a stress hormone), and heart rate measures will be assessed for changes over the course of the day. We separated the testing days in case the effects of one testing day persisted for some time afterwards. The diaries will allow the timing of gum chewing to be assessed, as well as allowing us to check that any effects are not due to differences in food and caffeinated drink consumption. You were requested to avoid eating before the after-work testing sessions to avoid the drowsiness that can occur after eating.

You may withdraw your data, including your saliva and heart rate data, without explanation. However, you may only do so until the data have been anonymised, which will happen at the end of the day. If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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Appendix 5.1: Study 4 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning the effects of chewing gum on attention and mood, which should take about one hour to complete. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve chewing gum, answering questions about my daily routine and completing tasks which assess attention, reaction time and mood.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment (or course credit).

I understand that I will **not** be eligible to participate if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. My responses will be made anonymous, so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ______________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:

(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 5.2: Study 4 debriefing sheet

Debriefing Form: Circadian variation in effects of chewing gum on cognitive function

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum affects mood and performance on thinking tasks differently if it is chewed at different times during the day. People tend to naturally experience different levels of arousal during the course of the day (circadian variation). This is why you were randomly assigned to a 9 o'clock or an 11 o'clock group. The questionnaire on your sleep and waking patterns was necessary to ensure that the 9 and 11 o'clock groups did not differ in these factors.

You performed with and without chewing gum so that a clear comparison could be made between performance with and without chewing gum. The tests you completed measured simple reaction time, mood, sustained attention, focused attention and visual search skills.

You may withdraw your data without explanation, but only up to the point at which it is anonymised (i.e. the end of the data collection for this study).

If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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Appendix 5.3: Study 5 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning the effects of chewing gum on attention, reaction time and mood. There will be a familiarisation session on a day before the testing day which should last about one hour.

On the testing day, you will return to complete the same group of tasks three times, which should take about 2 hours. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve completing tasks which assess attention, reaction time, and mood. I understand that it may also involve chewing gum during some tasks.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment.

I understand that I will **not** be eligible to participate if I do not work full-time, if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw and/or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. At the end of the testing day, my responses will be made anonymous, so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ____________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:
(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 5.4: Study 5 debriefing sheet

Debriefing Form: The effects of chewing gum on mood and cognitive function

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum affects mood and performance on thinking tasks and if it has differing effects over multiple testing sessions.

Participants are asked to chew gum or avoid chewing gum and to complete tasks with and without chewing gum so that a clear comparison can be made between the effects of chewing gum and not chewing gum. The tests you completed measured simple reaction time, mood, sustained attention, focused attention and visual search skills.

You may withdraw your data without explanation. However, you may only do so until the data have been anonymised, which will happen at the end of the day.

If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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Appendix 6.1: Study 6 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning the effects of chewing gum on mood, which should take about thirty minutes to complete. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve sitting quietly while either chewing flavoured or flavourless gum or not chewing, as well as completing tasks which assess mood, and if I am in a gum condition I will be asked how much I like the gum.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment (or course credit).

I understand that I will **not** be eligible to participate if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. My responses will be made anonymous, so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, _________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:

(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 6.2: Study 6 debriefing sheet

Debriefing Form: <u>The effects of chewing gum on mood</u>

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum affects mood. Previous studies have looked at the effect of chewing gum on mood while completing other tasks. You were asked to chew gum while sitting quietly so that it can be established if it is length of chewing, as opposed to length of task performance, which leads to mood effects.

Participants are asked to complete questions about mood with flavoured and flavourless gum and without chewing gum so that a clear comparison can be made between the effects of the act of chewing gum, its flavour and not chewing gum.

You may withdraw your data without explanation. However, you may only do so until the data have been anonymised, which will happen after you leave.

If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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Appendix 7.1: Study 7 consent form

EEG/Heart rate experiment

Name..

The research staff involved in this practical are not qualified medical practitioners. It is important that you realise that these experiments / activities will not provide any information that may help in the diagnosis of any medical condition, nor should you regard results obtained from these experiments as a medical screening procedure. If you do have any health concerns, you should contact a qualified medical practitioner, such as your GP, in the normal way.

1. I understand that my participation in this project completing tasks which assess attention and mood, and having measurements of EEG and heart rate taken by the experimenter (EEG and heart rate will be measured using electrodes and a heart rate monitor). I may also have to chew gum base. The study should take an hour to complete. I hereby give my consent to participate in a research study involving psychological and physiological responses to chewing gum base.
2. I am unaware of any circumstance or condition that may affect my suitability to participate in this study and undertake to disclose any information that may be relevant.
3. I am aware that I can withdraw at any time without prejudice. I understand that I can have access to the information that I provide or ask for it to be deleted or destroyed, up until the point at which it is anonymised, in accordance with the Data Protection Act.
4. I understand the recordings will be analysed and may be used for further research or publication and that any information I give here will be treated in the strictest confidence. Any personal information will be filed with the assigned ID number and will NOT include my name.
5. This form will be kept separately (only as a paper copy), securely, for 5 years, after which it will be destroyed. It will not be shared with anyone else.
6. I understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

Signed.. Date............................

(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Tim Jacob; Jacob@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 7.2: Study 7 debriefing sheet

<u>Debriefing form: The psychophysiology of chewing gum</u>

Thank you very much for taking part in this research.

This study aims to find out if chewing gum has an effect on heart rate and EEG (electroencephalographic) measures. These variables were measured in order to see if chewing gum affects brain activity and/or arousal in the nervous system as a whole. You were also asked to complete measures of attention and self-reported mood to see if any changes in physiology are associated with changes in subjective mood and/or mental performance.

Flavourless chewing gum was used in order to investigate the effects of gum chewing, independent of flavour. We test participants with and without chewing gum so we can compare the effect of chewing gum to what mood, physiology and attention levels are normally like.

If you have any questions, please feel free to ask me or to contact myself or Prof Tim Jacob:

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Appendix 8.1: Study 8 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning the effects of chewing gum on attention, reaction time, stress and mood, which should take about one hour and twenty minutes to complete. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation in this project will involve chewing gum, answering questions about my attitudes to chewing gum and completing tasks which assess attention, reaction time and mood.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment (or course credit).

I understand that I will **not** be eligible to participate if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. My responses will be made anonymous, so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ______________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:

(Andrew P. Allen; AllenAP@cf.ac.uk)
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Appendix 8.2: Attitudes towards chewing gum

Questionnaire

Please read the information given below and mark the response which best matches your attitude.

Do you think that chewing gum is pleasurable or unpleasant? (-*3 = very unpleasant, 0 = neither pleasurable nor unpleasant, +3 = very pleasurable*)

-3 -2 -1 0 +1 +2 +3

Do you think that chewing gum has an effect on mood? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

Do you believe that chewing gum has an effect on concentration? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

Do you think that chewing gum has an effect on stress? (-*3 = strong increase in stress, 0 = no effect, +3 = strong reduction in stress*)

-3 -2 -1 0 +1 +2 +3

Do you believe that chewing gum has an effect on speed of mental processing? (-*3 = very negative effect, 0 = no effect, +3 = very positive effect*)

-3 -2 -1 0 +1 +2 +3

Do you think that chewing gum is generally rude/ill-mannered in most social situations? (-*3 = not at all rude, 0 = moderately rude, +3 = highly rude*)

-3 -2 -1 0 +1 +2 +3

Appendix 8.3: Manipulation probe

Do you feel that you understood the idea behind this research?

Yes □ No □

Do you think any additional factors were being studied?

____

____

Appendix 8.4: Study 8 debriefing sheet

Debriefing Form: Expectancy and the effects of chewing gum on mood, stress and cognitive performance

Thank you very much for taking part in this research.

The aim of this study is to find out whether chewing gum has differing effects on mood and performance on thinking tasks if it is presented in a positive or negative light. This is important, because experiments involving chewing gum cannot administer gum without the participants knowing whether they are receiving gum or not, so effects may be due to a desire to please the experimenter. You were assigned to a group which involved positive *(or negative, or neutral)* presentation of chewing gum - it was predicted that this would lead to better cognitive performance and reports of improved mood when chewing gum.

Please do **not** inform your friends of the nature of this study, as it may undermine the quality of the experiment if they subsequently participate in it.

Participants are asked to complete tasks and questionnaires with and without chewing gum so that a clear comparison can be made between chewing gum and not chewing gum following a given set of instructions. The tests you completed measured simple reaction time, mood, sustained attention, focused attention and visual search skills.

You may withdraw your data without explanation. However, you may only do so until the data have been anonymised, which will happen at the end of the day. If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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Appendix 9.1: Study 9 consent form

School of Psychology, Cardiff University

Consent Form - Anonymous data

After signing up through EMS, you will be asked to come to 63 Park Place to participate in this study concerning attention and mood, which should last approximately 75 minutes. The study will also involve you being filmed. To this end, please avoid covering your face while taking part in this experiment. You will be debriefed at the end of the study.

Please read the statements given below, and, if you are satisfied with them, please sign where indicated:

I understand that my participation will involve tasks which assess attention and mood.

I understand that I will be filmed during this experiment. This footage will be kept in a locked office with limited access and will only be used for the purpose of this experiment.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time (as well as withdrawing all data, including footage) without giving a reason and without loss of payment (or course credit).

I understand that I will **not** be eligible to participate if I am currently taking medication, if I currently suffer from any health problems, if I consume more than 40 units of alcohol per week or smoke more than 10 cigarettes in the daytime and evening.

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Prof Andy P. Smith.

I understand that I will be assigned a study number. Only this will be used to allow data analysis. At the end of testing, my responses will be made anonymous (i.e. the link between my name and my study number will be deleted), so that it is impossible to trace this information back to me individually. I understand that this information may be retained indefinitely.

I, ______________________________________ (NAME) consent to participate in the study conducted by Andrew P. Allen, School of Psychology, Cardiff University with the supervision of Prof Andy P. Smith.

Signed:

Date:

(Andrew P. Allen; AllenAP@cf.ac.uk)
(Prof Andy P. Smith; smithap@cf.ac.uk)

Appendix 9.2: Study 9 debriefing sheet

Debriefing Form: Intensity of chewing, alertness and attention

Thank you very much for taking part in this research. We appreciate your time and effort.

Although previous research has indicated an alerting effect of gum, as well as some effects on attention, it is unclear why this may be the case. The aim of this study is to find out whether chewing gum has a differing effect on attention and alertness depending on how you chew it. Hence, you were asked to report how hard you chewed, and you were filmed so that chewing rate can be measured.

You may withdraw your data, including filmed footage, without explanation. However, you may only do so until the data have been anonymised, which will happen at the end of the testing. The footage will be destroyed once it has been fully analysed, which will happen in the next six months.

If you have any questions, please feel free to ask me or to contact myself or my supervisor:

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