

# Chapter 43

## Relationships Between Gum-Chewing and Stress

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**Abstract** Studies have shown that chewing is thought to affect stress modification in humans. Also, studies in animals have demonstrated that active chewing of a wooden stick during immobilization stress ameliorates the stress-impaired synaptic plasticity and prevents stress-induced noradrenaline release in the amygdala. On the other hand, studies have suggested that the right prefrontal cortex (PFC) dominates the regulation of the stress response system, including the hypothalamic-pituitary-adrenal (HPA) axis. The International Affective Digitized Sounds-2 (IADS) is widely used in the study of emotions and neuropsychological research. Therefore, in this study, the effects of gum-chewing on physiological and psychological (including PFC activity measured by NIRS) responses to a negative stimulus selected from the IADS were measured and analyzed. The study design was approved by the Ethics Committee of Tokyo Dental College (No. 436).

We studied 11 normal adults using: cerebral blood oxygenation in the right medial PFC by multi-channel NIRS; alpha wave intensity by EEG; autonomic nervous function by heart rate; and emotional conditions by the State-Trait Anxiety Inventory (STAI) test and the 100-mm visual analogue scale (VAS). Auditory stimuli selected were fewer than 3.00 in Pleasure value. Sounds were recorded in 3 s and reproduced at random using software. Every task session was designed in a block manner; seven rests: Brown Noise (30 s) and six task blocks: auditory stimuli or auditory stimuli with gum-chewing (30 s). During the test, the participants' eyes

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were closed. Paired Student's t-test was used for the comparison ( $P < 0.05$ ). Gum-chewing showed a significantly greater activation in the PFC, alpha wave appearance rate and HR. Gum-chewing also showed a significantly higher VAS score and a smaller STAI level indicating 'pleasant'. Gum-chewing affected physiological and psychological responses including PFC activity. This PFC activation change might influence the HPA axis and ANS activities. In summary, within the limitations of this study, the findings suggest that gum-chewing reduced stress-related responses. Gum-chewing might have a possible effect on stress coping.

**Keywords** Prefrontal cortex • Near-infrared spectroscopy • International Affective Digitized Sounds-2 • Electroencephalogram • Gum-chewing

## 1 Introduction

The basic function of mastication is to make food soft, smaller, and to mix it with enzymes in saliva for swallowing and digestion. However, many people chew gum for relaxation and concentration. Studies have shown that gum-chewing is thought to affect both physical and psychological stress modification in humans [1–4]. Also, studies in animal have demonstrated that active chewing of a wooden stick during immobilization stress, ameliorates the stress-impaired synaptic plasticity [5]. However, the effect of chewing gum on stress has not received unequivocal support and the neurophysiological mechanisms involved are unclear.

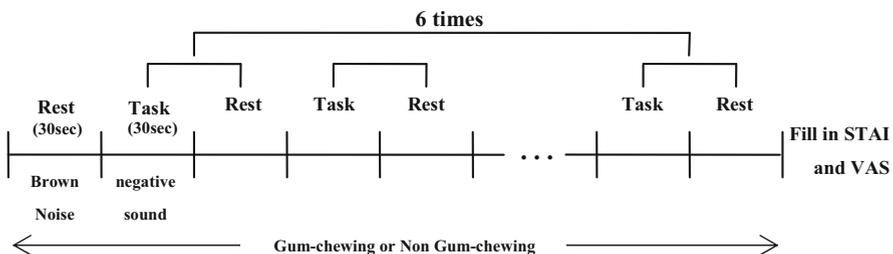
The prefrontal cortex (PFC) is the most sensitive to the effects of stress exposure [6]. The stress response involves activation of the PFC which stimulates the hypothalamic-pituitary-adrenal (HPA) axis and influences Autonomic nervous system (ANS), since neuronal networks exist between the PFC and the neuroendocrine centers in the medial hypothalamus [7], and the PFC has direct access to sympathetic and/or parasympathetic motor nuclei in brainstem and spinal cord. The PFC will set the endocrine/autonomic balance, depending on the emotional status [7]. The left hemisphere is specialized for the processing of positive emotions, while the right hemisphere is specialized for the processing of negative emotions [8].

The International Affective Digitized Sounds-2 (IADS) is a standardized database of 167 naturally occurring sounds, which is widely used in the study of emotions. The IADS is part of a system for emotional assessment developed by the Center for Emotion and Attention [9, 10]. Studies using IADS stimuli have revealed that auditory emotional stimuli activate the appetitive and defensive motivational systems similar to the way that pictures do.

Therefore, in this study, the effects of gum-chewing on a negative stimulus selected from the IADS on the right medial PFC activity using NIRS and other physiological responses, were measured and analyzed.

## 2 Materials and Methods

A total of 11 healthy volunteers participated in the study (mean age,  $26.8 \pm 1.66$  years, male: female = 9: 2). Participants were told to refrain from substances (e.g., coffee etc. including caffeine) that could affect their nervous system before and during the period of testing, and not to eat for 2 h before the test. They were also instructed to avoid excessive drinking and lack of sleep the night before the test. In order to avoid the influence of environmental stress, the participants were seated in a comfortable chair in an air-conditioned room with temperature and humidity maintained at approximately 25 °C and 50 %, respectively. The study was conducted in accordance with the Principles of the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Tokyo Dental College (Ethical Clearance NO.436). Written informed consent was obtained from all participants. After a 10-min rest, they then performed an auditory stimulation task with eyes closed, negative sounds (NS) selected from the IADS, the NS were fewer than 3.0 in Pleasure value, in random order (Fig. 43.1). Activity in the right PFC was measured by a multi-channel NIRS; (OEG-16, Spectratech, Japan). The source-detector distance of the NIRS device is 30 mm. The locations of the shells were determined on the international 10–20 system. The most inferior channel was located at Fp2. The region of interest was placed at medial right PFC [8]. Electroencephalogram (EEG) (Muse Brain System, Syscom, Japan) and heart rate (HR) (WristOx, NONIN, USA) were monitored simultaneously with PFC activity (Fig. 43.2). The self-rated psychological measurement was taken using a 100-mm visual analogue scale (VAS) [11] and we used the State-Trait Anxiety Inventory (STAI) [12] to assess psychological assessments. We analyzed the Oxy-Hb values during task averaged across three channels on the medial right PFC. Alpha wave (8–13 Hz) appearance rates in theta, alpha and beta waves were calculated. Statistical evaluations between NS and NS with Gum-chewing, were performed using a paired Student's t-test (Excel Statistics, Microsoft Japan). A p-value of  $<0.05$  was considered significant.



**Fig. 43.1** Experimental protocol trial consisted of seven (Smoothed Brown Noise, 30 s) and six blocks of task: negative sounds from IADS



**Fig. 43.2** PFC activity was measured by a multi-channel NIRS. The region of interest was placed at medial right PFC across three channels. EEG and HR were monitored simultaneously with NIRS

### 3 Results

Results are summarized in Table 43.1. PFC activity show a significantly greater activation with gum-chewing in the right PFC ( $NS = 0.045 \pm 0.032$ ,  $NS$  with Gum =  $0.084 \pm 0.055 \mu\text{mol/l}$ ). A significantly greater alpha wave appearance rate ( $NS = 44.00 \pm 0.06$ ,  $NS$  with Gum =  $47.10 \pm 0.08 \%$ ) and HR ( $NS = 61.91 \pm 8.57$ ,  $NS$  with Gum =  $67.83 \pm 7.26 \text{ bpm}$ ) was obtained in gum-chewing. The STAI level tended to show smaller values in gum-chewing ( $NS = 2.55 \pm 1.04$ ,  $NS$  with Gum =  $2.45 \pm 0.82$ ), and a significantly higher VAS score was obtained in gum-chewing indicating ‘pleasant’ ( $NS = 40.36 \pm 15.95$ ,  $NS$  with Gum =  $54.80 \pm 15.82$ ).

### 4 Discussion

Judged mainly by the psychological results, the subjects felt discomfort during NS, which could cause stress responses in the brain. Indeed, NS increased Oxy-Hb in the right medial PFC, indicating that NS induced neural activation of the PFC. This is in line with previous findings used loud noise [16]. The unpleasant task-induced PFC activation could cause activation of the HPA axis and influence ANS, on the basis of networks between the PFC and the medial hypothalamus and ANS [7].

**Table 43.1** Psychological and physiological assessment

		Stimuli of site	Mean (S.D.)	Statistics	
Psychological assessment	STAI level (bigger figure indicates “more unpleasant”)	Negative sound	2.55 (1.04)		
		Negative sound + Gum	2.45 (0.82)		
	VAS level (smaller figure indicates “more unpleasant”)	Negative sound	40.36 (15.95)		*
		Negative sound + Gum	54.80 (15.82)		
Physical assessment	Heart rate (bpm)	Negative sound	61.91 (8.57)	*	
		Negative sound + Gum	67.83 (7.26)		
	Alpha wave (%) (appearance rate in theta, alpha, and beta waves)	Negative sound	44.00 (0.06)	*	
		Negative sound + Gum	47.10 (0.08)		
	NIRS $\Delta$ Oxy-Hb (a.u.) Approximately stabilized 15 s date in task—8 s of pre rest	Right PFC	Negative sound	0.045 (0.032)	*
			Negative sound + Gum	0.084 (0.055)	

\*p < 0.05

Gum-chewing reduced the unpleasant psychological feeling and increased the alpha wave appearance rate, indicating the subjects’ unpleasant feeling with coping. Gum-chewing increased HR and decreased PFC activity. This PFC activation change might influence the HPA axis and ANS activities. These gum-chewing effects in stress responses are also consistent with those of previous reports regarding the relationship between gum-chewing and stress [1–5, 16].

EEG reflects neuronal activities of a human brain that can be directly affected by emotional states. Especially, alpha wave appearance in the awaked EEG with an eyes-closed condition seems to indicate a relaxed state [13]. Listening to an unpleasant tone [14] and a loud siren reduced the alpha wave [15]. The effect of the increased alpha wave by gum-chewing might indicate a reduction of the uncomfortable mood.

Gum-chewing itself increased HR [16]. In the present study, NS with gum-chewing increased HR. The HR increase could relate to PFC blood flow. The blood supply change might have an influence on emotional control.

Gum-chewing reduced negative psychological scores on the VAS and STAI, indicating relief of mental stress.

Two possible interpretations for this Gum-chewing in the subjects being distracted from the unpleasant sounds was: Gum-chewing or some other activity may shield the organism from the external stressor (i.e., the noise) through attention distraction and reduces the experience of stress. Gum-chewing generates internal noise within the auditory system which may itself partially mask the impact of external noise or distract attention away from external noise [4].

The NIRS technique has some shortcomings; NIRS can detect only in surface areas of the brain, NIRS measurement has possible confounders such as skin blood flow, respiration and blood pressure, NIRS has relatively low spatial resolution. Despite its shortcomings, NIRS is becoming increasingly useful in neuroscience.

In summary, within the limitations of this study, the findings suggest that gum-chewing reduced stress-related responses, and there was a gum-chewing-induced change in the level of PFC activity. Gum-chewing might have a possible effect on stress coping [1–4].

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