The Response Time of the Stroop Test Is Delayed during Lemon-Flavored Gum Chewing

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Summary In the present study, we examined the cognitive function during mastication of lemon-flavored gum, which is said to enhance cerebral blood flow. Nine healthy subjects (8 female and 1 male) participated in this study. Subjects chewed the gum for 3 min after fasting for 2 h and conducted a Stroop test while continuing to chew. At the end of all answers, gum chewing ended. The response time in the Stroop test was used as an indicator of cognitive function. We set the three conditions (lemon-flavored gum, mint-flavored gum, no gum chewing). There was no significant difference in reaction time between chewing mint-flavored gum and not chewing ($p > 0.05$). However, the response time during chewing gum with a lemon flavor was significantly slower than the conditions with mint-flavored gum and without gum chewing ($p < 0.05$, in both). From the results of the present study, it was suggested that the response time delay of the Stroop test observed during the chewing of lemon-flavored gum revealed temporary decay of cognitive function during lemon-flavored gum chewing. It is suggested that lemon-flavored chewing gum forces a brain overload, resulting in a temporary decrease in cognitive function.

Key Words gum, mastication, Stroop test, cognition

In various sports such as baseball and soccer, we can see participants chewing gum during play. We can imagine that this action during play actually has a positive influence. So far, it has been reported that gum chewing stabilizes the heart rate (1), and so it is thought that competition performance will be improved. In addition, it has been reported that gum chewing contributes to alertness (2–4) and shortens selection reaction time (5), and increases working memory (6–8). It has also been reported that P300 of event-related potential is shortened by gum chewing (9). These reports about increased cognitive function after gum chewing seem to indicate that cognitive function will be enhanced during the chewing of gum. On the other hand, in a study using near-infrared spectroscopy (NIRS), it has been reported that cerebral oxygenation increases during gum chewing, especially during the chewing of lemon-flavored gum (10). However, what this increase in cerebral oxygenation implies is not clear. Two factors can be considered as explaining an increase in cerebral oxygenation. One is a positive factor such as arousal and an increase in cognitive function of the brain. The other is a negative factor—that chewing is putting additional stress on the brain (11). It is not clear which of these conflicting factors is causing cerebral oxygenation to increase during chewing. Therefore, in the present study, we examined whether cognitive function during chewing was elevated using the case of comparing non-gum-chewing versus using lemon-flavored gum or mint-flavored gum.

There are various ways to evaluate cognitive function. The Stroop test is one of them (12–14). The Stroop test is a test in which subjects use a keyboard to respond to the color of characters presented on the monitor of computer (12). For example, when the word “blue” written in red is presented, the subject answers by pressing a button corresponding to red. This is a cognitive function evaluation method utilizing the effect that mutual activities interfere with each other when the activity of the motor cortex for solving with the visual cortex which recognizes color and the keyboard are integrated in the parietal association cortex. In the present study, we evaluated the cognitive function in the task by using this Stroop test. The purpose of the present study was to examine cognitive enhancement during gum chewing, especially chewing gum with lemon flavor, which was said to increase cerebral oxygenation using one of cognitive function evaluation methods of Stroop test.

Methods

Subjects. The subjects were nine healthy adults (8 females, 1 male, average age 21.6 ± 0.2 (SE) y old). All subjects received information describing the dangers of the experiment. In carrying out this experiment, we received approval from Niigata University of Health and Welfare Ethics Committee (No. 17699-06701). Experiments were conducted based on the Declaration of Hel-
sinki, and subjects were asked to explain the protocols and dangers of the experiments, and accepted them with consent.

**Experimental procedures.** Subjects were subjected to three conditions: 1) non-gum condition, 2) mint-flavored gum condition, 3) lemon-flavored gum condition. The components of the mint- and lemon-flavored gum are shown in Table 1. The hardness was adjusted to be same between the mint-flavored gum and lemon-flavored gum. In the measurement, practice with the Stroop test was carried out in advance to the tests under the three conditions; then, to prevent excessive familiarity with the Stroop test (14), each condition was set at intervals of 3 to 7 d. Three experimental sequences were randomly performed for each subject. All of the three conditions were measured after fasting for at least 2 h. Subjects came to the laboratory 30 min before the test and carried out a Stroop task (5 min) after 30 min of rest and 3 min of gum chewing (mint gum condition and lemon gum condition). After the rest of 30 min, the subjects were asked to chew gum for 8 min at a relaxed self-pace in the gum-chewing conditions. Then after 3 min of gum chewing, in the Stroop task, subjects clicked the mouse button at the “start” cue and executed 360 Stroop cognitive tasks.

**Stroop task.** In the Stroop task, words of color names such as “あか”, “あお”, “みどり”, and “きいろ” appear at random in red, blue, green or yellow. The subjects answer with the color of the words on the screen as quickly and accurately as possible. The response time required to answer for one stimulus (reaction time) was recorded. For stimulus presentation, a 17-inch CRT monitor (LCS 172VXL, NEC, Japan) with a resolution of 1,024×768 pixels was used and the refresh rate was 100 Hz. The stimulus was controlled by computer (M8-D, NEC). We used Psychopy (15, 16) for visual stimulation. Subjects were instructed to look at the cross that was presented at the center of the monitor (Gazing point). At randomly spaced intervals of 800 to 1,200 ms after the gazing point disappeared, words of two Kanji were presented in the center of the screen. Subjects were instructed to answer the color of the presented word as soon as possible. The subject answered the color with the keyboard, and the time to response (reaction time) and the answer were recorded in the computer. Kanji remained on the screen until subjects answered (~3,000 ms). Subjects were sitting so that their eyes would be at a distance of 40 cm from the screen. The circumference of the stimulus was unified to a gray background of 43.5 cd/m².

**Statistical analyses.** Values are indicated by means±SE. The time from when the stimulus was presented to when the subject responded was taken as the response time and how the presentation condition affected the reaction time was examined. For the test, reaction time (360 answers per subject) was used for all stimuli. In this data analysis, 9,720 data were targeted (Supplemental Online Materials, Table S1). For this reason, in the linear model analysis, the possibility of occurrence of Type I error is high, so analysis of variance (ANOVA) was performed using a generalized linear mixed model (GLMM) of repeated measurement design. The gum condition was set as a fixed effect, and subject ID was set as a random effect. Satterthwate was used for the degree of freedom estimation method in ANOVA, the difference of the least square mean was used as the post-hoc test, and the difference between each pair of conditions was tested. Statistical significance was accepted when p-values were <0.05.

**Results**

The average rates of chewing pace were 63.0±2.1 rpm in non-gum, 62.9±2.1 rpm in mint-flavored and 62.09±2.0 rpm in lemon-flavored conditions. There were no significant differences among three conditions (p>0.05). The average correct answer rate of subject in the Stroop test was 99.9%. The reaction time under three conditions (non-gum, mint-flavored-gum, lemon-flavored-gum) was 494.2±2.5 ms under the non-gum condition, 487.7±2.3 ms under the mint-flavored-gum condition and 484.7±2.3 ms under the lemon-flavored gum condition (Fig. 1). The three conditions were set as a fixed effect on reaction time, subjects were set as a random effect, and ANOVA was performed from the results of GLMM. GLMM revealed that the lemon-flavored gum condition delayed the reaction time compared with the mint-flavored gum condition and the non-gum condition. As a result, statistical significance was confirmed under three conditions (F=5.056, p=0.006). The post-hoc test revealed the response time during chewing of

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Mint-flavored gum (%)</th>
<th>Lemon-flavored gum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gum base</td>
<td>33.5</td>
<td>26.3</td>
</tr>
<tr>
<td>Xylool</td>
<td>55.3</td>
<td>62.7</td>
</tr>
<tr>
<td>Maltitol</td>
<td>2.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Aspartame l-phenylalanine compound</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Acesulfame potassium</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Other perfumes</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Acidulant</td>
<td>0.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Softeners</td>
<td>3.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
the lemon-flavored-gum was significantly slower than the reaction time for mint-flavored-gum \((p=0.033, \text{95\% confidence interval (CI): 0.5 to 12.5 ms})\), and slower than the reaction time under the non-gum condition \((p=0.002, \text{95\% CI: 3.5 to 15.5 ms})\). There was no significant difference between the mint-flavored gum condition and the non-gum condition \((p=0.329, \text{95\% CI: } -3.0 \text{ to } 9.0 \text{ ms})\).

**Discussion**

The main result of the present study was that the response time in the Stroop test was significantly delayed during gum chewing, especially gum chewing with lemon-flavored gum. In the results with 95\% CI, we confirmed the delay of 0.5 ms to 12.5 ms in the reaction time under the lemon-flavored condition compared to the non-gum condition. We also confirmed the delay of 3.5 ms to 15.5 ms in the reaction time under the lemon-flavored gum condition compared to the mint-flavored gum condition. It has been reported that among gum flavors, the cerebral oxygation was greatest mint and lemon \((10)\). It is thought that this cerebral oxygenation enhancement has two meanings. One is brain function enhancement, and the other is additional stress on the brain. In the present study, we investigated whether chewing lemon-flavored gum, which was reported to increase the cerebral oxygenation \((10)\), is linked to the enhancement of cognitive function during gum chewing. As a result of the present study, delay of reaction time in the Stroop test was observed for lemon-flavored gum, which was most expected to increase cerebral activity. The response time delay in the Stroop test reflects the magnitude of the Stroop interference during the Stroop task \((17)\). It is also believed that increased cognitive function results in alleviation of these stolen interferences and damping of cognitive function results in increased stolen interference \((18)\). That is, the reaction time delay in the Stroop test, was shown during lemon-flavored gum chewing in the present study, indicates that the cognitive function was temporally attenuated during lemon-flavored gum chewing compared with during mint-flavored gum and non-gum chewing conditions. This suggests that the increase in cerebral oxygenation with lemon-flavored gum, which was confirmed in previous research \((10)\), might be due to additional stress on the brain, not due to increased brain function. However, since cerebral oxygenation during gum chewing was not measured in the present study, it is necessary to verify with cerebral oxygenation and the Stroop test in combination for the purpose of confirmation in the future.

There is the phrase “dual task” in cognitive science. In the case in the present study, it was a dual task to perform the cognitive tasks of chewing gum and the Stroop test. In that case, there was a possibility that only the interference occurred during Stroop test but also the brain activity related to the taste of lemon flavor and the neural activity responsible for the chewing movement worked simultaneously, and as a result of interfering with each activity, the reaction time during the Stroop test greatly delayed. Even with similar gum chewing, in the case of mint-flavored gum, there was a reaction time equivalent to that without gum chewing. It is conceivable that the magnitude for the taste stimulus differs between the mint flavor and the lemon flavor. Indeed, it has also been reported that brain activity rises greatly due to lemon-flavor \((10)\). Moreover, it can be easily imagined that the brain is putting a big cost on the recognition of lemon flavor.

In the present study, in order to set the same conditions as Sakamoto et al. \((9)\), we asked subjects to chew gum at a relaxed self-pace. In addition, the non-gum condition was set as the control condition, and the differences of the reaction times under the mint-flavored condition and the lemon-flavored condition were verified against the non-gum condition. Further studies are needed to reveal the influence of flavor by experiments using a tasteless gum condition as a control condition and to reveal the influence of chewing by using specifying the rate of chewing. Increased sympathetic nervous activity may be considered to affect cognitive function \((9)\). Sympathetic nervous response is considered to be activated by elevated blood glucose levels \((19, 20)\). In the previous studies cited, the influence of blood glucose on sympathetic nervous activity was examined when glucose was ingested from gum \((19)\) and via the glucose infusion technique \((20)\). The gum used in the present study did not contain ingredients that increase blood glucose levels, so we thought that there were no effects of mint- or lemon-flavored gum on cognitive functions. Adjustments were made to ensure that gum hardness would be the same between mint-flavored and lemon-flavored gum (approximately 6.0 kg/cm$^2$). In the results of the present study, because there was no sig-
significant difference between the non-gum condition and the mint-flavored gum condition, the results be due to chewing gum with lemon flavor rather than chewing gum with flavor itself.

In conclusion, it was suggested from the results of the present study that chewing gum with lemon flavor would impose a heavy burden on the brain, causing temporary cognitive decline. Enhancement of cognitive function after chewing remains a subject to be studied in the future.

Supporting Information
Supplemental Online Material is available on J-STAGE.

REFERENCES