Research article

Effects of chewing gum on mood, learning, memory and performance of an intelligence test

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Rationale: Recent research suggests that chewing gum may increase alertness and lead to changes in cognitive performance. The present study examined effects of chewing gum on these functions within the context of a single study.

Objectives: This study had four main aims. The first was to examine whether chewing gum improved learning and memory of information in a story. The second aim was to determine whether chewing gum improved test performance on a validated intellectual task (the Alice Heim task). A third aim was to determine whether chewing gum improved performance on short memory tasks (immediate and delayed recall of a list of words, delayed recognition memory, retrieval from semantic memory, and a working memory task). The final aim was to determine whether chewing gum improved mood (alertness, calm and hedonic tone).

Subjects and methods: A cross-over design was used with gum and no-gum sessions being on consecutive weeks. In each week, volunteers attended for two sessions, two days apart. The first session assessed mood, immediate recall of information from a story and performance on short memory tasks. The second session assessed mood, delayed recall of information from a story and performance of an intelligence test (the Alice Heim test).

Results: There were no significant effects of chewing gum on any aspect of recall of the story. Chewing gum improved the accuracy of performing the Alice Heim test which confirms the benefits of gum on test performance seen in an earlier study. Chewing gum had no significant effect on the short memory tasks. Chewing gum increased alertness at the end of the test session in both parts of the study. This effect was in the region of a 10% increase and was highly significant ($P < 0.001$).

Conclusions: The results of this study showed that chewing gum increases alertness. In contrast, no significant effects of chewing gum were observed in the memory tasks. Intellectual performance was improved in the gum condition. Overall, the results suggest further research on the alerting effects of chewing gum and possible improved test performance in these situations.

Keywords: chewing gum, learning and memory, intelligence test, alertness

Introduction

In 1939, Hollingworth[1] found that chewing gum improved cognitive performance. Until recently, there has been no further research on the effects of chewing gum on cognitive function. This is rather surprising given the anecdotal evidence suggesting that people

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often chew when they need to maintain concentration (*e.g.* when driving) or when they feel they are under stress. However, there have now been a number of recent studies of the topic and these, plus unpublished research from our laboratory and other groups, are reviewed here.

Wilkinson *et al.*[2] carried out a study to compare the effects of chewing gum with sham chewing and no chewing (total sample size = 75, 25 per group). Heart rate was found to increase in the chewing condition. Chewing gum improved immediate and delayed recall of a list of words and there was also some evidence of improved working memory. Neither psychomotor speed (*e.g.* simple reaction time) nor sustained attention were influenced by chewing gum. Mood was not measured in this study. The major problem with this study was that no baseline measures were taken prior to the test conditions; this means effects attributed to gum conditions may reflect individual differences.

Baker *et al.*[3] investigated effects of chewing gum on learning and recall of a word list with chewing being at either learning, recall or both (experiment 1: gum–gum, n = 23; gum–no-gum, n = 20; no-gum–gum, n = 20; no-gum–no–gum, n = 20). Chewing gum at initial learning had a beneficial effect and a switch between gum and no gum between learning and recall led to poorer performance. In a second experiment (n = 48), sucking the gum led to the same effects as chewing it. Again, there was no baseline session prior to the test conditions.

Tucha *et al.*[4] examined effects of chewing gum on a range of measures investigating memory and attention in two experiments. Each volunteer (n = 58 in both studies) was tested in four conditions: no chewing, sham chewing, chewing a piece of tasteless gum and chewing spearmint gum. Chewing gum did not improve memory but it did improve sustained attention. In contrast, chewing gum reduced alertness and flexibility. Chewing did not influence heart rate. The authors concluded their results suggested that claims that chewing gum improves cognition should be treated with caution. This study also has methodological problems. Effects of order of conditions were not included in the analyses and this may mask any effects of chewing gum. In addition, no baseline measures were taken prior to the test sessions.

Stephens and Tunney[5] tested the view that chewing increases heart rate which leads to an increased flow of nutrients, such as glucose, to the brain. Volunteers (n = 30) carried out four conditions made by combining gum/mint and glucose/water factors. Chewing gum improved immediate and delayed recall and working memory. Glucose produced similar improvements in all but the delayed recall task. They interpreted their findings in terms of chewing improving delivery of glucose but also suggested that the motor activity of chewing may increase adrenergic arousal. Again, there were no baseline measures prior to testing and effects of order of conditions were not included in the analyses.

The results from the above studies have been debated in a number of other articles. Essentially, these papers discuss the criticisms of the experimental designs outlined above and also suggest that sample sizes may not have been enough to detect smaller effects in some studies. They also focus on the possible role of flavour as well as chewing. In addition, regular chewing habit is considered a possible confounder across studies. It has also been concluded that many of the laboratory measures have limited ecological validity and that future studies should examine the effect of chewing gum on measures of cognition in everyday settings such as the classroom or workplace.

Johnson and Miles[6] examined the prediction that chewing gum at learning and/or recall facilitated subsequent memory. They tested 96 volunteers who were assigned to one of four groups (gum/no-gum at learning; gum/no-gum at learning and recall). The results showed that chewing at learning had a detrimental effect upon recall. There was no evidence of a context-dependent effect of chewing gum. These findings contradict results obtained in an earlier study with an identical design.[3] Miles and Johnson[7] reported two experiments designed to re-examine effects of chewing gum on learning and also context dependent memory effects. The studies differed from Baker *et al.*[3] in that they involved a within-subject design and a sequential presentation of the words. No context-dependent effect was apparent in the gum condition although it was in the no-gum condition (*i.e.* recall was best with no-gum at both learning and recall). Results from the first experiment provided no support for a beneficial effect of gum on word learning nor did they suggest that gum can produce context-dependent effects. The second experiment replicated these findings and also showed that chewing gum had no effect on delayed recall.

Johnson and Miles[6] found that significantly more words were recalled in the no-gum learning condition. No context-dependent effect was present in the gum condition even though it was involved in the no-gum condition (*i.e.* recall was best with no-gum at both learning and recall). Johnson and Miles[23] examined the effects of chewing flavourless gum or mint-flavoured strips on the learning and recall of a list of words. Again, no context-dependent effect was observed in the gum condition but chewing gum did improve recall of the words. Mint-flavour improved learning of a list of words but, again, no context-dependent memory effect was observed in the mint-flavour condition. Overall, these findings show that the effects of chewing gum on learning and recall of a list of words are variable and further research is needed to determine whether more robust effects of chewing occur for other outcomes.

The studies above tell us little about effects of chewing gum on mood. In two studies, Smith[8,9] examined this issue. The first (n = 122) examined effects of prior chewing of both caffeinated gum and placebo gum on mood. Both gum conditions increased ratings of alertness and hedonic tone at the start of the test session. A second study[9] examined effects of chewing gum during performance. The aims of the study were to determine if: (i) chewing gum improved mood and mental performance; (ii) chewing gum had benefits in stressed individuals; and (iii) chewing habit, type of gum and level of anxiety modified the effects of gum. A total of 133 volunteers completed the study. Approximately half were tested in 75-dBA noise and the rest in quiet. Each volunteer carried out a test session when they were chewing gum and without gum, with order of gum conditions counterbalanced across subjects. Baseline sessions were conducted prior to each test session. Volunteers were stratified on chewing habit and anxiety level. Approximately half the volunteers were given mint gum and half fruit gum. The volunteers rated their mood at the start and end of each session and had their heart rate monitored over the session. Saliva samples were taken at the start and end of each session to allow cortisol levels (good indicators of alertness and stress) to be assayed. During the session, volunteers carried out tasks measuring a range of cognitive functions (aspects of memory, selective and sustained attention, psychomotor speed and accuracy).

The results showed that chewing gum was associated with greater alertness and a more positive mood. Reaction times were quicker in the gum condition, and this effect became bigger as the task became more difficult. Chewing gum also improved selective and sustained attention (the volunteers chewing gum sampled a wider visual field and were less likely to have lapses of attention). Several of the memory tasks showed impaired performance in the gum condition. This may reflect the effects of increased alertness or chewing interfering with sub-vocal rehearsal. Chewing gum increased heart rate and cortisol levels suggesting that it was having an arousing effect.

Overall, the above results suggest that chewing gum produces a number of benefits that are generally observed and not context-dependent (*i.e.* they were observed in both stressed and non-stressed individuals, and did not depend on chewing habit or flavour). Furthermore, the study had appropriate statistical power and involved baseline measurements prior to the test condition.

Like most areas, there have been a number of, as yet, unpublished studies of behavioural effects of chewing gum. Reports of some of these studies have been made available to the author by the Wrigley Science Institute. Three studies were conducted at Beijing University to investigate effects of gum on memory and learning. The first compared gum, sucking a mint and nothing in a cross-over design (n = 43). There were no significant effects of conditions and it was suggested that this reflected lack of familiarity with the gum. The second study examined immediate and delayed recall of information from a story by 10–13-year-olds (parallel groups design: n = 43–57). Short-term recall was improved by chewing gum at both learning and recall. Long-term recall was not improved by gum. The final study looked at the effects of chewing gum on maths and language tests. No effects of gum were observed.

Research at a New York dental school examined whether chewing gum during a lecture, laboratory class and studying had an effect on learning. Chewing gum resulted in better performance in a written examination but not a practical examination.

Research in Germany has examined the effects of chewing gum on concentration by examining performance of school children over time. The results showed that chewing gum improved performance at the end of the test period, which supports the improved sustained attention result reported by Smith.[9]

In conclusion, the literature described above clearly shows variable effects of gum. One could argue that there is evidence from specific tasks but the problem is that one can cite other studies that do not support such claims (*e.g.* some studies support an effect of chewing gum on memory for a list of words, others do not). Indeed, the findings must be viewed within the context of methodological problems outlined above. The review of the existing studies suggests that there may well be some benefits of chewing gum on mental functioning. Future research must use a sound experimental design and first clarify the type of functions that are improved, then try and understand the underlying mechanisms and also study real-life activities (*e.g.* effects of chewing gum on learning and retrieval of educational material; effect of chewing gum on simulated driving; effect of chewing gum on efficiency at work). Results from two unpublished studies suggest two areas of practical relevance that require further investigation. A study at Beijing University showed that chewing gum resulted in better immediate recall of information from a story. Second, the study carried out at New York University showed that chewing gum resulted in better written examination performance in dental students. The main aim of the present study was to replicate these effects using modified procedures suitable for use with university students from a range of disciplines. In addition, the study provides another opportunity to examine the effects of chewing gum on basic memory functions and reported alertness.

Subjects and methods

The experiment was sub-divided into two parts carried out on consecutive weeks. These will be referred to as parts 1 and 2.

PART 1

This study used a technique that has been employed to study effects of changes in alertness (*e.g.* circadian variation in alertness) on recall of information from a story.[10–12] These results show better long-term memory when alertness is higher and this is largely due to an increased focus on important information (*i.e.* the themes of the story). In contrast, more unimportant information is recalled when the material is learnt when alertness is low. Chewing gum may be considered to be alerting (both physiologically and in terms of subjective reports) and one can predict that this will lead to better memory for important information. The present technique has the advantage of allowing the effects of chewing at learning and recall to be compared and it allows one to look at immediate recall and delayed recall (2 days later). In addition, interpolated tasks are required in between learning the story and short-term test and these were short memory tasks used in previous studies of the effects of gum. This allows comparison of different effects of gum within the same study.

Design

A cross-over design was used with each volunteer being tested in gum and no-gum conditions in a counterbalanced order. One group (n = 40) chewed gum at both learning and test. Another group (n = 40) only chewed gum at learning and the final group only chewed gum at test.

Table 1 The design of the study

Group	Week 1	Week 2
1	Gum, learning and recall (n = 20)	No-gum
2	Gum learning (n = 20)	No-gum
3	Gum recall (n = 20)	No-gum
4	No-gum (n = 20)	Gum learning and recall
5	No-gum (n = 20)	Gum learning
6	No-gum (n = 20)	Gum recall

Summary of design

The design of the study is summarised in Table 1.

Sample size

Sample size considerations are complicated in this type of study where one is considering multiple outcome measures and using different parts of the database to address different hypotheses. In general, it is important to have sample sizes that will be able to detect significant effects in the region of 0.5 SD. In the case of gum and memory, one is making a within-subject comparison. For such sample size calculations, one needs to know the standard deviation of the difference scores of gum and no-gum conditions. With n = 64, power set to 0.8 and $P < 0.05$, then one should be able to detect an effect size of 0.35 SD. The chosen sample size was actually 120 which provides additional power for the study.

Another way of assessing sample size is to look at those in previous studies using this technique. Oakhill[12] demonstrated time-of-day effects with a parallel groups design and a total of n = 64. Similarly, the Beijing study showed effects of chewing gum on story recall with parallel groups of 40–50. These all suggest that a cross-over design with a total of n = 120 should be powerful enough to detect such effects.

Ethical approval

The study was carried out with the approval of the ethics committee (School of Psychology, Cardiff University) and with the informed consent of the volunteers.

Procedure

Volunteers were familiarised with the procedure and then completed the gum and no-gum conditions on separate weeks (order of conditions counterbalanced across volunteers). On the first day, volunteers rated

Table 2 Schedule of testing for participant 1 (gum at both learning and recall)

Test session	Tests carried out	Gum during session (Y/N)
Familiarisation	All tests	N
Test 1		Y
	Mood	
	Story	
	Free recall	
	Logical reasoning	
	Semantic processing	
	Delayed recall	
	Recognition memory	
	Recall of story	
	Mood	
2 days later		Y
	Mood	
	Recall of story	
	Alice Heim task	
	Mood	
One week after test 1		N
	Mood	
	Story	
	Free recall	
	Logical reasoning	
	Semantic processing	
	Delayed recall	
	Recognition memory	
	Recall of story	
	Mood	
2 days later		N
	Mood	
	Recall of story	
	Alice Heim task	
	Mood	

their mood and then read a short story (which took about 10 min). Following this, they carried out the short memory tests (20 min). Their recall of the story was then tested using questions designed to cover the themes of the story and specific details. This took about 5 min. Mood was then assessed again. Two days later, volunteers attended for another session and their mood recorded and delayed recall for material presented in the story tested. In the rest of this session volunteers carried out the Alice Heim 5 task (see part 2).

One week later, the volunteers repeated the procedure in the other condition (gum or no-gum). Table 2 shows the testing procedure for a volunteer tested in the order gum/no-gum.

Gum was the volunteer's choice of the commercially available product they preferred.

Inclusion/exclusion criteria

Inclusion/exclusion criteria are shown in Table 3.

Tests

1. **Mood** – This was measured using 18 bipolar visual analogue scales (*e.g.* drowsy–alert, tense–calm) presented on the screen of an IBM-compatible computer. Mood was rated at the start of each session and at the end. This provided information about initial and longer term effects of the manipulations. Three scores were derived from the mood scales: alertness, hedonic tone and anxiety.

2. **Memory for information in a story** – The stories selected were short stories by Somerset Maugham (*Mr Knowall* and *A string of beads*). These were not familiar to current students and it was easy to select questions about important and trivial details of the story. Recall was tested by open-ended questions (available from the author).

Interpolated memory tasks

I **Immediate free recall task** – A list of 20 words was presented on the PC screen at a rate of one every 2 s. At the end of the list, the volunteer had 2 min to write down (in any order) as many of the words as possible.

2. **Logical reasoning task** (a measure of working memory) – In this task, the volunteers were shown statements about the order of the letters A and B followed by the letters AB or BA (*e.g.* A follows B: BA). The volunteers had to read the statement and decide whether the sentence was a true description of the order of the letters. If it was, the volunteer

Table 3 Inclusion/exclusion criteria

Is the participant able to chew gum for a period of approximately 45 min?	Yes	**No**
Is the participant aged between 18 and 40 years?	Yes	**No**
Does the participant consume more than 40 units of alcohol per week?	**Yes**	No
Does the participant smoke more than 10 cigarettes in the daytime and evening?	**Yes**	No
Is the participant currently taking any medication?	**Yes**	No
Is the participant currently experiencing any medical problems (including dental problems) or have any serious medical conditions (including phenylketonuria (inability to tolerate phenylanaline *i.e.* additives in foods), diabetes, heart or kidney disease)?	**Yes**	No
Does the participant suffer from any allergic reactions to mint or fruit flavours?	**Yes**	No

Any response to the 'bold' categories excluded the participant from the study.

pressed the T key on the keyboard; if it was not, they pressed the F key. The sentences ranged in syntactic complexity from simple active to passive negative (*e.g.* A is not followed by B). Volunteers carried out the task for 3 min.

3. **Semantic processing task** – This test measured speed of retrieval of information from general knowledge. Volunteers were shown a sentence and had to decide whether it was true (*e.g.* canaries have wings) or false (*e.g.* dogs have wings). The number completed in 3 min was recorded, as was the accuracy of responding.

4. **Delayed free recall task** – After the other tasks, the volunteer had 2 min to write down (in any order) as many of the words as possible from the list shown at the start of these tasks.

5. **Delayed recognition memory task** – At the end of the test session, volunteers were shown a list of 40 words, which consisted of the 20 words shown at the start of the session plus 20 distracters. The volunteers had to decide as quickly as possible whether each word was shown in the original list or not.

PART 2

Unpublished research at New York University has shown that chewing gum may improve the written examination performance of dental students. This was tested here using a test of different types of intellectual functioning (verbal and numerical skills and non-verbal intelligence) that is suitable for university students from a range of disciplines (the Alice Heim 5 test [AH5][24]). Each test session lasted for 20 min and the tests were completed after the delayed recall tests in part 1. In other respects (design, sample size, *etc.*), the study was identical to part 1. Again, a cross-over design with $n = 120$ provides greater power than the original study of gum and test performance in dental students.

Analyses of variance were carried out with the within-subject factor of gum/no-gum and the between subject factor of order of gum conditions.

How do the tests relate to the aims of the study?

1. The story task evaluated whether chewing gum improves learning and memory of text.

2. The mood rating provided an indicator of whether chewing gum increases alertness.

3. The short memory tasks allowed evaluation of whether chewing gum improves episodic memory (immediate and delayed), retrieval of information from general knowledge (semantic memory) and working memory (logical reasoning).

4. The Alice Heim test measures verbal and non-verbal intelligence and allowed one to determine whether chewing gum improves these skills in a test situation.

Statistical analysis

This involved analyses of variance with the within subject factor of gum versus no-gum and the between-subject factors of 'order of gum conditions' and 'when gum chewed' (both learning and test; learning only; test only). Other task-specific factors were included for the different tasks (*e.g.* story recall: immediate versus delayed recall; important versus unimportant information).

Results

The results from the first part of the study are shown in Table 4. The only significant effects of gum were the increased alertness and hedonic tone at the end of the test session.

Table 5 shows the results from the second part of the study. Again, chewing gum was associated with increased alertness at the end of the session and improved performance on the Alice Heim test (significant at the one-tail level).

Discussion

The present study examined four main issues. The first was to examine whether chewing gum improved learning and memory of information in a story. The second aim was to determine whether chewing gum improved test performance on a validated intellectual task (the Alice Heim task). A third aim was to determine whether chewing gum improved performance on short memory tasks (immediate and delayed recall of a list of words, delayed recognition memory, retrieval from semantic memory, and a working memory task). The final aim was to determine whether chewing gum improved mood (alertness, calm and hedonic tone). The results confirmed that chewing gum increased alertness and improved intellectual task performance. This is consistent with the physiological effects of chewing

Table 4 Tests carried out in first week

	No-gum		Gum		
	Mean	SE	Mean	SE	*P*-value
Alertness before tests	242.98	5.06	241.20	5.21	0.76
Hedonic tone before tests	197.98	3.37	195.20	3.43	0.46
Calm before tests	87.30	1.98	90.00	1.82	0.16
Free recall (number correct)	8.32	0.29	8.45	0.27	0.61
Logical reasoning (number done)	42.36	1.49	40.46	1.18	0.07
Logical reasoning (% correct)	85.21	1.37	85.43	1.43	0.87
Semantic memory (number done)	57.15	1.35	56.08	1.38	0.14
Semantic memory (number correct)	53.74	1.48	52.74	1.49	0.21
Delayed recall (number correct)	6.38	0.28	6.10	0.312	0.28
Recognition memory (hits)	15.46	0.26	14.93	0.28	0.09
Recognition memory (hit RT)*	1102.2	39.57	1102.3	45.13	0.94
Recognition memory (false alarms)	4.36	0.29	4.41	0.29	0.84
Recognition memory (false alarms RT)*	1458.5	73.47	1413.6	61.82	0.72
Story – immediate recall (total)	6.14	0.18	6.28	0.18	0.44
Story – immediate recall (unimportant)	2.33	0.09	2.36	0.09	0.88
Story – immediate recall (medium)	1.30	0.07	1.35	0.06	0.22
Story – immediate recall (important)	2.52	0.09	2.56	0.10	0.70
Alertness after tests	**227.57**	**5.23**	**245.55**	**4.66**	**0.002**
Hedonic tone after tests	**186.29**	**3.33**	**193.62**	**3.26**	**0.02**
Calm after tests	85.36	1.80	87.32	1.78	0.27
Story – delayed recall (total)	4.41	0.18	4.36	0.17	0.72
Story – delayed recall (unimportant)	0.90	0.08	0.84	0.09	0.73
Story – delayed recall (medium)	0.91	0.07	0.81	0.06	0.17
Story – delayed recall (important)	2.61	0.10	2.71	0.09	0.54

High scores indicate good performance/mood unless marked with an asterisk.

Table 5 Tests carried out in second week

	No-gum		Gum		
	Mean	SE	Mean	SE	*P*-value
Alertness before testing	236.27	5.12	229.88	5.02	0.27
Hedonic tone before testing	191.60	3.25	192.49	4.31	0.80
Calm before testing	86.76	1.74	86.44	1.93	0.90
Alice Heim – number correct	**13.39**	**0.48**	**13.92**	**0.55**	**0.045 (1-tail)**
Alice Heim – speed	19.22	0.14	19.27	0.16	0.73
Alertness after testing	**222.94**	**5.59**	**236.26**	**5.32**	**0.01**
Hedonic tone after testing	182.11	3.67	186.81	3.27	0.16
Calm after testing	81.16	1.81	81.18	2.01	0.77

gum, which suggest that it increases arousal. Increased arousal benefits intellectual performance and tasks involving selective and sustained attention. Smith[9] has shown that chewing gum increases the speed of encoding of new information and he has suggested that this may reflect changes in cholinergic function. Episodic memory may be impaired by high arousal and it is possible that the absence of memory effects in the present study reflect opposing effects of chewing on different stages of information processing. This could plausibly account for the variability in results from studies of chewing gum and recall of lists of words.

In contrast to effects of chewing gum on memory, the alerting effects of chewing appear to be extremely robust. Indeed, subjective alertness can now be used as a positive control to determine the sensitivity of studies examining other functions. Further research is now required to determine the practical implications of the alerting effect of chewing gum and to understand the brain mechanisms that underlie such changes. However, the alerting effects of chewing gum are consistent with results from EEG studies[13,14] and it has been suggested that chewing gum activates at least two types of mechanism, one related to the chewing and the other to the flavour of the gum.[14,15,25] Studies measuring EMG confirm that EMG activity in particular facial muscles is related to the mobilization of energetic resources.[16] Mastication also has effects on both sympathetic and parasympathetic activity.[17]

Studies of brain imaging also demonstrate that chewing activates wide-spread regions of the brain.[18–21] Other research has demonstrated that chewing gum influences neurotransmitter function, specifically the 5-HT descending inhibitory pathway.[22]

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