Chapter 30
Relationships Between Gum Chewing and Stroop Test: A Pilot Study

Y. Kawakami, T. Takeda, M. Konno, Y. Suzuki, Y. Kawano, T. Ozawa, Y. Kondo, and K. Sakatani

Abstract Cognitive function tends to decrease with aging, therefore maintenance of this function in an aging society is an important issue. The role of chewing in nutrition is important. Although several studies indicate that gum chewing is thought to improve cognitive function, it remains debatable whether gum-chewing does in fact improve cognitive function. The Stroop test is a psychological tool used to measure cognition. A shorter reaction time indicates a mean higher behavioral performance and higher levels of oxy-Hb concentration. fNIRS is a powerful, non-invasive imaging technique offering many advantages, including compact size, no need for specially equipped facilities, and the potential for real-time measurement. The left dorsolateral prefrontal cortex (DLPFC) seems to be mainly involved in the Stroop task.

The aim of the present study was to investigate the hypothesis that gum-chewing changes cerebral blood flow in the left DLPFC during the Stroop test, and also changes the reaction time. Fourteen healthy volunteers (mean age 26.9 years) participated in this study after providing written informed consent. A piece of tasteless gum weighing 1.0 g was used. Each session was designed in a block manner, i.e. 4 rests (30 s) and 3 blocks of task (30 s). A computerized Stroop test was used (including both congruent and incongruent Stroop tasks) which calculates a response time automatically. The Binominal test was used for comparisons ($p < 0.05$). The results show activation of the left DLPFC during the Stroop task and that gum chewing significantly increases responses/oxy-Hb concentration and significantly shortens the reaction time.

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1 Introduction

Cognitive function tends to decrease with aging [1]. Maintenance of this function in aging society is an important issue [2]. The role of chewing in nutrition is important and studies have shown the relationship between chewing and cognitive performance including memory, attention, and executive function. Several studies have indicated that gum-chewing is considered to improve cognitive function [3–7]. Mastication has been shown on magnetic resonance imaging (MRI) to increase prefrontal cortex (PFC) blood flow [8, 9]. Increased blood flow to the brain may, in part, be the reason for increased cognition. However, it remains debatable whether or not chewing gum does improve cognitive function.

The Stroop test [10, 11] is a psychological tool that measures cognition and the ability to focus attention on a task. Stroop Interference is the well-known increased response time (RT) for naming font colors of incongruent color words compared to font colors of congruent color words.

NIRS can investigate the changes in cerebral hemodynamics and metabolism measures [12, 13]. Signal changes represent changes in local cerebral blood flow and oxygen expenditure, and the oxy-Hb level represents brain activity [14]. Functional NIRS is a powerful, non-invasive imaging technique offering many advantages, including compact size, no need for specially equipped facilities, and the potential for real-time measurement [15, 16].

Mean concentration levels of oxy-Hb were correlated with behavioral performance in the cognitive task. A shorter reaction time in the Stroop test showed higher levels of oxy-Hb concentration [17] in the left dorsolateral PFC (DLPFC) [10].

Therefore, the aim of the present study was to investigate the hypothesis that gum-chewing changes cerebral blood flow in the left DLPFC during the Stroop test and also changes the reaction time.

2 Methods

The study design was approved by the Ethics Committee of Tokyo Dental College (No. 436). Fourteen healthy volunteers (7 females, 7 males; mean age 26.9 ± 2.98 years) participated in this study after providing written informed consent. Participants had no personal or family history of neuropsychiatric illness, were free of medication, and all were right-handed. A piece of tasteless gum weighing 1.0 g (Lotte, Saitama, Japan) was used as a chewing sample. The hardness of the gum base was 6.4×10^3 Pa s (medium type). Chewing rate and force were

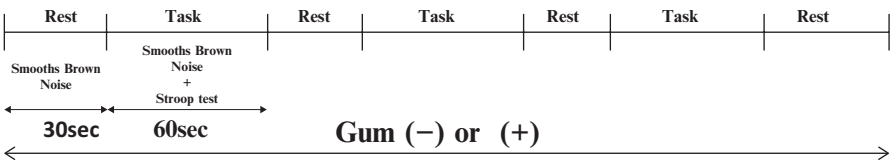

Fig. 30.1 Each task session was designed in a block manner: 4 rests (30 s) and 3 tasks (Stroop test) (30 s)

determined by the participants themselves. Under the gum chewing condition, chewing was done throughout the measurement. NIRS measurements were conducted during resting periods and trials of the Stroop test. Each session was designed in a block manner, i.e. 4 periods of rest (30 s) and 3 blocks of tasks (30 s). During the rest periods, participants were instructed to sit still with their eyes open. During the test periods, the participants conducted a computerized Stroop Test, including both congruent and incongruent Stroop trials (Don't Be Confused! Version 2.10, Japan) (Fig. 30.1). The response time was calculated automatically.

Activity in the PFC was measured by a multi-channel NIRS; (OEG-16, Spectratech, Japan) operated by an OEG-16. Exe V 3.0 [18]. The measurement probes (inter-optode distance 30 mm) were affixed to the participant's forehead. The recording channels resided in the optical path in the brain between the nearest pairs of emitter and detection probes. A 2 × 6 probe configuration involving 6 light emitters (wave-length 840 and 770 nm) and 6 detector probes was used, which resulted in a total of 16 channels. The array of the light emitter and detector probes covered an area of the forehead, with the most inferior channel located at Fp1 and Fp2 according to the International 10–20 system of electrode placement. The region of interest was placed at the left DLPFC [10]. Data from three channels were averaged for analysis.

To obtain the hemodynamic response, changes in the concentration of oxy-Hb, deoxy-Hb and total hemoglobin were calculated. BRain Suite (BRSystems, Japan) software was used for the analysis. A bandpass filter and a moving average were used. A linear fitting function for baseline correction was employed. The pre-task baseline was determined as the mean across 7 s just before the active-task period; the post-task baseline was determined as the mean across the last 8 s of the resting period; then linear fitting was performed on the task data between these two baselines. Following this correction, the 3 task repetitions, data were averaged in 3 channels of the left DRPFC and subject. For subsequent analyses, only changes in the oxy-Hb concentration registered during each task were considered. This is because the NIRS parameter usually shows the clearest pattern of activation and is proposed to be the most sensitive indicator of changes in regional cerebral blood flow [14]. The neural activity did not increase immediately after the start of the tasks; therefore, the oxy-Hb values between 10 and 30 s in each task were used for the analysis. The Binominal test was used for the comparisons ($p < 0.05$).

3 Results

Gum chewing significantly increased responses/oxy-Hb concentration in the left DLPFC of the region of interest (Fig. 30.2). Also, gum chewing significantly shortens the reaction time (Fig. 30.3).

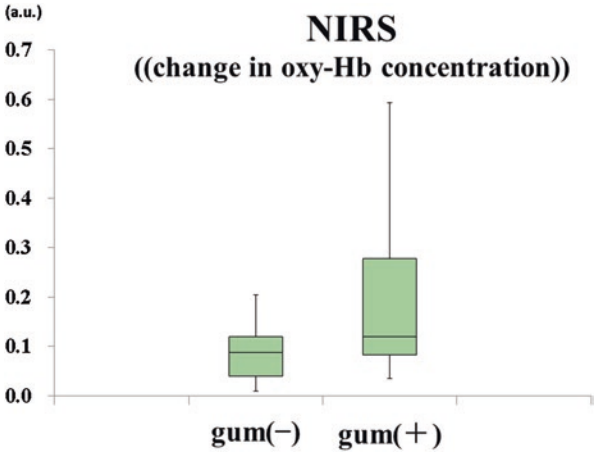

Fig. 30.2 oxy-Hb concentration changes in Gum (−) and Gum (+)

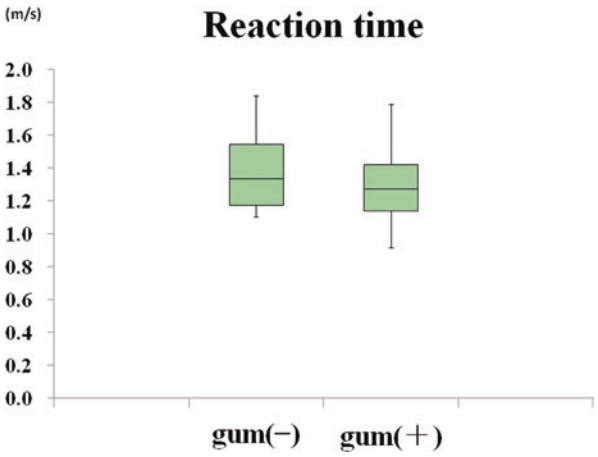

Fig. 30.3 Changes in reaction time in Gum (−) and Gum (+)

4 Discussion

The main findings of the present NIRS study are that gum-chewing significantly increases responses/oxy-Hb concentration and significantly shortened the reaction time of the Stroop test. Following these Stroop trials, this suggests that cerebral activation is specifically related to cognitive interference in this part of the brain. This result is largely in line with previous findings [3–7]. It is thought that the increase in cognition while chewing gum might be due to an increase in cerebral blood flow, a specific aspect of attention, increases the amount of glucose released, or creates a context-dependent effect [3, 5, 19] .

Cognitive training has shown the potential to slow down or even restore some aspects of age-related decline in working memory function [20–22]. The effects of acute gum-chewing in cognitive function showed the same kind of result [3–7]. Thus, daily gum-chewing might improve cognitive function in an elderly group.

For that, a proper occlusion and a mastication function in each person should be maintained. Erbay et al. [23] showed that chewing gum may not be directly effective on depressed mood; however, it may reduce the symptoms originating from depression such as the gastrointestinal symptoms, including, for example, loss of appetite, and flatulence. Narita et al. [24] concluded that a partial dental prosthesis significantly stimulates both masticatory muscle and dorsal PFC activities, which might contribute to the prevention of cognitive impairment in elderly individuals. Hosoi et al. [25] showed that brain function activity was enhanced by improvement of complete dentures and by wearing of partial dentures.

In summary, the finding of this study is that gum-chewing significantly increased responses/oxy-Hb concentration of the DLPFC and shortened the reaction time during the Stroop task.

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