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Humorous sentences enhance memory and induce beta and gamma power in the human frontal cortex.

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Abstract

Humor is often used to facilitate memory in education. Previous studies have shown that students memorize humorous sentences and cartoons more easily than they memorize sentences and visual stimuli without humor. However, little is known about the electrophysiological effects of humor on attention. In this study, we recorded electroencephalograms (EEGs) to assess the effect of humorous sentences, which were confirmed herein to reduce ongoing body movement during learning and enhance recall test scores. In all experiments, EEG signals were recorded while the participants read sentences that either contained or did not contain elements of humor. Analysis of the EEG data revealed that beta power and slow gamma wave power were enhanced in the prefrontal cortex. Therefore, humorous sentences enhance concentration and encourage learning.

Introduction

In education, humor is used to attract the attention of the students. One of the theories explaining why educational materials presented in a humorous manner facilitates learning, instructional humor processing theory, maintains that the recognition of humor increases students' attention[1]. Studies have shown that individuals tend to score higher on subjects with humorous materials than on those without humor[2-5]. This may be caused by the increased attention evoked by humor, but there is little evidence for a relationship between humor and attention. In this study, we took an electrophysiological approach; we recorded electroencephalograms (EEGs) to assess the effect of humor on attention.

Children aged 9-10 years participated in this study, and EEGs were recorded while the participants responded to humorous or control stimuli. The participants' concentration and learning efficiency were also assessed for humor and control conditions.

Materials and Methods

Stimuli

For humorous stimuli, sentences were adopted from the Kanji vocabulary workbook with toilet humor (The Poop Kanji Workbook, Bunkyosha, Tokyo, Japan). For control stimuli, example sentences of vocabularies without humor were used. For each stimulus, 40 example sentences were prepared.

Experimental scheme for EEG recording

Eight children (9 or 10 years old) participated in the study. After the EEG system was attached to the heads of the participants, stimuli were presented in 30 second intervals; then, participants were instructed to sit on a chair in front of a monitor. The distance between the monitor and a participant was 30 cm. During trials, a sentence either with or without humor was displayed on the monitor. After the subjects finished reading the displayed sentence, they switched to the next sentence by clicking a button. For each subject, two trials, each lasting 5 min, were performed while the electroencephalogram (EEG) and electrooculogram (EOG) data were recorded. One of the trials was performed with a set of humorous sentences, and the other was performed without any humorous expressions; stimuli were presented in a randomized crossover design. After each trial, participants rested for a 30-s interval.

Human EEG

The human EEG signals at Fp1, Fpz, Fp2, F3, Fz, F4, and Cz (following the international 10/10 coordinate convention) were collected at a sampling rate of 500 Hz (the left earlobe was used as a reference) with a wireless EEG system (Polymate Mini AP108, Giken Co., Ltd, Tokyo, Japan) with paste-less dry electrodes (National Institute of Information and Communications Technology, Japan)[6]. Eye movements and blinks were simultaneously recorded with an electrode placed on a left lower eyelid. The recorded EEG and blink–related signals were passed through an online notch filter (50 Hz) and saved on a computer using the Mobile Acquisition Monitor Program (NoruPro Light Systems) through a Bluetooth wireless connection (Naruse, 2014). The EEG signals were analyzed using custom Python codes. The raw data were preprocessed offline by bandpass filtering (1 to 40 Hz or 40 to 80 Hz). Additionally, EEG epochs that contained large potentials, abnormal spikes or drifting components were excluded semiautomatically. These noisy epochs were generally derived from eye movements and blinks. These blink-related data were removed manually.

EEG data analysis

Data analyses were performed using Python. To remove muscle artifacts, the first and last 30 s were removed from the 5-min EEG recordings. Then, the raw data were preprocessed by bandpass filtering. A set of bandpass filters (8-12, 12-30 and 30-40 Hz) was used in the analysis of alpha waves, beta waves and slow gamma waves, respectively. With this preprocessing, we obtained clean data from eight participants. The change in the relative intensity of each wave (A to B Hz) was calculated by the following equation:

$$\text{AUC ratio} = \frac{\int_{A\,Hz}^{B\,Hz} P(f)\,df}{\int_{1\,Hz}^{80\,Hz} P(f)\,df}$$

where $P(f)$ represents the EEG power at frequency f. This AUC ratio was calculated for two conditions: humorous stimuli and control stimuli. The EOG signal from the lower left eyelid was used for manual blink detection.

We calculated the EEG power and represented the increase in EEG power in pseudocolored maps smoothed by a Gaussian filter (σ=0.5, single time). The increase in EEG power (ΔEEG power) and relative ΔEEG power was calculated by the following equations:

$$\Delta\text{EEG power} = \text{AUC ratio}^{humrous} - \text{AUC ratio}^{control}$$

$$\text{relative } \Delta\text{EEG power} = \frac{\Delta\text{EEG power}}{\Delta\text{EEG power}_{maxmimum}}.$$

Experimental scheme of the learning test

In a cognitive examination, 32 children who were 9 or 10 years old were tested in a randomized crossover design with humor and control conditions. We used a vocabulary workbook for humorous and control sentences (see *Stimuli*), each containing 40 new vocabularies. A custom test was prepared to assess participants' learning before and after working on the workbooks. The test consisted of a 'reading' section with 15 vocabulary words and a 'writing' section with 10 vocabulary words for each test condition. Participants first solved the test in 15 min (pretest). Participants then worked on either the workbook with humorous sentences or the workbook with control sentences and then worked on the other workbook (Work 1 and Work 2). Works 1 and 2 were performed for 20 min each in intervals of 5 min. After each work session, participants were given 15 min to resolve the same test as the pretest (posttest). While testing, the movement of the participants during each work session was captured by a camera (UCAM-C310FBBK, ELECOM, Osaka, Japan) at the rear of the room.

Data analysis of the learning test

The scores of the vocabulary test were analyzed using Microsoft Excel. Scores were tabulated separately for the humor and control groups. The difference between the posttest and pretest score rates was calculated for each participant. The video files were analyzed using Python. The video was converted to grayscale and divided into frame-by-frame pictures. In every frame, the number of pixels that showed different intensities from in the previous frame was counted as movement. The movement in each frame was calculated as the number of differed pixels in the frame. For each work section, the most frequent value was set as the baseline and subtracted from the data. After this preprocessing step, movements performed by participants while working on workbooks with humorous sentences were compared with their movements in the control condition.

Results

We collected EEG data from 8 participants and analyzed the EEG power in two conditions (control stimuli and humorous stimuli). EEG signals were recorded from seven sites in accordance with the international 10/20 system (**Figure 1**). We calculated the EEG power (AUC ratio) in both conditions and compared in each characteristic frequency band (alpha, beta and slow gamma). No significant difference in alpha wave power was observed between the two conditions in all recording sites (control *vs*. humorous) (**Figure 2 top**). The power of beta waves in the humorous sentence condition was significantly higher than that of the control condition at the Fz, Fp1 and Fp2 sites (*P* (control *vs.* humorous) = 0.0137, 0.00524 and 0.0404, respectively) (**Figure 2 middle**). Similarly, the power of the slow gamma waves was significantly higher in the humorous sentence condition at Fp2 (*P* (control *vs.* humorous) = 0.0475) (**Figure 2 bottom**). Since the power of beta waves and slow gamma waves increased in the humorous sentence condition, we visualized their relative delta power (humorous - control) as pseudocolored maps (**Figure 3**). There was no increase in the alpha wave power in any of the recorded regions. On the other hand, a large increase in beta power was seen at positions Fz, Fp1 and Fp2, and, although not statistically significant, a similar increase in slow gamma waves was observed in the same brain regions.

Next, we examined the learning effectiveness and concentration of the 32 participants by requiring them to work on a Kanji workbook containing each stimulus (control stimuli and humorous stimuli). In the 'Reading' section, scores for Kanji learned in the workbook containing the humor stimuli increased at a significantly higher rate than the scores for Kanji in the control workbook (*P* (control *vs.* humorous) = 0.037) (Figure 4 left). In the writing section, the scores for Kanji learned in the humorous workbook tended to increase at a higher rate than that of the control workbook, but not significantly (*P* (control *vs.* humorous) = 0.333) (Figure 4, right). We also quantified participants' movements in each work session (see Materials and Methods). There was significantly less body movement in sessions with the humor workbook compared to the body movement in the sessions with the control workbook (*P* (control *vs.* humorous) = 1.43×10^{-68}, Kolmogorov–Smirnov test) (Figure 5B).

Discussion

In this study, we compared the EEG power of subjects while they were exposed to sentences either with or without humor. We found that reading sentences with humorous expressions significantly increased beta and slow gamma waves. Consistent with our findings, a previous study has shown that humorous visual stimuli evoke an increase in EEG power under 30 Hz[7]. Beta activities are often associated with visual attention[8]. An increase in beta power in the stimulus expectancy period has been reported in human subjects[9,10]. Other studies observed a correlation between alertness to visual stimuli and an increase in beta power along with a decrease in alpha power[11,12]. Our study did not find a significant decrease in alpha wave power, but this is most likely due to the difference in the age of the subjects. Previous studies used subjects aged approximately 20 years, but the subjects in our study were 9 to 10 years old. Since fast alpha wave activity (9.5-12.5 Hz) is known to increase as children develop into adults, participants in our study may not have been old enough to express changes in alpha wave power[13]. Gamma activity is associated with percept and memory, and studies show that selective visual or auditory-spatial attention induces gamma band responses in human subjects[14,15]. The increase in gamma wave power is also observed in associative learning[16]. Since an increase in slow gamma wave power was also observed in our study, we may conclude that humorous stimuli induce associative learning when used in educational materials.

Furthermore, we examined the effects of humorous stimuli on learning. We found that subjects who studied with a workbook containing humorous sentences had higher learning efficiency in the reading section and concentration than those who studied with a workbook containing regular sentences. These findings are consistent with previous studies that show that humorous stimuli enhance attention[1] and learning performance[2-5]. Notably, there was no significant increase in learning efficiency in the writing section. Since writing is a task that requires accurate memorization of complex Kanji shapes, it is possible that the short, single 20-min learning task examined in this study was not suitable for the present assessment. The effects of more complex tasks on long-term learning need to be examined separately, as long-term repetitive learning also plays an important role in actual education.

This study integrates the effects of humor stimuli on EEG and memory. Although it has been proposed in the field of psychology that humor is useful in facilitating learning, little is known about the ways in which humor affects learning, enhances concentration and encourages learning. In electrophysiological studies, increased EEG in slow-gamma power has been reported in memory encoding[17]. Based on these findings and our results, it is suggested that humor stimuli are more useful than normal stimuli in promoting learning by facilitating stronger slow gamma waves. This theory is consistent with the results of the tests in this study. Moreover, we also observed an increase in beta power by humor stimuli. It is known that beta activities are associated with visual attention[8]. As the degree of concentration can be assessed by body movements[18], the study assessed concentration by body movements of the participants during the task and showed that humor improved the degree of concentration. This result suggests that humor may increase the degree of concentration through increased beta power. These results support the instructional humor processing theory that humor has a positive impact on learning.

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Notes

This work was performed as a part of private investigations and is free copyrights. We declare no conflicts of interest. Correspondence should be addressed to Yuji Ikegaya (yuji@ikegaya.jp).

Figure

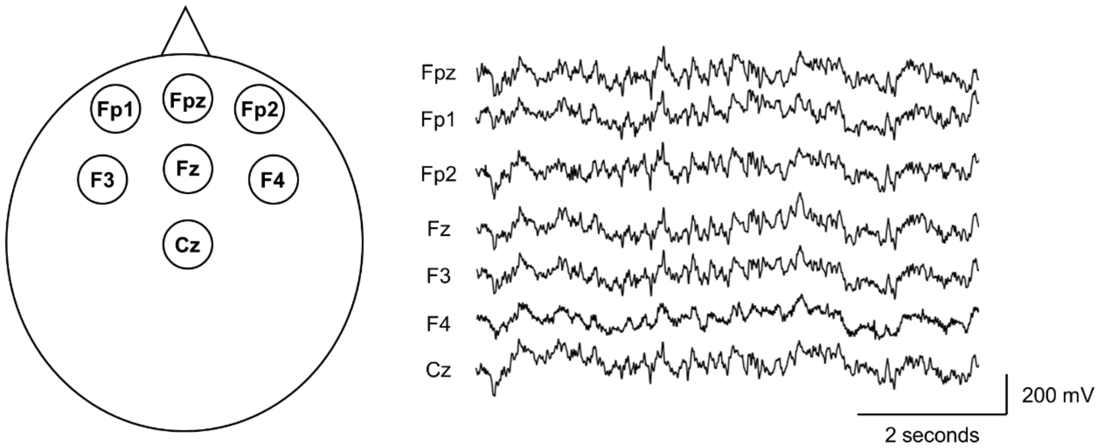

Figure 1. The recording sites of EEG signals. *Left*: Positions of the EEG electrodes used in this study (Fp1, Fpz, Fp2, F3, Fz, F4, and Cz). The electrodes were placed according to the international 10/20 system. *Right*: representative figure of recorded EEG waves preprocessed with a notch filter and a bandpass filter.

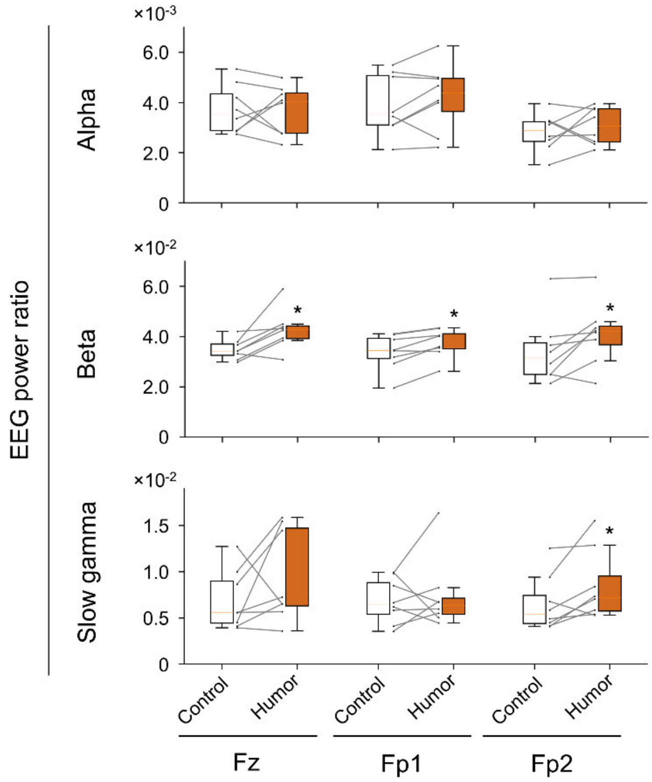

Figure 2. Comparison of the EEG power ratios between the control and humorous stimuli. Power of the alpha (*top*), beta (*middle*) and slow gamma (*bottom*) waves in the control and humorous sentence conditions for three recording sites (Fz, Fp1 and Fp2, respectively, from left to right) (*P < 0.05, paired t-test).

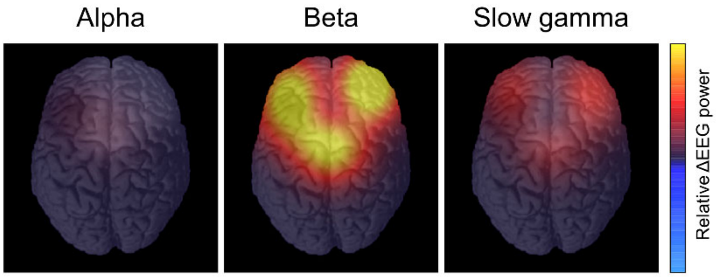

Figure 3. The difference in active brain areas in response to control and humorous stimuli. The pseudocolored maps of the ΔEEG power at the prefrontal cortex. A warmer color signifies a larger increase in ΔEEG power, and a cooler color signifies a larger decrease in ΔEEG power. There are seven channels, and each electrode is located at Fpz, Fp1, Fp2, F3, Fz, F4, and Cz sites in the international 10/20 system. *Left*: the pseudocolored map of prefrontal ΔEEG alpha wave power. *Middle*: the pseudocolored map of prefrontal ΔEEG beta wave power. *Right*: the pseudocolored map of prefrontal ΔEEG slow gamma wave power.

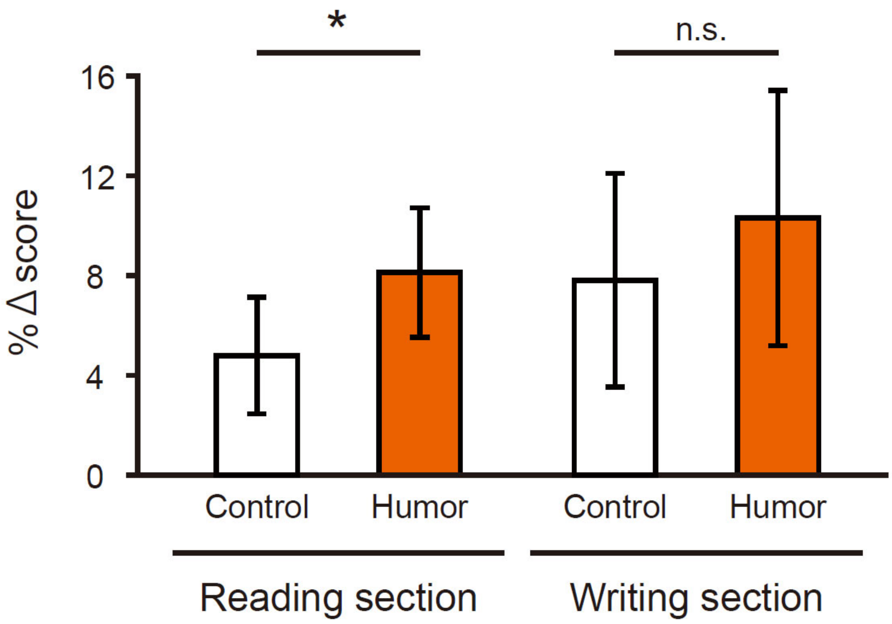

Figure 4. Learning induced changes in reading and writing test scores under control and humor conditions. The bars represent the mean and 2SEM of learning-induced change in scores (n = 32 persons). *P < 0.05, paired t-test.

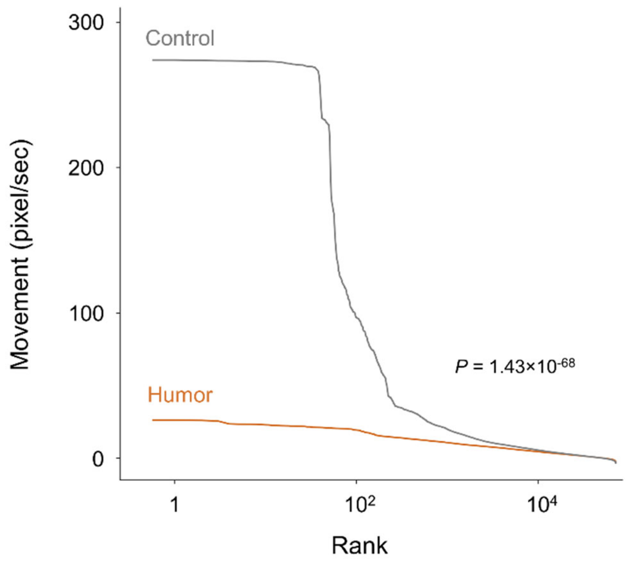

Figure 5. Rank plot of movement in the humor and control groups. The gray trace shows the movement while the participants worked on the workbook with control sentences, and the brown trace shows the movement while the participants worked on the workbook with humorous sentences. There was significantly less movement during humorous conditions ($P = 1.43 \times 10^{-68}$, Kolmogorov–Smirnov test).