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CHANGES IN BRAIN WAVES UPON THE RECOGNITION OF EVACUATION SIGNS IN A DISASTROUS SITUATION IN A SUBWAY STATION

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ABSTRACT

Smoke caused by a fire in a subway station makes it difficult to breathe and it is also difficult to find an exit in a state of fear in darkness and fires. This study aimed to examine changes in brain waves in four cerebral areas including the frontal, parietal, temporal and occipital lobes when people can effectively evacuate with the help of an identifiable evacuation sign in this disastrous situation. The frequency of waves observed in the left and right frontal lobes showed that the frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves without an evacuation sign was about 3.4%, 3.8%, 10.6%, 28.1% and 54.1% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves with an evacuation sign was about 3.5%, 4.1%, 12.3%, 38.6% and 41.5% respectively, indicating that the frequency of beta waves (β) increased by about 10%, and that the frequency of gamma waves (γ) decreased by about 13%. The frequency of waves observed in the left and right parietal lobes showed that the frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves without an evacuation sign was about 4.8%, 5.8%, 11.5%, 32.1% and 45.8% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves with an evacuation sign was about 4.9%, 5.2%, 12.1%, 34.5% and 43.3% respectively, indicating that the frequency of beta waves (β) increased by about 2%, and that the frequency of gamma waves (γ) decreased by about 2%. The frequency of waves observed in the left and right temporal lobes showed that the frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves without an evacuation sign was about 5.8%, 8.6%, 8.6%, 32.1% and 44.9% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves with an evacuation sign was about 4.6%, 7.9%, 10.9%, 40.5% and 36.4% respectively, indicating that the frequency of beta waves (β) increased by about 8%, and that the frequency of gamma waves (γ) decreased by about 8%. The frequency of waves observed in the left and right occipital lobes showed that the frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves without an evacuation sign was about 2.1%, 4.2%, 14.9%, 34.1% and 44.7% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves with an evacuation sign was about 3.6%, 3.9%, 12.6%, 41.8% and 38.1%, indicating that the frequency of beta waves (β) increased by about 7%, and that the frequency of gamma waves (γ) decreased by about 6%. All the four cerebral areas showed a decrease in gamma waves (γ) and an increase in beta waves (β) when there was an evacuation sign, which can be attributed to the reasonal judgements of the subjects based on the evacuation sign.

KEYWORD: Subway station, evacuation sign, brain wave, beta wave.

INTRODUCTION

Fires that occur in subway stations have caused serious casualties. In fact, many combustible materials are used as an interior material in subways, and thus fires that occur inside subways are uncontrollable. Since toxic gases caused by the materials make it difficult to breathe and see ahead, people get very confused.[1] When a fire occurs in spaces like subways, most people try to find an exit, and the golden time for escaping and surviving from the occurrence of a fire is 3 minutes. The survival of victims cannot be assured after the golden time. This study aimed to identify what kind of electrical flows are generated in the cerebrum through brain waves when people can quickly find an exit and effectively evacuate with the help of an evacuation sign in the early stage of fires in subways. Since it is impossible to simulate a fire in an actual subway space, a disastrous situation was simulated using virtual reality (VR) with high efficiency and reliability, and subjects wore a brain wave detector. An actual subway station was reproduced for VR simulation in this study, and those who frequently use subway stations were mainly tested. A removable brain wave detector was used to analyze the brain waves of the subjects. Brain wave signals differ depending on the five senses or the conditions of the body such as arousal and sleep, and different brain activities are observed depending on the psychological state of humans.[2,3,4]

The brain is divided into the frontal, parietal, temporal and occipital lobes, and the frontal lobes control high-level functions including personality, ethics and the ability to think.[5,6] The parietal lobes control motor skills[6,7], and the temporal lobes play a pivotal role in the sense of hearing and language skills.[6,8] The occipital lobes play a pivotal role in the sense of sight, and detect and identify colors and shapes.[6,9] Electrodes to measure brain waves were attached based on the Internationally Standardized 10-20 System. Using the 10-20 System, 4 points from the inion point to the nasion point, and between the preauricular points of the two ears are connected with a tape measure, and the center is set as Cz (central zone). From the center, electrodes are placed at the intervals of 10% and 20% in order.[10] Therefore, the location of electrical waves generated on the scalp can be analyzed, and the correlation between points on the scalp of the cerebrum can be identified using the 10-20 System.[11] An earlier study on brain waves conducted a navigation test using movement or sound, which is a simple cognitive function test[12], and some studies examined changes in the speed of the cerebral blood flow and changes in hormones caused by stress in the hippocampus of those who experienced a disaster.[1,13,14,15] Another study analyzed changes in delta waves (δ) and serotonin in the hypothalamus that distinguishes day and night.[16] More recently, a study on the areas of the cerebrum based on creative ideas such as the floor height of a space was performed[17], but there were few studies that measured electrical signals generated from the cerebral cortex by the area of the cerebrum depending on the existence of an evacuation sign in a subway station. Therefore, the results of this study are expected to be utilized as basic data for understanding electrical flows in the cerebrum depending on the condition of disasters.

EXPERIMENTAL METHODS

Electroencephalography (EEG)

Brain waves are divided into delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves depending on the frequency of signals, and they are activated by various activities (Table 1).

Table 1. Wave of EEG (Electroencephalography)(18).

Wave	Hertz	Function
Delta, δ	1~4Hz	Deep sleep, brain malfunction, etc.
Theta, θ	4~8Hz	Light sleep, etc.
Alpha, α	8~13Hz	Arousal, etc.
Beta, β	13~30Hz	Arousal, muscular activity, stress, etc.
Gamma, γ	31~100Hz	Severe stress, urgent situations, etc.

EEG Analysis and VR Device

EEG headset called Quick-20 (PELICAN PRODUCTS TORRANCE CA, USA) that supports the International 10-20 System was used (Figure 1). The EEG of subjects were measured by analyzing electrical signals that were generated from the frontal, parietal, temporal and occipital lobes depending on the existence of an evacuation sign in a subway space.

The sampled frequency when measuring brain waves was 0.3~100 Hz, and 60Hz was selectively blocked. The low-frequency and high-frequency filter range was 0.3~100 Hz, and the setting conditions for EEG analysis were as follows: 8 channels were used and the sensitivity of measurement was 5mm/50㎶. The virtual reality (VR) device used in this study was HTC VIVE Pro Virtual Reality Headset (Taiwan).

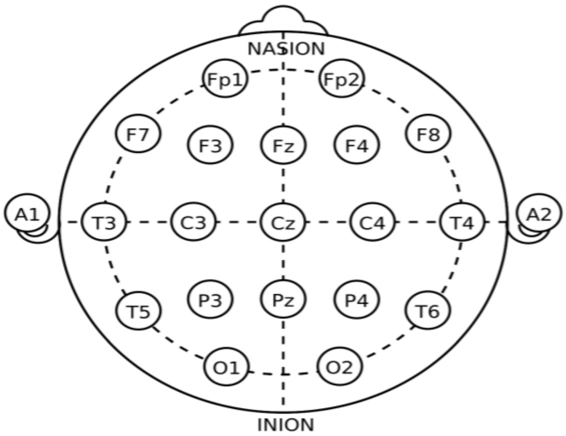


Figure 1. Internationally Standardized 10-20 System. Abbreviation: odd number, the left hemisphere of the brain: even number, the right hemisphere of the brain, Fp, Frontal-pole: F, frontal: C, central:, P, parietal: O, occipital: A, auricular.

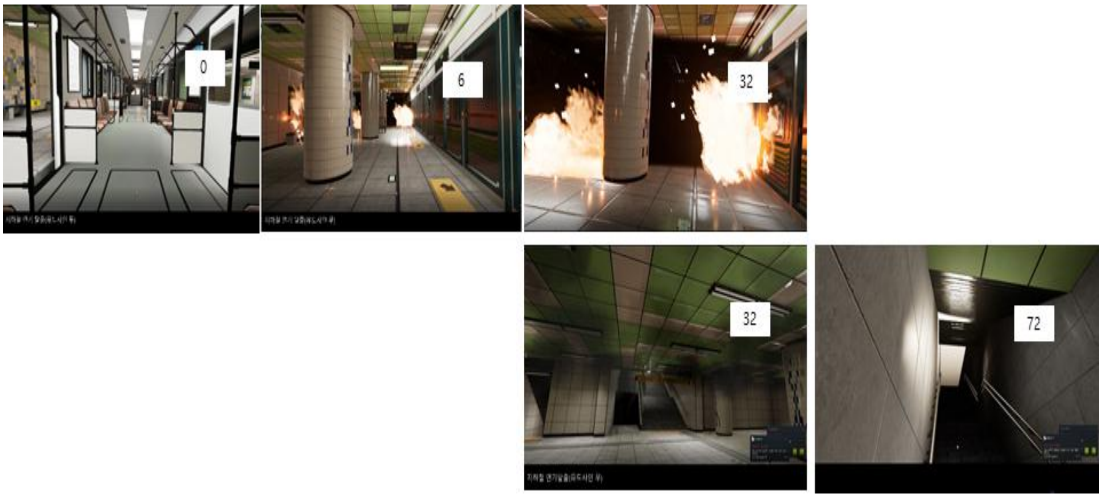


Figure 2. An VR example of a subway station without an evacuation sign from a subway to an exit.

0 sec: Started → 6 sec: Moved from the B3 area to the B2 area and failed to find the direction to an exit in a state of panic.
→ 32 sec: Failed to find an exit way in the B3 area and died.
→ 32 sec: Successfully found an exit, overcoming the difficulty.
→ 72 sec: Successfully found an exit in 72 seconds as the subject knew the exit route.

Figure 2 shows examples of a subway station without an evacuation sign from a subway to an exit in virtual reality (VR). Subjects failed to find an exit, and, even though they found an exit, but it took a long time to find an exit.

Figure 3. An VR example of a subway station with an evacuation sign from a subway to an exit.

1 sec: started → 8 sec: Successfully followed the direction of an evacuation sign, though being in a state of panic in the B3 area. → 22 sec: Identified an evacuation sign, and moved to the B2 area. → 41 sec: Identified an evacuation sign in the B1 area, and recognized an exit direction. → 48 sec: Successfully escaped through an exit.

Figure 3 shows an example of a subject who was first in a state of panic, but identified an evacuation sign and an exit direction in a subway station in virtual reality (VR) and thus successfully escaped within 48 seconds.

Subjects

This study was conduced among a total of 50 young adults (20 males, 30 females) aged between 20 and 26. they were informed of this experiment and expressed their consent for participation prior to this experiment.

Through a pre-survey questionnaire, those who had brain diseases, breathing disorders, claustrophobia, dizziness or tinnitus over the past 6 months were exclude from this experiment. The number of questions in the survey was 23, and this experiment was performed according to the research ethics of Dongeui University.

Statistical Analysis

Data obtained in this study were statistically analyzed using SPSS version 21, and were expressed as an average value and standard deviation. When the P value was 0.05 or lower, the data were statistically significant.

RESULTS AND CONCLUSIONS

Table 2 shows the general characteristics of the subjects of this experiment. They were young adults and their average age was 20~26 years. A total of 50 adults (20 males, 30 females) participated in this experiment. About 89% of the subjects did not have any dizziness and 92% did not have experience of claustrophobia. Only one person (4%) had experience of a fire, and about 56% had experience of a VR game. Only 4% had experience of a fire, and 14% answered that they already knew the golden time for evacuating from a fire is 3 minutes. About 76% knew emergency exits in the underpasses they usually used, but only 6% recognized evacuation signs. There were studies that found that cognition and judgement are significantly reduced in an unstable situation compared to a stable state.[2,19,20] Only very few subjects (6%) knew the location of emergency exits in the subways and underpasses that they frequently used, and the results indicates that it will take more time to find an evacuation exit upon the occurrence of a fire in a state of panic than usual. Similar results can be found in Table 3.

Table 2. Summary of subjects.

Description			N (total=50)	%
Subject of study	age	20-26	50	100
	sex	male	20	40.0
		female	30	60.0
Experiential aspect	VR game	no	22	44.0
		yes	28	56.0
	fire	no	48	96.0
		yes	2	4.0
	evacuation simulation	no	45	90.0
		yes	5	10.0
Preparation for accident	cognition of fire golden time (3 min.)	no	43	86.0
		yes	17	14.0
	cognition of emergency exits	no	12	24.0
		yes	38	76.0
	cognition of safe place	no	42	84.0
		yes	8	16.0
	cognition of evacuee guidance	no	47	94.0
		yes	3	6.0
Disease History	encephalopathy	no	48	96.0
		yes	2	4.0
	dizziness	no	45	90.0
		yes	5	10.0
	respiratory disturbance	no	46	92.0
		yes	4	8.0
	claustrophobia	no	45	90.0
		yes	5	10.0

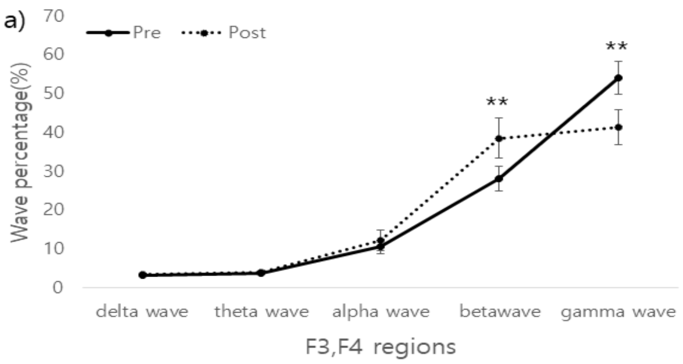
Abbreviations: VR, Virtual Reality.

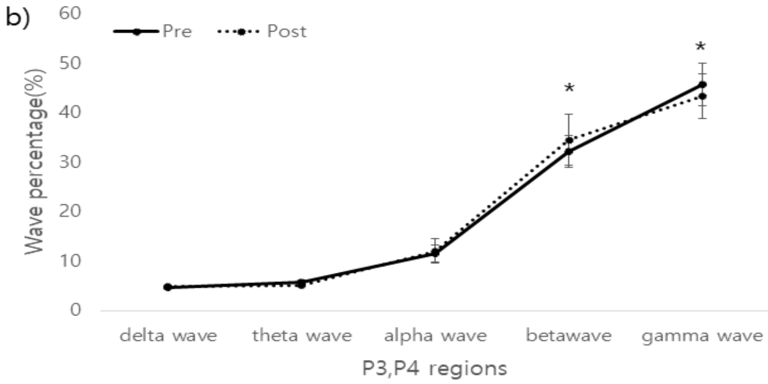
Table 3. 2-paired t-test according to the taxiway line status.

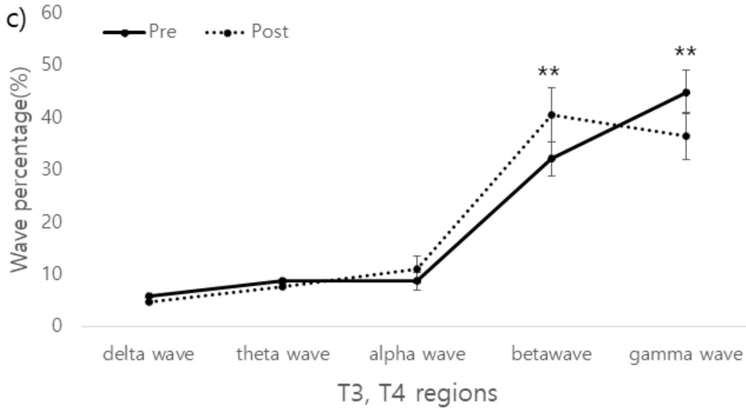
Group	Mean ± s.d. (sec)	T	Significance probability
Pre	77.44 ± 17.11	9.47	0.00
Post	51.92 ± 13.16		

Abbreviations: Pre, pretest not with taxiway line status; Post, postest with taxiway line status; S.D., standard deviation.

Table 3 shows the results of a t-test on the time fore evacuation in a subway station depending on the existence of evacuation signs. The time for evacuation in a subway station without an evacuation sign was 77.44 ± 17.11 sec, while that for evacuation in a subway station with an evacuation sign was 51.92 ± 13.16 sec, down by about 26 seconds. About 65% of the subjects answered in the pre-survey that they used the subway station in reality, and they answered that they knew well passages in the subway station, and that they were able to find an exit in darkness caused by the fire with the help of the evacuation sign in VR.







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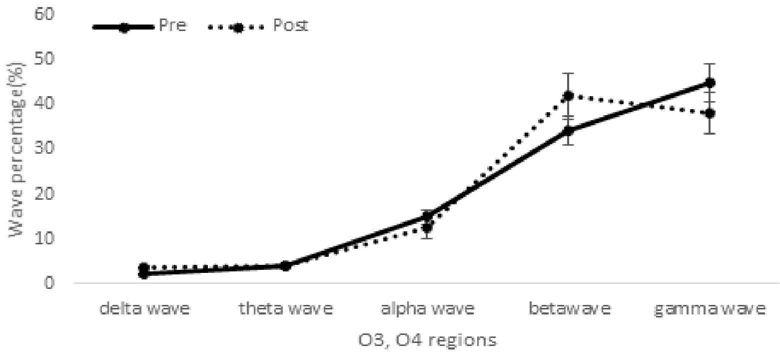

Figure 4. Illustration of Absolute Power of electrodes. (a) F3, F4 (b) P3, P4 (c) T3, T4 (d) O1, O2. Beta and gamma waves in a): p=0.006; Beta and gamma waves in p=0.004; Beta and gamma waves in b): p=0.005; p=0.003; Beta and gamma waves in c): p=0.023, p=0.028; Beta and gamma waves in d): p=0.008, p=0.007.

Figure 4 shows the frequency of waves observed in the frontal, parietal, temporal and occipital lobes of the cerebrum.

Figure 4 a) shows the frequency of waves in the left and right frontal lobes. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station without an evacuation sign was about 3.4%, 3.8%, 10.6%, 28.1% and 54.1% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station with an evacuation sign was about 3.5%, 4.1%, 12.3%, 38.6% and 41.5% respectively, indicating that the frequency of beta waves (β) increased by about 10%, and that the frequency of gamma waves (γ) decreased by about 13%. Figure 4 b) shows the frequency of waves observed in the left and right parietal lobes. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station without an evacuation sign was about 4.8%, 5.8%, 11.5%, 32.1%, and 45.8% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station with an evacuation sign was about 4.9%, 5.2%, 12.1%, 34.5% and 43.3% respectively, indicating that the frequency of beta waves (β) increased by about 2%, and that the frequency of gamma waves (γ) decreased by about 2%. Figure 4 c) shows the frequency of waves observed in the left and right temporal lobes. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station without an evacuation sign was about 5.8%, 8.6%, 8.6%, 32.1% and 44.9% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station with an evacuation sign was about 4.6%, 7.9%, 10.9%, 40.5% and 36.4%, indicating that the frequency of beta waves (β) increased by about 8%, and that the frequency of gamma waves (γ) decreased by about 8%. Figure 4 d) shows the frequency of waves observed in the left and right occipital lobes. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station without an evacuation sign was about 2.1%, 4.2%, 14.9%, 34.1% and 44.7% respectively. The frequency of delta (δ), theta (θ), alpha (α), beta (β) and gamma (γ) waves in the case of a subway station with an evacuation sign was about 3.6%, 3.9%, 12.6%, 41.8% and 38.1% respectively, indicating that the frequency of beta waves (β) increased by about 7%, and that the frequency of gamma waves (γ) decreased by about 6%. When there was an evacuation sign in virtual reality (VR), in particular, gamma waves (γ) increased. The signal frequency of normal people is 2~30Hz, while the signal frequency of 30Hz or higher is mainly observed in those who have mental illnesses. In particular, those who have diseases such as schizophrenia and bipolar disorder show a rapid signal frequency across the cerebrum.[20,21] Significant changes are observed in a state of fear due to a disaster or while finding a way, and theta waves increase across the cerebrum once starting to finding a way[20,21], which is similar to the results of this study. In this study, once the subjects started to find an exit in a subway station, alpha (α) and theta (θ) waves increased across the cerebrum. When there was no evacuation sign in this experiment, theta waves (θ) decreased, and very low gamma waves (γ) that increase when people are in a state of panic or in a situation of danger increased. In the long term, persistently increased gamma waves (γ) are reported to cause many mental illnesses[22,23], and short and long-term memory loss[24], having a negative impact on mental health. Therefore, the results obtained in this experiment showed that the subjects were able to find an exit about over 20 minutes more quickly when there was an evacuation sign. In particular, theta waves (θ) increased and gamma waves (γ) decreased, indicating that rational judgements made the subjects find an exit quickly.

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