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Chewing gum and context-dependent memory: The independent roles of chewing gum and mint flavour

Andrew J. Johnson* and Christopher Miles
Cardiff University, School of Psychology, Cardiff, UK

Two experiments independently investigated the basis of the chewing gum induced context-dependent memory effect. At learning and/or recall, participants either chewed flavourless gum (Experiment 1) or received mint-flavoured strips (Experiment 2). No context-dependent memory effect was found with either flavourless gum or mint-flavoured strips, indicating that independently the contexts were insufficiently salient to induce the effect. This is found despite participants' subjective ratings indicating a perceived change in state following administration of flavourless gum or mint-flavoured strips. Additionally, some preliminary evidence for a non-additive facilitative effect of receiving gum or flavour at either learning and/or recall is reported. The findings raise further concerns regarding the robustness of the previously reported context-dependent memory effect with chewing gum.

The effect of chewing gum on the performance and cognitive state of the participant has been shown to be both contradictory and difficult to replicate (e.g. the effect of chewing gum on calorific intake; Hetherington & Boyland, 2007; Julis & Mattes, 2007). This inconsistency is mirrored with respect to the effect of chewing gum on immediate and delayed word recall (e.g. Wilkinson, Scholey, & Wesnes, 2002; Stephens & Tunney, 2004; Tucha, Mecklinger, Maier, Hammerl, & Lange, 2004). For instance, Wilkinson *et al.* (2002) showed that chewing gum led to improved performance on both immediate and delayed word recall. They proposed that memorial facilitation is governed by increased blood flow to the fronto-temporal brain regions via the process of mastication. Such a proposal is consistent with fMRI studies demonstrating activation of the prefrontal cortex (Fang, Li, Lu, Gong, & Yew, 2005) and increases in neural blood oxygenated level-dependent (BOLD) signals following gum chewing (Onozuka *et al.*, 2002). Furthermore, this proposal is compatible with the observation of significantly raised heart rates for chewing participants relative to controls (Farella, Bakke, Michelotti, Marotta, & Martina, 1999; Wilkinson *et al.*, 2002). In contrast, however, Stephens and Tunney (2004)

* *Correspondence should be addressed to Andrew Johnson, Cardiff University, School of Psychology, Park Place, Cardiff, UK (e-mail: JohnsonAJ@Cardiff.ac.uk).*

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hypothesized that chewing-induced memorial facilitation is governed via enhanced cerebral glucose delivery. They showed that chewing gum and drinking a glucose solution (compared to sucking a mint and drinking water) improved word recall at immediate but not delayed testing. This finding suggests that another mechanism is required to explain the long-term episodic memory facilitation observed by Wilkinson *et al.* (2002).

In contrast to the above findings, replication of the facilitative effect of chewing gum has proved to be problematic. For instance, Tucha *et al.* (2004) instructed participants to learn a list of 15 nouns whilst chewing spearmint gum, chewing flavourless gum, sham chewing or not chewing. Following a 40-minute retention interval, memory for the words was not improved through any of the chewing conditions. Scholey (2004) argued that Tucha *et al*'s failure to observe a memorial benefit might be explained through a shift in context. He suggested that following the 40-minute retention interval in which participants chewed the same piece of gum, the texture of the gum changed sufficiently to induce a context-shift between learning and recall. During learning it has been argued that, in addition to the to-be-remembered items, participants encode the learning context; reinstatement of that context at recall facilitates retrieval (e.g. Godden & Baddeley, 1975; Goodwin, Powell, Bremer, Hoine, & Stern, 1969; Miles & Hardman, 1998). In the Tucha *et al.* (2004) study, disparate chewing contexts between learning and recall may have acted to inhibit memorial facilitation. This idea was explored directly by Baker, Bezance, Zellaby, and Aggleton (2004, Experiment 1) who instructed participants to either chew spearmint-flavoured gum or not, whilst learning a 15-word list. Immediate free recall followed whilst either chewing gum or not. All participants returned 24 hours later and free recalled in the same gum recall condition as Day 1. Although there was no evidence of a context shift at immediate recall, a memory benefit for the gum–gum group was observed at delayed (24 hours) recall.

However, the chewing gum induced context-dependent memory effect demonstrated by Baker *et al.* has proven difficult to replicate. In a very close methodological replication of that study, Johnson and Miles (2007) failed to observe a context-dependent memory effect at either immediate or delayed recall, nor did they observe memorial facilitation through chewing gum at learning. One explanation for this disparity in findings cites chance differences in the populations sampled in the between-participants designs employed by both studies. This possibility was explored directly by Miles and Johnson (2007) where participants performed each of the four context conditions in a counterbalanced within-participants design. In two experiments, despite minimal evidence of intrusion errors across recall conditions, no context-dependent memory advantage was observed when participants learned and recalled with gum.

That the context-dependent memory effect for delayed recall observed by Baker *et al.* (2004) may not be due to chewing gum *per se*, but rather, due to the intense initial spearmint flavour of the gum has been suggested by Johnson and Miles (2007). On Day 1 of the Baker *et al.* (2004) study, participants in the gum/gum group received the gum and were then immediately given the words to learn. At immediate recall participants in the gum/gum group continued chewing the same piece of gum. Therefore, during Day 1 learning, participants chewed gum with an intense initial spearmint flavour. However, at the immediate recall phase it is likely that both the intensity of the mint flavour and the texture of the gum had diminished, thereby explaining the absence of a context-dependent memory effect at immediate recall. On Day 2, participants in the gum/gum group received a fresh piece of gum and then recalled the previously presented word list. As participants received a fresh piece of

gum, the intense spearmint flavour present at learning was reinstated, and thereby the original learning context. We argue that this reinstatement of context in the delayed recall condition underpinned the beneficial recall observed. Indeed, some evidence exists for the role of mint flavour in memorial facilitation. For instance, Baker *et al.* (2004, Experiment 2) reported superior recall following the sucking of gum at both learning and recall compared to those who did not suck gum at learning but did at recall. Moreover, Stephens and Tunney (2004) argue that this finding may be due to 'the general arousing effect of flavouring (mint)', concluding a need to 'examine the effects of flavour on cognitive functions, while controlling all other variables' (p. 218).

To date, there have been limited attempts to examine the independent roles of flavour and chewing in producing the context-dependent memory effect. In Baker *et al.* (2004), it is unclear whether the context-dependent memory effect is underpinned by flavour or the act of chewing. The present study independently manipulates the presence of chewing flavourless gum (Experiment 1) and the presence of mint-flavoured strips (Experiment 2) at both learning and recall in order to examine their independent and combined contributions.

One important methodological feature absent from previous studies investigating chewing gum and context-dependent memory concerns independent evidence demonstrating the subjective perception that a context shift has indeed occurred. Consider the study by Miles and Hardman (1998) in which participants learned a list of words while pedalling a pedal ergometer. Learning in the pedal ergometer exercise condition only commenced once the heart rate had reached approximately double the normal resting level. Employment of an internal metric (heart rate) allowed the authors to observe the presence of an internal context (or state) shift. In addition, Miles and Hardman (1998) found that greater proportional heart rate changes in the inconsistent conditions were associated with greater word recall impairments. In the current studies, we collected additional self-rating data from participants. This was achieved by requiring participants to provide ratings devised to measure the extent to which the act of chewing flavourless gum or having the mint-flavoured strip altered the participants' subjective assessment of their state. These ratings were taken at baseline, post-learning, and post-recall in order to demonstrate that participants experienced different states at each experimental stage. The inclusion of ratings is a necessary addition for two reasons. Firstly, if an apparent context-dependent effect is observed then subjectively perceived contexts shifts help support the hypothesis that the effect was underpinned through reinstatement of learning context at recall. Secondly, in the absence of a context-dependent memory effect, subjective ratings help to elucidate the extent to which the null finding was due to a shift in context not being perceived or whether the context of chewing flavourless gum/receiving mint strips was insufficient to produce the effect.

EXPERIMENT 1

Experiment 1 replicated the Johnson and Miles (2007) methodology with two exceptions. Firstly, to assess the role of chewing independently of flavour, Wrigley's flavourless gum was employed. Secondly, ratings of perceived mouth activity were taken at three stages on Day 1 and two stages on Day 2, in order to assess the subjective perception of a context shift.

Method

Participants

Ninety-six (17 males and 79 females, mean age 20 years and 5 months) Cardiff University undergraduates from a variety of disciplines participated. Each was randomly assigned to one of the four experimental groups.

Materials

Each participant was given a single list of 15 disyllabic nouns printed on a single sheet of paper. The 15 disyllabic nouns were matched on scores of frequency and imagine-ability (Morrison, Chappell, & Ellis, 1997). Four different word orders were employed and were randomly distributed amongst the participants. In all gum conditions, participants were provided with Wrigley's flavourless gum.

Design

The design followed that described by Johnson and Miles (2007) such that the four experimental groups differed with respect to whether they were instructed to chew gum at learning and/or recall. A three-factor ($2 \times 2 \times 2$) mixed design was employed. The first between-participants factor concerned whether participants were instructed to chew gum at learning (gum vs. no gum), the second between-participants factor concerned whether participants were instructed to chew gum during word recall (gum vs. no gum), and the within-participants factor compared retention interval (immediate recall vs. recall following 24 hours). The between-participants manipulation generated four groups (gum/gum, gum/no gum, no gum/no gum, and no gum/gum).

Procedure

The procedure followed very closely that was described by Johnson and Miles (2007). Participants were told that the experiment was a measure of word recall rates and were not informed that the study aimed to assess the effect of chewing gum on context-dependent memory and memorial facilitation. Participants were instructed that they would be required to learn a list of 15 words and were informed in advance whether they would have to chew gum at learning and/or recall.

On Day 1, upon entering the laboratory, all participants were given glass of water and asked to provide a Likert rating with respect to the extent of current mouth activity/chewing on a scale of 1–7 (with 1 = 'no at all' and 7 = 'extremely'). A 15-second initiation interval preceded learning. All participants were then presented with the 15-word list on a piece of A4 paper and given 2-minute learning time in which to study the list and learn as many words as possible. Following the 2-minute learning phase, all participants were instructed to provide another rating with respect to the extent of current mouth activity/chewing. Participants were then given another glass of water and given a 1-minute rest period. Another 15-s initiation phase then followed. Participants were then given 2 minutes to write down on a piece of paper as many of the 15 words that they could remember. Following recall participants provided a final chewing/mouth activity rating.

Participants returned 24 hours later. On entering the laboratory, they were given a glass of water and were asked to provide a baseline rating of mouth activity/chewing. A 15-s initiation interval was then employed. Participants were then given 2 minutes to

write down on a piece of paper as many of the 15 words that they could remember from the Day 1 learning phase. Following the recall phase, participants provided a final rating of mouth activity/chewing. Participants were unaware that they would be required to recall the words 24 hours later.

The specific procedures for the four between-participant groups are detailed below.

(1) Gum–gum (G/G): After the initial mouth activity rating, the participant was given a piece of flavourless gum and instructed to chew throughout the 15-second initiation phase and the 2-min learning phase. Following the post-learning mouth activity rating, the gum was removed. After the 1-minute rest period, the participant was given a new piece of chewing gum and instructed to chew throughout the second initiation phase and throughout the 2-minute recall phase. Following the final mouth activity rating, the gum was removed.
(2) Gum–no gum (G/NG): The learning phase was identical to that described for the G/G group. Following the 1-minute rest period, participants were not given any chewing gum and were instructed to sit in silence throughout the second 15-second initiation phase and then perform the recall phase without chewing.
(3) No gum–no gum (NG/NG): After the initial mouth activity rating, the participant was not given any flavourless gum and was instructed to sit in silence throughout the 15-second initiation phase. No gum was provided during the 2-minute learning phase. The recall phase was identical to that described for G/NG, with no gum given at recall.
(4) No gum–gum (NG/G): Both the learning and recall phases were identical to those described for the NG/NG group and the G/G group, respectively.

Results

Rating data

In order to assess the extent to which participants were sensitive to the context shift, ratings for mouth activity/chewing were compared across the four gum groups (gum/gum, gum/no gum, no gum/no gum, and no gum/gum) at both Days 1 and 2. Figure 1 demonstrates the mean ratings on Day 1 across the four gum groups.

For Day 1, a single-factor within-participants ANOVA with three levels was computed for each of the four gum groups comparing the baseline rating with the rating immediately post-learning and immediately post-recall. The ANOVAs revealed a main effect of rating for the gum/gum ($F(2, 46) = 131.69$, MSe $= 0.36$), the gum/no gum ($F(2, 46) = 1,373.86$, MSe $= 0.07$), and the no gum/gum condition ($F(2, 46) = 266.92$, MSe $= 0.28$). The no gum/no gum condition produced a null effect of rating ($F = 1.82$). The finding is consistent with the predicted effect of the manipulation; with the no gum/no gum condition the only group not experiencing a context shift. Further analysis (Newman–Keuls; $p < .05$) supported this manipulation with all mouth activity ratings in the gum groups significantly greater than ratings in the no gum groups.

Day 2 mouth activity ratings were assessed through computing the proportional change in rating between the baseline rating and the rating immediately following recall (post-recall rating divided by baseline rating). Since participants either received flavourless gum during Day 2 recall or not, a *t* test was computed

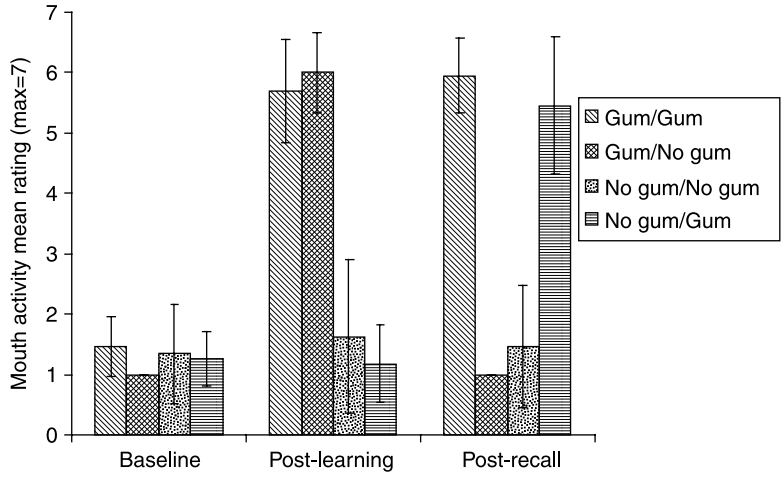

Figure 1. Mean mouth activity/chewing ratings for the four gum conditions (gum/gum, gum/no gum, no gum/no gum, and no gum/gum) following the three rating stages on Day 1.

comparing the proportional changes between baseline and post-recall for those who received gum at recall (mean proportional shift = 4.15) and those who did not (mean proportional shift = 1.02). The proportional shift was found to be significantly greater for those who received gum at recall, $t(94) = 11.86$, $p < .05$. The significant effect is once again consistent with the predicted effect of the manipulation, with a shift in mouth activity ratings experienced by the gum, but not the no gum, group.

Recall

Following the observation of a subjectively perceived shift in internal context with respect to mouth activity, recall data were analysed for each group. Figure 2 demonstrates the mean percentage total number of words recalled at immediate and delayed testing in the four learning/recall group.

The facilitative effect of chewing gum was investigated through a 2 × 2 × 2 mixed design ANOVA, where the first factor refers to whether participants received gum at learning (gum vs. no gum), the second factor whether participants received gum at recall (gum vs. no gum,) and the third factor retention interval between learning and test (immediate vs. delay).

The ANOVA revealed a null effect of receiving gum at learning, $F = 2.62$. However, a significant main effect of receiving gum at recall was observed, $F(1, 92) = 7.37$, MSe = 1.43, $p < .05$; means = 70.6 and 61.7% for the gum and no gum groups, respectively. Additionally, immediate recall scores were significantly greater than delayed recall scores, $F(1, 92) = 240.10$, MSe = 1.43, $p < .05$; means = 75.1 and 57.2% for immediate and delayed conditions, respectively.

The effect of chewing gum at recall was modified by the significant interaction between the effect of gum at learning and gum at recall, ($F(1, 92) = 4.34$, MSe = 1.43, $p < .05$). Further analysis (Newman–Keuls; $p < .05$) revealed that the interaction was due to poor performance in the no gum/no gum group, with performance between the gum/gum and inconsistent gum groups equivalent.

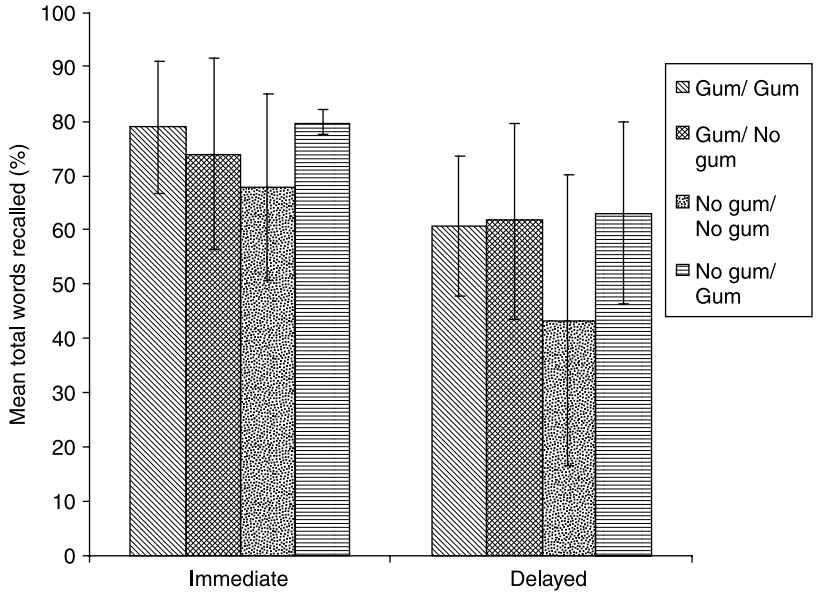

Figure 2. Mean percentage number of words recalled after a 2-minute retention interval (immediate) or after 24 hours (delayed). The participants either chewed flavourless gum at both learning and recall (gum–gum), chewed gum at learning but not at recall (gum–no gum), neither chewed gum at learning or recall (no gum–no gum) or did not chew gum at learning but did at recall (no gum–gum). Errors bars denote 1 *SD*.

Additionally, a significant interaction between the effect of gum at learning and retention interval was observed ($F(1, 92) = 5.53$, MSe $= 1.43$, $p < .05$). Further analysis (Newman–Keuls; $p < .05$) revealed that the interaction was due to large decrements between the gum and no gum learning groups on Day 2 (specifically gum recall = 61.3% and no gum recall = 53.2%). The interaction between gum at recall and retention interval was non-significant ($F < 1$).

In conclusion, Experiment 1 indicates that the act of chewing gum *per se* (i.e. without flavour) is an insufficiently salient context to produce a context-dependent memory effect. Such a result is consistent with the previous findings of both Johnson and Miles (2007) and Miles and Johnson (2007). This is despite the subjective mouth activity ratings showing that participants perceived a significant shift in context as assessed by chewing activity. Contrary to Baker *et al.* (2004), Experiment 1 also failed to find a facilitative effect of chewing gum at learning on subsequent recall.

EXPERIMENT 2

Experiment 2 investigates whether the chewing gum induced context-dependent memory effect reported by Baker *et al.* (2004) was driven not by chewing *per se* but rather, through the intense mint flavour of the gum (as proposed by Johnson & Miles, in 2007). Experiment 2 therefore replicated the methodology of Experiment 1 with the exception that mint-flavoured strips were used rather than flavourless gum.

Method

Participants

Ninety-six (35 males and 61 females, mean age 22 years and 1 month) Cardiff University undergraduates from a variety of disciplines participated. Each was randomly assigned to one of the four experimental groups. None had participated in Experiment 1.

Materials

Materials were identical to those used in Experiment 1, with the exception that Wrigley's Extra Thin Ice spearmint-flavoured micro-strips were used rather than flavourless gum.

Design

The design was identical to Experiment 1, such that four experimental groups differed with respect to whether they received mint-flavoured strips at learning and/or recall.

Procedure

Experiment 2 followed the same procedure as described for Experiment 1, with two exceptions. Firstly, participants were given mint-flavoured strips rather than flavourless gum. Secondly, participants were instructed to rate mint intensity on a five-point Likert scale where 1 = not at all, 2 = slightly, 3 = moderately, 4 = substantially, and 5 = extremely.

Results

Ratings data

As in Experiment 1, the effectiveness of the flavour manipulation was assessed via participant mint intensity ratings recorded at three stages of Day 1 testing and at two stages of Day 2 testing. Figure 3 demonstrates the mean mint intensity ratings on Day 1 across the four flavour groups.

For Day 1, a single-factor within-participants ANOVA with three levels was computed for each of the four flavour groups comparing the baseline rating with the rating immediately post-learning and immediately post-recall. The ANOVA revealed a main effect of rating for the flavour/flavour ($F(2, 46) = 96.81$, MSe = 0.31), the flavour/no flavour ($F(2, 46) = 200.57$, MSe = 0.17), and the no flavour/flavour conditions ($F(2, 46) = 166.15$, MSe = 0.26). Inexplicably, a main effect of rating is also observed in the no flavour/no flavour condition, despite participants receiving no flavour at any experimental juncture ($F(2, 46) = 9.78$, MSe = 0.14). It should though be noted that the F value is far smaller for the NF/NF group than that of the other three groups.

Further analysis (Newman–Keuls; $p < .05$) of the flavour/flavour group reveals that mint intensity ratings after both learning and recall were significantly greater than the baseline ratings. Additionally, post-learning ratings were significantly greater than the post-recall ratings. Since flavour was provided at both learning and recall, the finding suggests evidence of subjectively perceived habituation to the flavour. In the flavour/no flavour group, despite significantly higher mint ratings post-learning than recall, ratings were still greater post-recall compared with baseline despite no flavour being provided at recall. The finding suggests evidence of flavour endurance from the learning to the

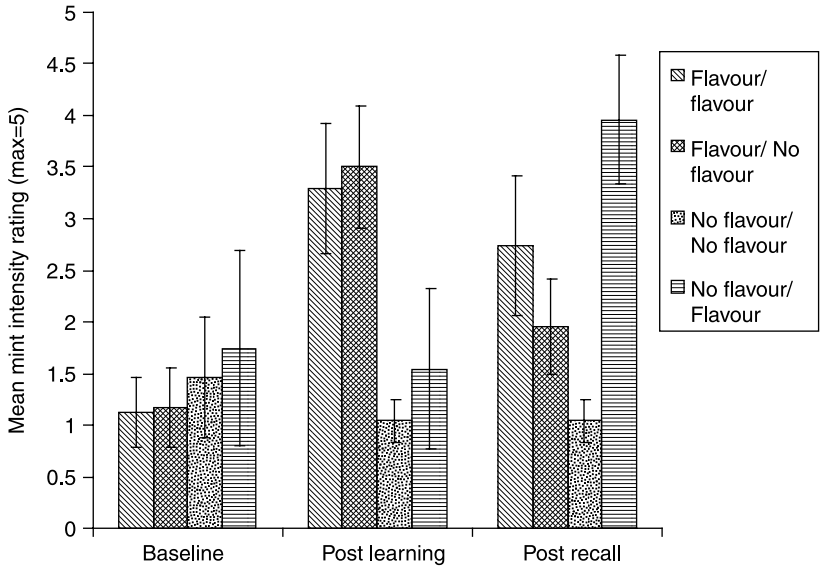

Figure 3. Mean mint flavour intensity ratings for the four flavour conditions (flavour/flavour, flavour/no flavour, no flavour/no flavour, and no flavour/flavour) following the three rating stages on Day 1.

recall phase, despite flavour not being given at recall. Further analysis of the no flavour/no flavour rating effect demonstrate the baseline rating to be significantly greater than both the post-learning and post-recall ratings. Importantly for this control group, however, there is a non-significant difference between the post-learning and post-recall rating, indicating no perceived shift in context between learning and recall. Consistent with the manipulation, the no flavour/flavour group exhibited a non-significant difference between the baseline and post-learning ratings. However, following flavour at recall, the post-recall ratings were significantly greater than both baseline and post-learning demonstrating a shift in flavour context.

As in Experiment 1, on Day 2 of the experiment participants either received the flavour or not depending on their recall condition on Day 1. Therefore, in order to assess the flavour manipulation on Day 2, ratings were collapsed to form two groups: those who received flavour at test on Day 2 (flavour/flavour and no flavour/flavour) and those who did not (flavour/no flavour and no flavour/no flavour). As in Experiment 1, perceived shift in context was assessed through an independent t test comparing proportional change in rating between Day 2 baseline and post-recall for the group who received the flavour (mean proportional shift = 2.97) and the group who did not (mean proportional shift = 0.90). The analysis revealed the shift to be significantly greater for those who received the flavour on Day 2, $t(94) = 14.50$, $p < .05$.

Recall data

As in Experiment 1, word recall data for each group were compared to assess the extent to which the flavour at learning and/or recall mediated accuracy. Figure 4 demonstrates the mean percentage total number of words recalled at immediate and delayed testing in the four learning/recall groups.

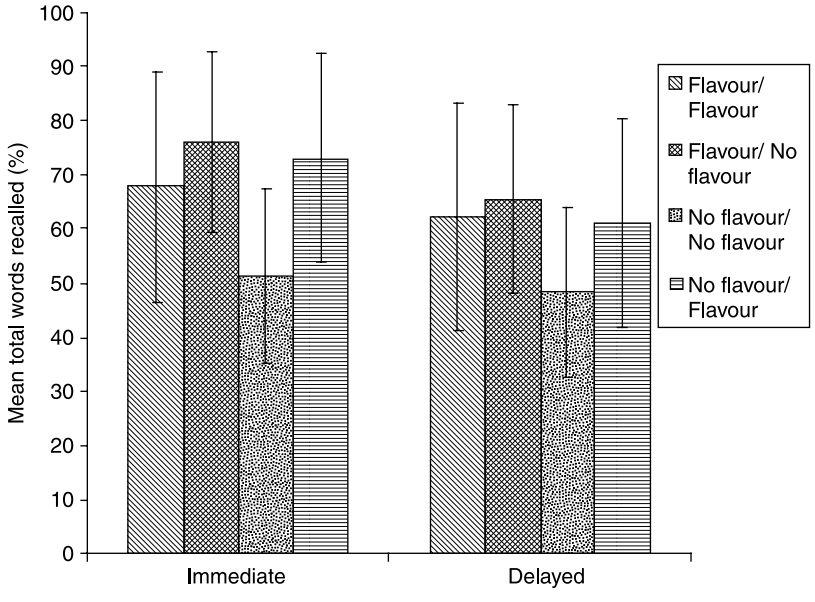

Figure 4. Mean percentage number of words recalled after a 2-minute retention interval (immediate) or after 24 hours (delayed). The participants either received the mint flavour at both learning and recall (flavour/flavour), received the mint flavour at learning but not at recall (flavour/no flavour), neither received the mint flavour at learning or recall (no flavour/no flavour) or did not received the mint flavour at learning but did at recall (no flavour/flavour). Errors bars denote 1 *SD*.

The facilitative effect of flavour was investigated through a 2 × 2 × 2 mixed design ANOVA comparing the effect of flavour at learning (flavour vs. no flavour), the effect of receiving flavour at recall (flavour vs. no flavour), and the effect of retention interval (immediate vs. delayed recall).

The ANOVA revealed a main effect of receiving flavour at learning ($F(1, 92) = 6.71$, MSe = 0.92, $p < .05$); mean = 67.9 and 58.47% for the flavour and no flavour groups, respectively. There was a non-significant effect of receiving the flavour at recall ($F = 2.44$, $p = .12$). Additionally, immediate recall scores were significantly greater than those for delayed recall, ($F(1, 92) = 71.10$, MSe = 0.92, $p < .05$); means = 67.08 and 59.31% for immediate and delayed conditions, respectively.

The effect of receiving flavour at learning was modified by the significant interaction between the effect of receiving the flavour at learning and whether participants received the flavour at recall ($F(1, 92) = 10.00$, MSe = 0.92, $p < .05$). Further analysis (Newman–Keuls; $p < .05$) revealed that the interaction was due to significantly inferior recall for the no flavour/no flavour group, rather than due to overall superior recall for the flavour/flavour group. The interactions between flavour at learning and retention interval and between flavour at recall and retention interval both failed to achieve significance (Fs < 1 and 1.11, respectively).

Combined analysis of Experiments 1 and 2

In order to assess the extent to which chewing gum *per se* or receiving a mint-flavoured strip *per se* affected performance levels differentially, the data for Experiments 1 and 2

were combined and analysed via a four-factor (2 × 2 × 2 × 2) mixed design ANOVA, where the first between-participants factor was experiment (flavourless gum vs. mint-flavoured strips), the second between-participants factor was manipulation at learning (gum/flavour vs. no gum/no flavour), and the third between-participants factor was manipulation at recall (gum/flavour vs. no gum/no flavour). The within-participants factor was retention interval (Day 1 recall vs. Day 2 recall).

The ANOVA revealed a null effect of Experiment, $F = 1.44$; mean recall = 66.2 and 63.2% for Experiments 1 and 2, respectively. Significant main effects of gum/flavour at learning ($F(1, 184) = 9.04$, MSe = 1.18, $p < .05$; means = 68.4 and 61.0% for the groups who did and did not have gum/flavour at learning, respectively), gum/flavour at recall ($F(1, 184) = 8.88$, MSe = 1.18, $p < .05$; means = 68.3 and 63.2% for the groups who did and did not have gum/flavour at recall, respectively), and retention interval ($F(1, 184) = 301.57$, MSe = 1.18, $p < .05$; means = 71.1 and 58.3% for Days 1 and 2, respectively) were reported. A significant interaction between groups who received gum or flavour at learning and groups who received gum or flavour at recall was observed, $F(1, 84) = 14.00$, MSe = 1.18, $p < .05$. This finding is not, however, theoretically important in a context-dependent memory framework as further analysis (Newman–Keuls; $p < .05$) reveal that this interaction is underpinned through significantly inferior recall for the groups that never received gum and never received flavour (i.e. NG/NG and NF/NF). Additionally, a significant interaction between experiment and retention interval was found, $F(1, 184) = 46.57$, MSe = 1.18, $p < .05$. Further analysis (Newman–Keuls; $p < .05$) indicates that the effect is driven through superior Day 1 recall levels for the flavourless gum experiment, with statistically equivalent Day 2 recall levels. This effect appears to be an artefact of poor Day 1 recall for the no flavour/no flavour group (mean recall = 51.4%) compared with that of the no gum/no gum group (mean recall = 67.8%).

Discussion

The two experiments reported here assessed the extent to which the context-dependent memory effect reported with spearmint chewing gum (Baker *et al.*, 2004) was governed by the context of either chewing (Experiment 1) or flavour (Experiment 2). However, consistent with the inability to replicate the chewing gum context-dependent memory effect (Miles & Johnson, 2007; Johnson & Miles, 2007), neither Experiment 1 nor 2 demonstrated a context-dependent memory effect with either flavourless gum or flavoured mint strips, respectively. That is, in neither Experiment 1 nor Experiment 2 did the consistent groups (G/G and F/F, respectively) produce word recall rates significantly greater than the inconsistent groups. In Johnson and Miles, it was proposed that the chewing gum context-dependent memory effect reported by Baker *et al.* was an artefact of Day 2 recall reinstating the intense flavour condition present on Day 1 learning. This hypothesis was investigated in Experiment 2, where flavour was manipulated independently of chewing. The findings demonstrate that the mint flavour was insufficient to produce a context-dependent memory effect.

One might argue that the independent effect of flavour and chewing gum may be insufficient to produce the context-dependent memory effect. However, in combination a more powerful context may be constructed thereby facilitating recall. This is clearly not the case as evidenced by the results of both Miles and Johnson (2007) and Johnson and Miles (2007) who were unable to replicate the context-dependent effect reported by Baker *et al.* (2004) using flavoured gum. Although overall recall levels for Johnson and

Miles (2007) of 70.2% are marginally greater than both Experiment 1 (mean recall = 66.2%) and Experiment 2 (mean recall = 63.2%) reported here, that did not of itself produce a context-dependent memory effect.

A fundamental unknown across the chewing gum context-dependent memory studies concerns the extent to which the chewing of gum was sufficient to induce a context/state perceptually different from the non-chewing condition. In contrast to Baker *et al.* (2004), Johnson and Miles (2007), and Miles and Johnson (2007), the present study assessed the extent to which the manipulated context was both induced and eradicated. In Experiment 1, participants rated their perceived degree of mouth activity: taken as an index of the chewing context. These ratings demonstrated that the manipulation was successful in producing a perceived subjective shift in mouth activity when flavourless gum was given. The ratings also suggest that this context was eradicated when the gum was not given, as evidenced by the significant attenuation in mouth activity ratings. Similarly, the mint intensity ratings in Experiment 2 suggest that receiving the flavour on Day 1 was successful in producing an intense mint flavour within the mouth. This is also evident on Day 2 with significantly higher mint intensity ratings for the flavour group relative to those who did not receive flavour.

However, when flavour is not given at recall, i.e. the flavour/no flavour group, there is significantly higher ratings post-recall relative to the baseline rating. This finding suggests that the mint flavour did not attenuate completely at test in the flavour/no flavour group. Thus, the flavour context may have been unintentionally reinstated at recall with the condition becoming a *de facto* flavour/flavour group on Day 1. This may explain why Day 1 recall for flavour/no flavour is not significantly different from that of flavour/flavour. However, this hypothesis is inadequate in explaining both the non-significant difference between flavour/no flavour and flavour/flavour on Day 2 and the non-significant difference between no flavour/flavour and flavour/flavour on Day 1. Even accepting that the insufficiently dissipated context on Day 1 in the flavour/no flavour condition produced a *de facto* flavour consistent context, this does not hold for Day 2 where no mint was given and recall was not significantly lower than the flavour/flavour group. Since participants in this group learnt with flavour, the recall context on Day 2 is undoubtedly inconsistent with Day 1 learning. However, despite this flavour context inconsistency between learning and recall, Day 2 recall remains very similar to that of the consistent flavour group (flavour/flavour).

Moreover, in the no flavour/flavour group, flavour attenuation is not an issue since the flavour was only introduced at recall. Mint intensity ratings were significantly higher post-recall for this group compared with ratings post-learning. Despite this inconsistency between learning and recall on both Days 1 and 2, recall rates were similar to that of the consistent flavour group (flavour/flavour). These mint intensity ratings serve to further emphasize the finding that although the manipulation was successful in inducing a shift in internal context, this was insufficient in producing a context-dependent memory effect.

Nevertheless, for both experiments, there is evidence that receiving either flavourless gum or mint-flavoured strips at some stage within the experiment facilitated recall. Throughout both Experiments 1 and 2, poorest recall levels were evidenced in those conditions where participants received neither gum nor mint-flavoured strips. This very preliminary finding might indicate that both chewing gum and receiving a mint flavour at either learning or recall (or both) can exert a general benefit in the learning or recall of word lists. Such a demonstration is important since chewing gum and flavour have not previously been independently investigated within this paradigm.

This preliminary finding is consistent with other demonstrations of chewing gum and mint flavour facilitating memory (e.g. Baker *et al.*, 2004; Stephens & Tunney, 2004; Wilkinson *et al.*, 2002). It remains unclear what underpins this effect (or even whether both chewing gum and receiving flavour facilitate recall through analogous processes), with further research necessary to ascertain the extent to which, for example, arousal levels increase through these chewing gum or receiving flavour. From a physiological perspective, the effect of chewing gum on memory performance is an intuitive finding, since it has been demonstrated that chewing gum acts to increase both cerebral blood flow (Fang *et al.*, 2005; Onozuka *et al.*, 2002) and heart rate (Farella *et al.*, 1999).

There are, however, two important caveats to this finding. The first is that the memorial facilitation induced through chewing gum or receiving flavour does not act additively. If the effect was cumulative one would predict poorest performance for those groups where the context is absent at both learning and recall (i.e. NG/NG and NF/NF). Conversely, one would predict superior performance for the inconsistent context groups (i.e. G/NG, NG/G, F/NF, and NF/F) and additionally, highest recall rates for the groups with the context at both learning and recall (i.e. G/G and F/F). This pattern of effects was not apparent. It is possible that a facilitation ceiling may therefore exist for the benefit of flavour and chewing gum, where, once reached, additional exposure to chewing gum and flavour elicits no further benefit. The second caveat comes from the finding that, in our laboratory at least, this non-additive facilitative benefit of receiving gum is not a robust one. In Johnson and Miles (2007), for instance, superior recall was found for the no gum/no gum group relative to the three other groups at both immediate and delayed testing. This finding may serve to highlight the limitation of employing a between-participants design. However, in a within-participants adaptation of the Baker *et al.* (2004) methodology, Miles and Johnson (2007) reported no significant differences between the gum conditions at immediate recall, therefore, removing the possibility of group differences confounding the scores.

In conclusion, Experiments 1 and 2 show that neither chewing flavourless gum nor receiving a mint-flavoured strip were sufficiently salient internal contexts to produce a context-dependent memory effect. The findings cast further doubts upon the robustness of the effect reported by Baker *et al.* (2004) and support the null findings of Johnson and Miles (2007) and Miles and Johnson (2007). In addition, Experiment 2 shows that the context-dependent memory effect reported by Baker *et al.* (2004) was not an artefact of intense mint flavour. These experiments are the first in this area of research to assess the extent to which the context had been subjectively experienced. Both Experiments 1 and 2 provided some evidence that participants perceived a subjective change in context in regard to mouth activity (Experiment 1) and mint intensity (Experiment 2), respectively. Experiments 1 and 2 demonstrated that receiving either flavourless gum or mint-flavoured strips at learning did not facilitate subsequent recall. There was, however, some evidence of a non-additive, facilitative effect of receiving either gum or flavour at some juncture in the experimental procedure on recall levels. However, both the origins and robustness of this finding necessitate further investigation.

References

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

Fang, M., Li, J. C., Lu, G., Gong, X. Y., & Yew, D. T. (2005). A fMRI study of age-related differential cortical patterns during cued motor movement. *Brain Topography*, *17*(3), 127–137.

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*, 835–842.

Godden, D. R., & Baddeley, A. D. (1975). Context dependent memory in two natural environments: On land and under water. *British Journal of Psychology*, *66*, 325–332.

Goodwin, D. R., Powell, B., Bremer, D., Hoine, H., & Stern, J. (1969). Alcohol and recall: State dependent effects in man. *Science*, *163*(#3873), 1358–1360.

Hetherington, M. M., & Boyland, E. (2007). Short-term effects of chewing gum on snack intake and appetite. *Appetite*, *48*(3), 397–401.

Johnson, A. J., & Miles, C. (2007). Evidence against memorial facilitation and context-dependent memory effects through the chewing of gum. *Appetite*, *48*, 394–396.

Julis, R. A., & Mattes, R. D. (2007). Influence of sweetened chewing gum on appetite, meal patterning and energy intake. *Appetite*, *48*(2), 167–175.

Miles, C., & Hardman, E. (1998). State-dependent memory produced by aerobic exercise. *Ergonomics*, *41*(1), 20–28.

Miles, C., & Johnson, A. J. (2007). Chewing gum and context dependent memory: A re-examination. *Appetite*, *48*(2), 154–158.

Morrison, C. M., Chappell, T. D., & Ellis, A. W. (1997). Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *Quarterly Journal of Experimental Psychology*, *50A*(3), 528–559.

Onozuka, M., Fujita, M., Watanabe, K., Hirano, Y., Niwa, M., Nishiyama, K., *et al.* (2002). Mapping brain region activity during chewing: A functional magnetic resonance imaging study. *Journal of Dental Research*, *81*(11), 743–746.

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

Stephens, R., & Tunney, R. J. (2004). Role of glucose in chewing gum-related facilitation of cognitive function. *Appetite*, *43*(2), 211–213.

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.

Wilkinson, L., Scholey, A., & Wesnes, K. (2002). Chewing gum selectively improves aspects of memory in healthy volunteers. *Appetite*, *38*, 235–236.

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