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Short Communication

Chewing gum selectively improves aspects of memory in healthy volunteers

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Many people chew gum partly due to the belief that it increases aspects of mental performance, including concentration. To the best of our knowledge no empirical evidence exists to support this contention. The present experiment, therefore, examined the effects of chewing gum using a comprehensive and sensitive cognitive assessment battery and two tasks manipulating cognitive load. Heart rate responses were also measured.

Seventy-five healthy adult participants (mean age 24·6 years) were randomly assigned to one of three experimental conditions ($N = 25$ per group): "*chewing*" – a piece of sugar-free chewing gum (Wrigley's Extra Spearmint) was chewed naturally and constantly throughout the procedure; "*sham chewing*" – participants mimicked chewing movements in the absence of gum; "*quiet control*" – no chewing behaviour was performed.

Aspects of attention, working memory and long-term memory were assessed using the Cognitive Drug Research (CDR) computerised battery. Stimuli were presented on a colour monitor and, except for two written word recall tasks, responses were collected automatically using a "Yes"/"No" response module. The tasks were presented in the order: Word presentation, Immediate Word Recall, Picture Presentation, Simple Reaction Time, Digit Vigilance, Choice Reaction Time, Spatial Working Memory, Numeric Working Memory, Delayed Word Recall, Word Recognition and Picture Recognition (for details, e.g. see Kennedy *et al*. 2000). Following the CDR battery, participants performed computerised Serial Subtractions tasks. These assess concentration and working memory and allow manipulation of cognitive load (see Scholey *et al*., 2001 for details). In the present study Serial Threes (involving the repeated subtraction of three from a randomly generated starting number using the computer's numeric keypad) then Serial Sevens (subtraction of seven) were used, each for 2 min.

Each cognitive task outcome measure was analysed by one-way analysis of variance, with Dunnett comparisons to isolate between-group effects where appropriate. The most striking finding was a significant effect on both immediate and delayed word recall, with more words being recalled in the chewing condition compared with the quiet control condition (Table 1). The Spatial Working Memory sensitivity index and Numeric working memory reaction time were similarly improved in the chewing condition, and also in the sham chewing condition for the latter measure (which reflects the efficiency of working memory operations). In addition, simple reaction times were slower in the sham chewing condition than in the quiet control condition.

Baseline heart rate recordings (sampled at 30-s intervals) began 240 s prior to treatment and continued during a 180-s period of chewing, sham chewing or sitting quietly prior to cognitive assessment (which lasted about 30 min in all). Heart rate (mean bpm) was calculated during baseline, treatment, each of the 10 CDR tasks and both Serial Subtraction tasks. Heart rate changes relative to baseline were subjected to a 3(Condition) × 14(Phase) factorial ANOVA with repeated measures on the latter factor. The main effect of condition approached significance, $F(2{,}936) = 3{\cdot}0$, $p = 0{\cdot}06$; heart rates were significantly higher in the chewing condition than in quiet controls, $p < 0{\cdot}05$ (Fig. 1). There was also a significant main effect of task, $F(13{,}936) = 13{\cdot}0$, $p < 0{\cdot}01$: with the exception of Simple Reaction Time and Delayed Word Recall, all task phases of the study were associated with significant increases in heart rate. There was also a significant task × condition interaction, $F(26{,}936) = 25{\cdot}6$, $p < 0{\cdot}01$.

These results provided the first evidence that the chewing of gum can improve episodic memory (involving the learning, storage and retrieval of information) and working memory (where information is held "on line"). They did not indicate that gum-chewing improves aspects of attention, at least as measured here.

The impaired Simple Reaction Time during sham chewing may reflect diversion of attentional resources during initial stages of performing this unfamiliar behaviour. This is consistent with the elevated heart rate observed while sham chewing in earlier phases of the experiment (Fig. 1). Although an active control is important, sham chewing may not be ideal for this purpose, because most cognitive scores (except, notably, Numeric Working Memory Reaction Time) in this group

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Table I. Cognitive effects of chewing

Measure	*Chew*	*Sham*	*Quiet*
Simple RT	0·27	**0·30**[a]	0·27
Dig Vig Acc	96	94	97
Dig Vig RT	0·41	0·43	0·41
CRT Acc	94	92	93
CRT	0·43	0·43	0·43
SPM SI	**0·89**[a]	0·80	0·81
SPM RT	0·71	0·71	0·75
NWM SI	0·84	0·85	0·84
NWM RT	**0·68**[a]	**0·66**[a]	0·79
Imm Recall	**8·6**[b]	5·2	6·9
Del Recall	**7·1**[b]	4·3	5·2
Word Rec SI	0·64	0·52	0·65
Word Rec RT	0·73	0·77	0·77
Pic Rec SI	0·69	0·59	0·66
Pic Rec RT	0·85	0·90	0·87

Mean scores of the chewing ('chew'), sham chewing ('sham') and 'quiet' controls, for CDR measures grouped according to whether they assess attention (top), working memory (middle) or long-term memory (bottom). SRT and CRT: simple and choice reaction time (s); Dig Vig: Digit Vigilance; SPM and NWM: spatial and numeric working memory; Imm Recall and Del Recall refer to immediate and delayed word recall; Word Rec and Pic Rec: Word and Picture recognition respectively. SI = sensitivity index for tasks with a recognition component, ranging from $+1$ to -1; Acc = percent accuracy. Bold numerals indicate significant differences from quiet control ((a), $p < 0{\cdot}05$; (b), $p < 0{\cdot}01$).

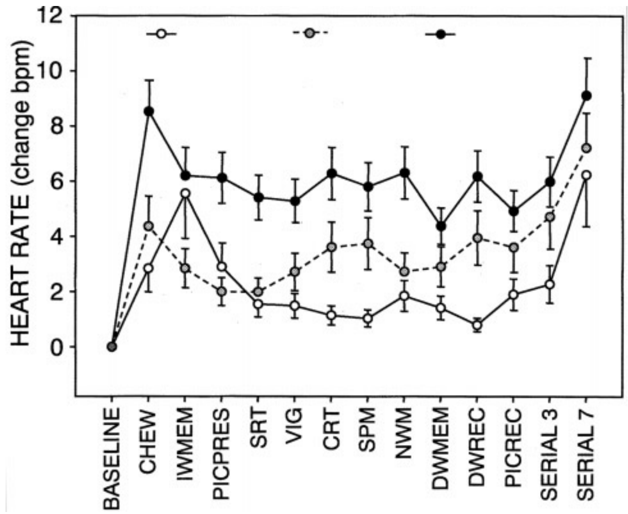

Figure I. Mean (with SEM) changes in heart rate (bpm) in all conditions. CHEW refers to the initial period of chewing, sham chewing or sitting quietly. IWMEM, Immediate Word Presentation and Recall; PICPRES, Picture Presentation; SRT, Simple Reaction Time; VIG, Number Vigilance; CRT, Choice Reaction Time; SPM, Spatial Working Memory; NWM, Numeric Working Memory; DWMEM, Delayed Word Recall; DWREC, Delayed Word Recognition; PICREC, Picture Recognition; SERIAL 3, Serial Threes; SERIAL 7, Serial Sevens.

were poorer than in the quiet control condition (Table I). Further research might usefully compare the impact of gums of different hardness on these aspects of performance.

Clearly the mechanisms underlying the memory enhancement associated with chewing gum are not known. It has been reported that mastication improves regional cerebral blood flow (Sesay *et al.*, 2000), including in fronto-temporal regions which are believed to mediate aspects of memory functioning. Additionally, chewing may promote the release of insulin which could influence memory via central mechanisms.

Elevations of heart rate support previous findings relating to chewing (Farella *et al.*, 1999), and to tasks with differing cognitive load (Kennedy & Scholey, 2000). Kennedy and Scholey (2000) argued that interventions improving the cerebral delivery of metabolic substrates interact with task demands to enhance performance. However, such a model predicts greater improvements during tasks with a higher cognitive load such as Serial Sevens (Scholey *et al.*, 2001), which was not found in the present study (data not shown). Perhaps investigation into the impact of chewing while co-administering a glucose load would further delineate such interactions. Additionally, it would be of interest to determine the extent to which the effects of chewing generalise to other types of memory.

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