The Influence of Taste Stimuli and Illumination on Electrogastrogram Measurements

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Abstract An electrogastrogram (EGG) is considered to be an index to the autonomic nervous system of the digestive organs. In the present study, we attempted to clarify whether or not an EGG can be used to evaluate the influence of illumination, and what kinds of effect taste stimuli and illumination have on the autonomic nervous system. In this study, we used the ratio of the normal wave component of the EGG (EGG-NR: 2–4.5 cpm power/1–10 cpm power) and the amplitude of a normal wave (EGG-NI: integrated EGG of 2–4.5 cpm). Thirteen healthy males participated in 16 experimental conditions (4 lighting conditions × 4 taste stimuli). The four lighting conditions were set by combinations of illuminance levels of 200 and 1500 lx and color temperatures of 3000 and 7500 K. The four taste stimuli were sweet (glucose), salty (salt), sour (acetic acid), and bitter (quinine). The changes in EGG-NR and EGG-NI were compared for different taste conditions. The results showed that EGG-NI was not significantly affected by the different taste conditions. However, the main effect of taste on EGG-NR was significant: sweet and salty tastes were significantly higher than the bitter taste. EGG-NR and EGG-NI in different lighting conditions were also compared. The main effect of different color temperatures was also significant, but the illuminance level did not affect EGG-NR. EGG-NR increased significantly at the lower color temperature. On the other hand, EGG-NI significantly increased at the lower illuminance. These results suggest that parasympathetic nervous activity has a predominant effect on gastric activity in different lighting environments. Therefore, EGG measurements may be useful indicators for illumination environment studies. J Physiol Anthropol 26(2): 191–195, 2007 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.26.191]

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Introduction

It has been reported in previous studies that the preference of atmosphere varies according to changes in the environmental illuminance and color temperatures (Noguchi, 1999). It is also known that people can feel happy when the color temperature of the illumination environment at mealtime is set at 2000–3000 K. However, most studies on lighting environments at mealtime used psychological methods such as subjective evaluation. Few used the physiology index of taste.

We found in a previous study that the amount of saliva and the taste threshold were influenced by the illuminance and color temperature (Jin et al., 2005). Both of these increased at conditions of low illuminance and low color temperature.

An EGG is considered to be an index to the autonomic nervous system of the digestive organs. In the present study, we attempted to clarify whether or not an EGG can be used to evaluate the influence of illumination and what kinds of effect taste stimuli and illumination have on the autonomic nervous system.

The autonomic nervous system regulates each physical organic action according to the outside environment or to changes in the internal environment based on the physical situation. Therefore, we evaluated the environmental influence on the human body by measuring autonomic nervous function. There are many kinds of indicators used to evaluate autonomic nervous function. In this study, for such evaluation, we used the EGG, which is directly connected with appetite.

The EGG is a reliable, non-invasive method for recording gastric myoelectrical activity (Muth, 1998). It is recorded by placing electrodes on the surface of the skin over the antrum of the stomach (Kaneoke et al., 1992). The frequencies recorded by the EGG are identical with frequencies of electrical activity recorded in or directly on the stomach and frequencies of stomach contractions when they occur (Muth, 1998). The EGG has been used to evaluate the function of the stomach in dysautonomia patients (Gianaros et al., 2001). The frequency of the EGG is often selected as a parameter in an analysis
(Nelsen et al., 1968); it is normally three cycles per minute (cpm), but a faster (tachygastria) or lower wave (bradygastria) than the normal frequency has also been found in cases of diabetes, dysautonomia, and gravidia with nausea (Koch et al., 1990; Walsh et al., 1996).

Methods

Subjects and experience conditions

Thirteen males participated in this study. All subjects were healthy nonsmokers. The mean age was 24±4.5 years old. All subjects gave full informed consent to participate in the study. The experiment was conducted in a lighting chamber in which the room temperature and relative humidity were controlled at 25°C and 50–60%. The environmental illumination was set by a lighting coordinate system (Matsushita Electric Works, Japan). The illuminance was measured by an illuminance meter at the subject's eye level, and the color temperature was controlled by a colorimeter (DP-100, Minolta, Japan).

Sixteen conditions (4 lighting conditions × 4 taste stimuli) were used. The four lighting conditions were set by combinations of 200 lx and 1500 lx in illuminance levels and color temperatures of 3000 K and 7500 K. The four taste stimuli were sweet (glucose), salty (salt), sour (acetic acid), and bitter (quinine). One taste stimulus was tested in a single day for each subject, thus requiring that each subject spend four days to experience all the taste stimuli. The illumination conditions tested were conducted according to a counterbalanced order.

Procedure

In this study, we asked the subjects not to take alcohol and pungent foods for three days before the experiment. Subjects were also asked not to take active exercise, and to sleep for at least six hours on the day before the experiment. The experimental procedures are shown in Figure 1. On the day of an experiment, the subjects had lunch with the same chosen menu at 12:00 hr. They entered the illumination chamber, which was set at 1000 lx and 5000 K, at 13:40 hr. After they had been informed about the experiment for five minutes, the electrodes were attached. After they had rested for two more minutes, the light condition was set at the test condition, and at that time the subjects were told to close their eyes. When the illumination condition began, at 14:25, they were allowed to read a book for 15 minutes. The EGG was recorded without taste stimuli for 10 minutes. After that, the subjects rinsed out their mouths with distilled water, and the test taste stimulus was given on the front part of the tongue by a Harvard syringe pump with the speed set at 1.2 mg/min. During this period, the EGG was also recorded for 10 minutes. After the taste stimulation, the subjects rinsed their mouths and then were exposed to the next illumination. The exposure order of the four illumination conditions was counterbalanced among the subjects. One taste stimulation was conducted per day, and the experiments were conducted for four days for each subject.

Electrode device and data analysis

The EGG measurements were recorded by bipolar electrodes (Ag–AgCl), which were attached on the abdomen. The electrode positions are shown in Figure 2 (Kaneoke Y. et al., 1992). The high-cut filter was set at 0.5 Hz, the low-cut filter at 0.005 Hz. The signals were recorded by a PC at a sampling frequency of 1.9 Hz through an A/D converter. The subjects were required to remain still while sitting to prevent noise from being mixed with the EGG measurements.

The majority of EGG activity occurred between the frequencies of 1 to 10 cycles per minute (cpm). The basic, normal pacesetter electrical activity of the stomach has frequencies around 3 cpm. That means a ratio of normal wave power around 3 cpm (2.0–4.5 cpm) is high in the normal condition, but a component of 1.0–2.0 cpm (bradygastria) or 4.5–10 cpm (tachygastria) shows an increase in unpleasant, angry, and stress conditions. Therefore, we used a ratio
between the normal wave component of the EGG (EGG-NR: 2–4.5 cpm power/1–10 cpm power) and the amplitude of the EGG (EGG-NI: integrated EGG of 2–4.5 cpm) as the indicator to evaluate autonomic nervous activity. EGG-NR was calculated by the following equations:

\[
\text{Ratio of normal wave} = \frac{\text{Normal wave power}}{\text{(normal wave} + \text{bradygastria + tachygastria) power}} \times 100\%
\]

Where: Normal wave = 2.0–4.5 cpm  
Bradygastria = 1.0–2.0 cpm  
Tachygastria = 4.5–10 cpm

We calculated the changes in EGG-NR and EGG-NI by subtracting the values before the taste stimulation from the values during taste stimulation (Δ). We used the remainder as an indicator to compare the influence on the EGG of the taste stimulations. A three-way (illumination × color temperature × taste stimulation) repeated measures ANOVA was conducted. In addition, we used the Student-Newman-Keuls method to provide a post hoc test. We also conducted a two-way (illumination × color temperature) repeated measures ANOVA to evaluate the influence of the illumination on the EGG without the taste stimulation. The level of significance was set at \(p < 0.05\).

**Results**

**Comparison of \(\Delta\text{EGG-NR}\) and \(\Delta\text{EGG-NI}\) among taste stimulations and illumination conditions:**

We compared \(\Delta\text{EGG-NR}\) and \(\Delta\text{EGG-NI}\) for all the subjects for the taste stimulation and illumination tests. Illumination had no significant influence. The results showed that \(\Delta\text{EGG-NI}\) was not significantly affected by the taste conditions. However, the main effect of the taste stimulations on \(\Delta\text{EGG-NR}\) was significant: sweet and salty tastes were significantly higher than the bitter taste (Figure 3, \(p < 0.05\)). No interaction between illumination and taste was found.

**Comparison of EGG-NR and EGG-NI among illumination conditions:**

When we compared the EGG-NR result before the taste stimulations for the illuminance and color temperature conditions, the main effect of the illuminance was not significant, but the main effect of the color temperature was. The EGG-NR value significantly increased at the low color temperature (Figure 4, \(p < 0.05\)).

When we compared the EGG-NI result before the taste stimulations for the illuminance and color temperature conditions, the main effect of the color temperature was not significant, but the main effect of illuminance was. The EGG-NI value significantly increased at low illuminance (Figure 5, \(p < 0.05\)).

**Discussion**

It is known that the stomach has a rhythmic muscle potential activity of approximately 0.05 Hz (3 cpm) (Geldof et al., 1986; Shen, 2002). A regular wave of approximately 3 cpm is observed in a healthy stomach, while tachygastria with a fast frequency of 4–5 cpm and a low electric potential, bradygastria with a slow frequency of 1–2 cpm and a relatively high electric potential, or arrhythmia that combines both may appear in a
stomach with a dysfunctional gastric movement (Sugiyama, 2000). It is reported that the frequencies of the EGG are defined as a slow wave at 1–2 cpm, a normal wave at 2–4.5 cpm, and a fast wave at 4.5–10 cpm (Himi, 2002). Recently, it has also been reported that stress affects the gastric myoelectric activity in healthy subjects (Peter et al., 2001). A gastric contraction is based on a component of 3 cpm, which reflects vagus activity, and the appearance of a high frequency component of 4–9 cpm, which characterizes sympathicotonia (Hu, 1991). Therefore, the analytical results from EGG measurements suggest that stress may increase sympathicotonia.

In the present study, when we compared ΔEGG-NR between the taste stimuli, the results showed that the ΔEGG-NR value with sweet and salty tastes was significantly higher than that with the bitter taste. This result may be explained by the fact that sweetness and saltiness are familiar tastes, whereas bitterness is an unpleasant taste. Sweet and salty tastes may activate the parasympathetic nerve, while the bitter taste may activate the sympathetic nerve. The bitter taste may have caused an uncomfortable feeling and increased stress. Usually, activated parasympathetic activity increases gastric secretion and brings about the appearance of a major normal wave of 3 cpm. On the other hand, activated sympathetic activity causes the gastric blood vessels to contract. This decreases blood flow, gastric movement, and the secretion of gastric acid or gastric mucosa (Kawai, 1994), resulting in EGG-NR also.

However, the main effect of illumination during taste stimulation on ΔEGG-NR was not significant. It might be that taste stimulation is more influential than illumination. In other words, when the illumination and taste stimulation were given at the same time, illumination did not have an influence because the stimulation of taste was more powerful.

The results of the influence of different lighting conditions on EGG measurements in this study demonstrated that EGG-NR was higher at lower color temperatures, and the integrated EGG was higher at a lower illuminance level. These results suggest that an increase in the EGG-NR and EGG-NI values was caused by an excited parasympathetic nerve. Light enters through the eyes, and the optical signal is converted into an electric impulse signal at the retina. The electric signal passes through the optic nerve and the optic chiasm, and part of the signal reaches the hypothalamus, affecting autonomic nervous activity as well as the endocrine system through the blood vessels. Sympathetic nervous activity is restrained, and the endocrine system is influenced in low color temperatures and low illumination conditions. The vagus nerve activity of the parasympathetic system is raised, and stomach activity is also promoted. This might be why the normal wave ratio and the EGG amplitude were elevated. Previous illumination studies also have reported that the lower the color temperature became, the more the parasympathetic nerve became dominant. Sugimoto (1980, 1981) reported that the heart rate increased, and Saito et al. (1996) reported that sympathetic nervous activity increased under the high illuminance condition, while Dijk et al. (1991) reported that arousal level was increased and that hypothermia was prevented during the high illuminance condition. Moreover, regarding the effect of color temperature, Mukae and Sato (1992) compared HRV between a 3000 K condition and a 6700 K condition, with the result that under the 6700 K condition, autonomic nervous activity increased. Deguchi and Sato (1992) compared CNV between a 3000 K condition and a 7500 K condition, showing that under the 7500 K condition, the arousal level rose. These results agree with those of our present study.

On the other hand, several previous studies have indicated that under the high illuminance condition, parasympathetic nervous activity increased while sympathetic nervous activity was inhibited. Tokura (2005) and Kim et al. (2000) reported that after high illuminance exposure in the morning, rectal temperature and a thermoregulatory set-point decreased in the afternoon or in the evening, and prevented melatonin suppression and decreased blood pressure significantly, suggesting a decrease in sympathetic nervous activity. In addition, Kanikowska et al. (2002) showed that after high illuminance exposure for several hours parasympathetic nervous activity increased, sympathetic nervous activity was inhibited, and salivation increased. The results of these previous studies were obtained following light exposure during the morning. However, in the present study, the results were obtained during light exposure during the afternoon. The reason for the difference between the results of our study and those of previous studies may be due to the difference in the time of light exposure. However, the results of Kanikowska’s study showed that low illuminance exposure in the evening caused an increase in salivation quantity, these results agreeing with those of our study. This suggests that the respective effects of light exposure in the morning and that in the afternoon/evening are different. In addition, we measured the physiological indexes during light exposure, but Tokura (2005) and Kim et al. (2000) measured the physiological indexes after light exposure. This difference may be one of the reasons for the difference in results.

In the field of physiological anthropology, studies on color temperature have been carried out in great numbers. For example, heart rate variability is often used as an index of autonomic nervous function to evaluate the relationship between color temperature and illuminance. Previous results showed that autonomic nervous activity, especially sympathetic nervous activity, was elevated under high color temperatures (Doi, 2003). This suggested that the rise of sympathetic nervous activity caused stress under a high color temperature. The autonomic nerve is stimulated when stress is sensed, thus elevating sympathetic nervous activity. At the same time, feelings such as uneasiness or anger develop. As a result, blood pressure and heart rate increase, and then circulation to the brain, heart, and muscles increases. On the other hand, blood vessels that go to the skin and visceral organs strongly contract. In this condition, peristalsis of the stomach stops and secretion of gastric juice decreases. This study showed that
high illuminance and high color temperature in the lighting environment at mealtime raised sympathetic nervous activity, thus suppressing the activity of the stomach and the digestive function. From the viewpoint of health maintenance, low illuminance and low color temperature increased the activity of the stomach and the digestive function. As an index of the autonomic nervous system of the digestive organs, the EGG is more suitable than other indexes for the evaluation of lighting environments at mealtime.

In conclusion, we have shown that the EGG, an index of the autonomic nervous system of the digestive organs, is useful for evaluating the effect of illumination. We also found that, when illumination and taste stimulation are given at the same time, the latter has a greater influence than the former.

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