Chapter 1
Effects of Experimentally Deviated Mandibular Position on Stress Response

Ai Amemiya, Tomotaka Takeda, Kazunori Nakajima, Keiichi Ishigami, Takeo Tsujii, and Kaoru Sakatani

Abstract The purpose of this study was to investigate the effects of stress on prefrontal cortex (PFC), emotion (using visual analogue scale, VAS, and State-Trait Anxiety Inventory, STAI), and the autonomic nervous system (ANS). Two types of stress were applied: (1) malocclusion-induced physical stress and (2) mental stress induced by an arithmetic task. Malocclusion was induced using an experimentally deviated mandibular device (EDMD) to obtain an experimentally deviated mandibular position (EDMP). A total of 11 healthy volunteers participated in the study. On day 1 they performed a pretrial arithmetic task followed by a 10-min rest, after which they performed a posttrial EDMD + arithmetic task or rest device + arithmetic task. These two tasks were selected at random and assigned at the rate of one per day. Activity in the PFC tended to show an increase in the pretrial arithmetic tasks and rest device + arithmetic task, but a decrease in the EDMD + arithmetic task compared with the rest device + arithmetic task. Heart rate significantly increased during the rest device + arithmetic task, whereas no significant difference was observed during the EDMD + arithmetic task. The EDMD + arithmetic task significantly increased STAI scores ($p = 0.0047$), and the significant decrease in VAS indicated "unpleasant" ($p = 0.035$). These findings suggest that EDMP-induced reduction in the level of PFC activity was a response to discomfort, indicating that EDMP affects systemic function such as that of the ANS as an unpleasant stressor.

Keywords Prefrontal cortex • Near-infrared time-resolve spectroscopy • Physical stress • Mental stress • Experimentally deviated mandibular position

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1 Introduction

Many studies have investigated the effects of mental stress: reaction of the circulation and central nervous system [4] and activity in prefrontal cortex (PFC) and the autonomic nervous system (ANS) [9, 10] were examined using a mental arithmetic task. Similarly, many studies have investigated physical stress: immunoglobulin A (IgA) antibody levels in saliva [5] and hypothalamic–pituitary–adrenal response [8] during restriction stress loading were investigated in animals; reaction of the ANS to cold stress has also been investigated [3]. The relationship between mental and physical stress, however, remains to be clarified. In an earlier study, we reported on experimentally deviated mandibular position (EDMP) and arithmetic-induced elevated levels of activity in the PFC using near-infrared spectroscopy (NIRS). However, with NIRS, the average path length is unknown and assumed to be a constant value. In practice, a certain value obtained by experimental measurements is substituted in each subject. Near-infrared time-resolve spectroscopy (TRS) is an emerging method which enables the absolute hemoglobin concentration in tissue to be evaluated.

The purpose of this study was to investigate the effects of malocclusion-induced physical stress and arithmetic task-induced mental stress on PFC activity, emotion, and the ANS.

2 Materials and Methods

A total of 11 healthy male volunteers participated in the study (mean age, 24.2 ± 4.3 years). 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 23 °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.164). Written informed consent was obtained from all participants.

On day 1 the participants were required to perform a pretrial arithmetic task. After a 10-min rest, they then performed a posttrial EDMD + arithmetic or rest device + arithmetic task at random (Fig. 1.1). Activity in the PFC was measured by TRS (TRS-20, Hamamatsu Photonics K.K.). The TRS probe was placed at Fp2. The location of the probe was determined according to the international 10–20 system. Heart rate (HR) was monitored simultaneously with PFC activity by placing a pulse oximeter (WristOx, Nonin, USA) on the participant's left earlobe to measure pulse waves.

We used the 100-mm visual analogue scale (VAS) and State-Trait Anxiety Inventory (STAI) to assess psychological stress levels.

We employed a mental arithmetic task as a psychological stressor. Participants were required to mentally subtract 2 digits from 4-digit numbers displayed on a personal computer (example: 3425–79) and input the answers using a keyboard. They were instructed to make their calculations as accurately and as quickly as

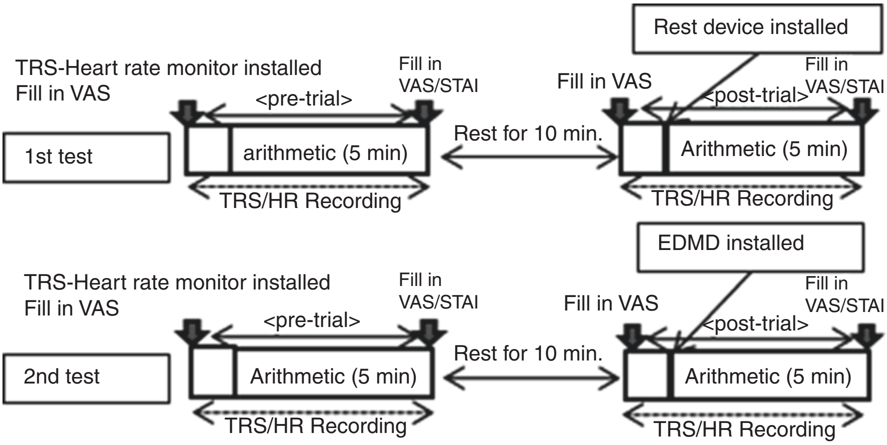

Fig. 1.1 Experimental protocol for rest device + arithmetic tasks and EDMD + arithmetic tasks to elicit TRS signals from participants. Trial consisted of baseline of 1 min; each task took 5 min. Rest device and EDMD were adopted at random

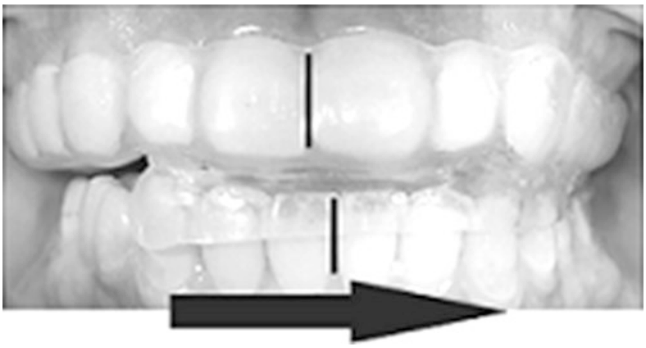

Fig. 1.2 In EDMP + arithmetic task, mandible was deviated toward the non-preferred chewing side using EDMD

possible. This mental arithmetic task has previously been used to investigate mental stress-induced PFC activity [11].

The mandible was in the mandibular rest position during the arithmetic tasks and rest device + arithmetic task. In the EDMP + arithmetic task, it was deviated toward the non-preferred chewing side using the experimentally deviated mandibular device (EDMD) (Fig. 1.2). The EDMD shifted the mandible until the cusps of the upper and lower canine teeth on the non-preferred chewing side touched each other. To minimize the influence of the EDMD itself on measurement, a resilient 3-mm Drufosoft sheet (Dreve Dentamid GmbH, Germany) was used to cover the crowns in the upper jaw and about 1/3 of the crowns in the lower jaw. The mandible was fixed in the deviated position [7]. The rest device was made of the same type of sheet, but allowed free movement.

Statistical evaluation of changes between the rest position and EDMP was performed using a paired Student's *t*-test. Only statistical differences in the HR data were tested using one-way measures ANOVA. When a significant difference was found, multiple comparisons were conducted using the Dunnett test to compare values at rest and task rate. A *p*-value of <0.05 was considered significant.

3 Results

Activity in the PFC tended to show an increase in the pretrial arithmetic and rest device + arithmetic tasks, but a decrease in the EDMD + arithmetic task compared with the rest device + arithmetic task (Fig. 1.3). Heart rate significantly increased during the rest device + arithmetic task, but no significant difference was observed during the EDMD + arithmetic task (Fig. 1.4). The EDMD + arithmetic task significantly increased STAI scores ($p = 0.0047$) (Fig. 1.5), and the significant decrease in VAS indicated "unpleasant" ($p = 0.035$) (Fig. 1.6).

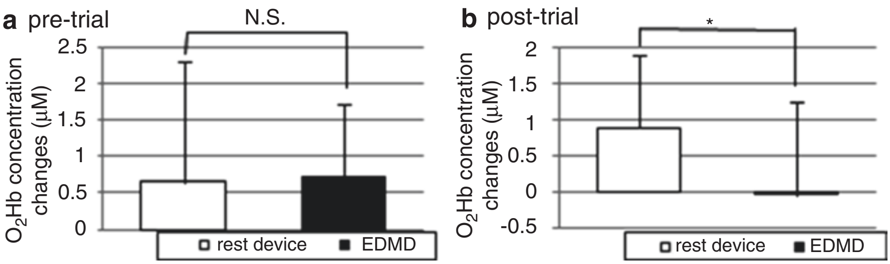

Fig. 1.3 Changes in oxy-Hb concentrations. Activity in PFC tended to show increase in pretrial arithmetic tasks and rest device + arithmetic tasks, but a decrease in EDMP + arithmetic task; means of variations in oxy-Hb in rest device and EDMD + arithmetic tasks were 0.902 ± 1.00 and -0.003 ± 1.28, respectively ($p = 0.026$)

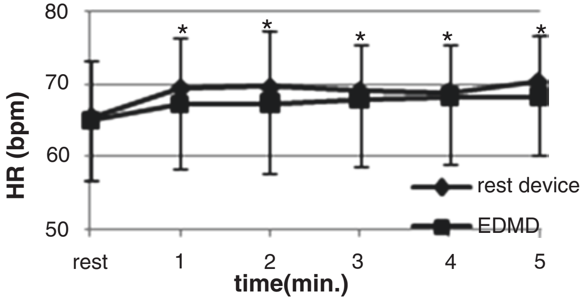

Fig. 1.4 Changes in HR concentrations. HR significantly increased in rest device + arithmetic task ($p < 0.05$), but no significant difference was observed in EDMD + arithmetic task

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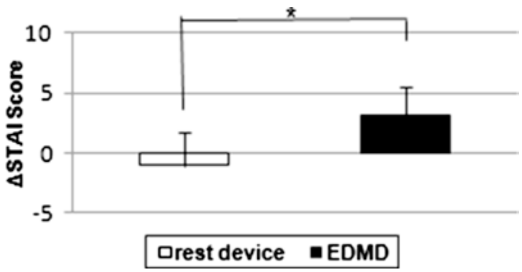

Fig. 1.5 Changes in STAI scores. EDMD + arithmetic task significantly increased STAI scores; means of variations in STAI scores in rest device and EDMD + arithmetic tasks were −1.00 ± 2.79 and 3.09 ± 2.34, respectively ($p = 0.0047$)

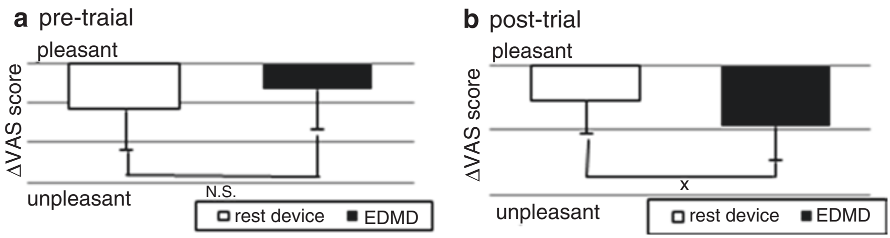

Fig. 1.6 Changes in VAS. The significant decrease in VAS indicated "unpleasant" at posttrial; means of variations in VAS in rest device and EDMD + arithmetic tasks were −105 ± 126and −190 ± 117, respectively ($p = 0.035$)

4 Discussion

The results showed that activity in the PFC tended to show an increase in the arithmetic task, but when the EDMD was installed, activity in the PFC showed a significant decrease compared with activity when the rest device was used. Although HR significantly increased in the rest device + arithmetic task, no significant increase was observed in the EDMD + arithmetic task. The EDMD + arithmetic task significantly increased STAI scores, and the significant decrease in VAS indicated "unpleasant." In a previous study, Tanida et al. [10] found PFC activation during the mental arithmetic task, which reflected general cognitive operations such as attention and emotion. In the present experiment, decreased activity in the PFC during the EDMD + arithmetic task suggests that the EDMD disturbed general cognitive operations. This assumption is consistent with the findings that occlusal disharmony induced spatial memory impairment in mice [2], occlusal disharmony increased stress response [12], occlusal interference affected the ANS [1], and clenching and malocclusal were involved in emotion and/or pain-related neural processing in the brain [6].

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Mental and physical stresses can induce sympathetic excitation and cause a rapid increase in HR and blood pressure. However, in this experiment, the EDMD-induced increase in HR was no greater than that with use of the rest device. This may have been due to an interaction between the mental and physical stresses applied. However, to the best of our knowledge, no study has clarified such an interaction.

The EDMP induced a significant decrease in VAS and increase in STAI scores, indicating an increase in the level of mental stress. These findings suggest that EDMP-induced decrease in the level of PFC activity was a response to discomfort, indicating that EDMP affects systemic function, such as that of the ANS, as an unpleasant stressor.

5 Conclusions

Within the limitations of this study, the findings suggest that the EDMP-induced reduction in the level of PFC activity observed here was a response to discomfort, indicating that EDMP affects systemic function, such as that of the ANS, as an unpleasant stressor.

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