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New Unexpected Use of Display Devices: Display Virtually Seeing on "Accidentally Happening Events of Construction Steel Directly Falling on Human-Head" Can be Sensed by Oneself?

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Abstract

Someone passed by a street in the vicinity of a highlight building broken down might have caught in an unexpected big accident on site, to have caused him seriously injured. However, in rare cases, it is possible for any human to avoid big accident by taking an action of avoiding accident, perceiving the serious fear status. Responding to such status, we tried to apply an experiment of simulation using a normal-sized, flat-panel high-definition image display. Incorporating virtual reality with high definition display, as well as generating big noise of iron angle poles crashed, letting a subject to see it with feeling of fear, instantaneously we measured subject's reaction against the crushing scenes as well as big noise. Responding to the noise heard as well as big iron poles crashing seen, a resulting only 6% of subjects acknowledged valid response safely. Avoiding crisis of reaction in the subject's behavior was taken from the virtual reality of experiment as some results. Seeing the fake big accidental scene on high definition image display was striking to the function of the subject's brain sensor. This display system alarms on time the dangerous accident encountered to the subject for avoiding ultimate damages by viewing scenes if the display might be of high definition version.

Keywords: Antioxidant alpha wave; Beta wave; Crisis avoidance behavior; Hearing stimulation; Tactile stimulation; Virtual reality; Visual stimulation

Introduction

In the current century, the world is spread out in highlight construction sites and highlight tall buildings in big and medium cities. As the city scale becoming great, the safety for the people of the cities seemed disregardful because the economy generally tends to the highest priority. For example, if parts in construction materials suddenly go fall down people who are passing by on the street in the vicinity of construction site of a buildings, newspaper might report a big accident has happened, but no one says any comments to avoid the accident if satisfactory. Although, a human passed by through a street in the vicinity of a highlight construction site in a building broken down might have been caught in an unexpected big accident, on site crushed, it might have been caught to someone unhappily be seriously injured. However, in rare cases, it is possible for any human to avoid big accident by taking an action of avoidance, perceiving the serious conditions. Conversely, rarely a result of taking an action of critical avoidance behavior instantly felt strong fear of a serious accidental environment.

An accidental environment can instantly be perceived by human-being due to merging together and interaction of the functions of such three human-sensors as eyes, ears, and skin, which would create a special function of mutual product of thee human sensors. Anyone along with streets can instantaneously be taken by action of critical avoidance due to generation of these human-sensors merging function on suddenly attacking accident. In this case, the brain organ sensor in the current study is defined as a special organ or a brain sensor [1].

Speedy featuring process of special organ sensor, from perception to take an action of the brain sensor, was defined in this study by avoiding crisis logically of which implies big accidents in the construction site will be avoided due to the special brain sensor [2]. For these reasons, we think that reduction of the numbers in onsite workers might have caused disasters happening at the construction site of buildings in cities, as well as of unexpected accidents of people in the vicinity of fallen parts at big accident might be immediate tasks of jobs from safety engineering. Therefore, we created a virtual reality model of experiment systems which virtually reproduce the miseries of the actual accidents on a frame of display. Also, it was assumed that the above-mentioned special organ of a brain sensor able to obtainable measuring changes in brain waves, between just after and before the accident has happened. For this purpose, we have started studying the display operations and watching a detailed study to prototype of measurement system. In the model of experiment system, it is assumed that the building material suddenly falls over the head of someone walked by on the street in the vicinity of the construction site, hitting an unexpected accident. We realized this pattern in the virtual reality, making it possible to reproduce a series of situations as "simulated 3D moving image" on the display [3,4]. Next, we would like to walk while looking at the "simulated 3D video", a brain waves changes at the time the subject perceived the unusual circumstances of the surrounding environment. Taking the behavior of avoiding crisis was obtainable by his own electroencephalographs (EEG) signal while the accident is being encountered. Data of this kind are belonging to three categories: The first one is the valid data saying speed is in time to avoid the accident. The second one is the valid data but the speed is out of time not to avoid the accident. The third one is the invalid data saying no response against the accident: The data ware categorized into either of three categories, the special brain sensor analyzes the data if the behavior of avoiding crisis was taken, resulting to quasi realistic accidents or any others [2].

Experimental System Model of Virtually Falling of Things on Human-Head

Estimating response time

The model of an experimental system is assumed such that a pedestrian is walking in the vicinity of accidental place, where pieces of building materials are assuming falling down to the pedestrian's head, and a virtual reality of an experiment is described here after.

Simulated video image of the accidental scene was such that the construction steel was assumed falling down from a building with a height of 45 meters, equal to the height of 15th stories building, aimed at overhead of human just passed by walking on a street. We assumed a situation that would lead to a fatal accident.

First, assuming that the acceleration of gravity is "g" (=9.8 m/s^2), the height "h" (m) from the ground to the construction site will be given by equation (1).

$$h = \frac{1}{2}gt^2 \qquad (1)$$

$$t = \sqrt{\frac{2h}{g}} \qquad (2)$$

Substituting height "h"=45 meters from the ground in this study, equation (2) give time "t"=3.03 seconds while no wind flows. Then, it was assumed that any action to taken by avoiding hit on head of human body if the time allowed for up to 3.03 seconds.

We have completed an action taken by a time of 3.03 seconds, and then the damage to the human being will be avoided. An experimental system model which virtually reproduced the misery of actual accident in the study (visually shown) was shown in Figure 1 [5,6].

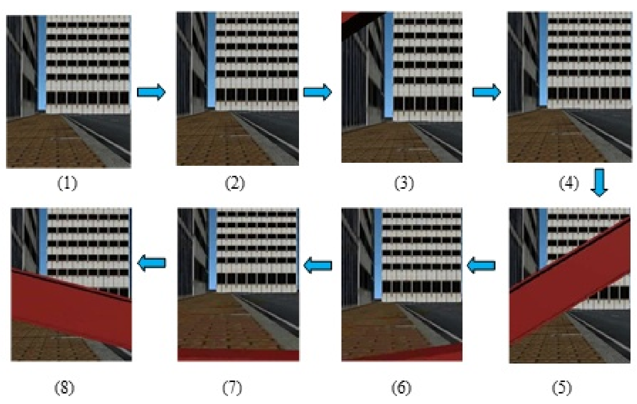

Figure 1: Construction steel falling on the road.

Figure 1 shows eight sequential image frames of parts in peripheral construction materials was assumed falling downward on the head of the subject. Next, in order to let the "simulated 3D sequential moving image" hit on the human head, as shown in Figure 1, closer to the reality, we decided to add a quite bit of large quantity of big sound with a sharply cut around in the construction work site, while the surrounding background give as a sound effect to the virtual reality (heard) [7,8]. Since the effective sound had been recorded beforehand, the system made the subject to listen to the effective sound from the loudspeaker attached to the system every time the experiment was performed.

The first "simulated 3D sequential moving image" was assumed to be created when the construction steel began to fall for passersby personal with big sound of both the construction site and the surrounding environment. In the virtual experiment using such the created moving image, every subject observes such the image as the construction steel began to fall, so that one clicks the mouse with ease to avoid the crisis. It was only perception of any subject by looking at the image where the construction steel began to fall. The problem of moving image could be solved, reconstructing such "simulated 3D sequential moving image" as shown in Figure 1. By utilizing the reconstructed 3D sequential moving image, we are able to take the crisis avoidance behavior by sudden actualizing of the subject's subconscious mind.

The virtual reality of the experimental system model thus was thought to be completed, quasi realistic scenery reproduced by generating a big sharp cut-off sound of construction steel crashed together, to a level of as high as 30 dB as if misery fatal accident could actually occur [9].

Prototype of virtual reality in experimental system model

From equation (2), it takes 3.03 seconds to be randomly displaced for a piece of construction materials located at a height of 45 m was going down to the ground. Therefore, the falling position of piece of building materials elapsing time of 1 and 2 seconds after the start position was also calculated, respectively. Figure 2 shows the relation between the starting time and elapsing time, at the falling positions at piece of building materials would be assumed to hit the subject's head. So, elapsing time of approximately 1 second is enough to save one's life, and is also to be 2.5 seconds to take a start the action of save life prior to the things come down to the ground.

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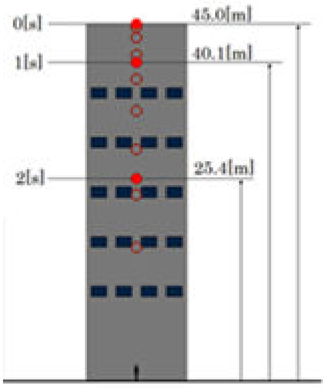

Figure 2: Relation between the starting time and elapsing time, at the falling positions.

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By letting the subject auxiliary hearing noise of sharp cut-off tone from the construction site as an effective sound to the "simulated 3D moving image", the effectiveness was greatly increased by hearing sensor. However, it is still insufficient to discuss the above three sensors only from the visual sensor, but the effective sound is complete obtainable from hearing sensor. In addition to obtainable from the visual, hearing and pressure sensing (tactile) stimulus sensors shows the maximum valued stimuli. Below, we discuss the relation among visual sensor, pressure sensor, (tactile) and auditory sensor, providing merging these sensors generating the brain sensor.

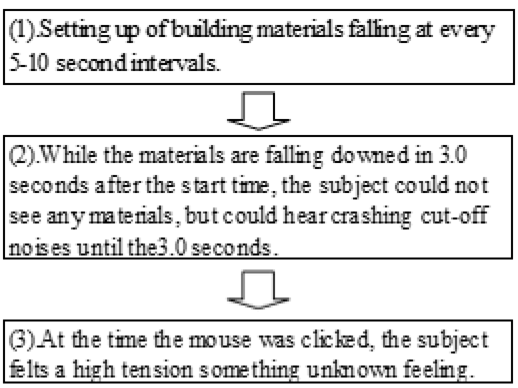

Figure 3: Timing relation in the accident.

Timing of visual, acoustic and tactile stimulus was clear for the timing chart is helpful for readers understanding, as shown in Figure 3. So, the timing chart is described below. At first, falling of construction steel on top of head is continuous for 3 seconds or more. While the construction steel is crashed, sharp cut-off sound is sounding for a period of 3.03 seconds until the construction steel arrive at the ground. The sensors are kept turned on during the time before test until the time of 3.03 seconds and thereafter.

These steps were imposed on each subject, respectively, until up to 10 subjects, and 10 groups were completed. A total of 100 subjects were sequentially imposed on the tests.

Electroencephalogram measurement system

In order to measure the function of the brain sensor defined in the study, we set up newly own EEG measurement system by hand-made devices. Figure 4 shows the configuration of the hand-made EEG measurement system.

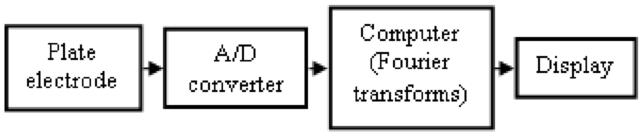

Figure 4: Self-made electroencephalogram measurement system.

The hand-made EEG measurement system includes a plate electrode for taking the EEG signal output from the frontal lobe, an A/D converter for converting the EEG signal from the analog signal to the digital signal, a computer for performing Fourier transforms from time-series digital signals in frequency domain, and stores the data in frequency domain, and a display for showing output voltage waveform in the frequency domain, followed by Fourier Transform [10].

The waveform group following the Fourier Transform is obtainable by applying the interpolation method to each output corresponding to each frequency to obtain the brain wave outputs in the frequency domain, such as for delta wave (1 to 3 Hz), theta wave (4 to 7 Hz), alpha wave (8 to 13 Hz), and beta wave (14 to 30 Hz), respectively.

Way of Measurement in Brain Sensor for Avoiding Accident

A one hundred, collected aged between 21 and 23 years old, in healthy both male and female students were taken as subjects. As shown in Figure 5, two anode electrodes and two cathode electrodes are attached to the frontal lobe of each subject across the EEG measurement system through the plate electrodes, and grounding electrode (GND) attached to the ears.

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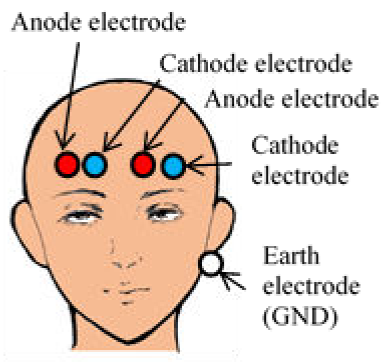

Figure 5: Plate electrodes attached to the frontal lobe.

Protocol of each experiment is also important. Number of tests for each subject, instructions for subjects, rest time and so on.

Totally 100 subjects were divided into 10 blocks each of which are 10 substitutes, so that we were obliged to have each subject could completely be accepted difficult test. Since the test were very difficult question, although the scenery to be considered were fake, not real but imaginal, the decision to make in virtual space was life-dependent serious problems. Previous test was required for each subject to understand the current experiment completely, for obtaining the valid response to the object and results. So, we have to let for each subject to educate himself training enough knowledge to give a correct response. It took whole one day. We might indicate to sense stimulus of active brain sensors by merging together the visual, auditory, and tactile sensors whose stimuli are at maximum (which is shown in Figure 5). We managed the test sequence of each of the 10 subjects was carefully to perform the meaning of test once at a time. Both alpha wave (relaxed state: 8-13 Hz) and beta wave (tensioned state: 14-30 Hz) were appeared concurrently at their peaks from the valid response, of which their bodies or lives were not injured but harmless, namely by which imaginary actions.

Plate electrodes for inspecting the brain wave were attached to each subject's frontal lobe. Connecting the plate electrodes through the coaxial cables, connecting between the plate electrodes and the A/D converter, are used to pick up brain wave together with noise from the surrounding environments picked up. The noise was derived from contact resistance caused by mainly soldering to plates electrodes, and these were kept minimized so that the electrodes and leads were purchased from the manufacturer. The "simulated 3D moving image" shown in Figure 1 was used for the experiment, which was a real drawing of the image for the subject walking in the vicinity of the construction site. Virtual reality has become even more realistic by adding the noise around the construction site together with surrounding environments.

By showing the simulated 3D video to the subject just before the start of the measurement, it makes the subject fully feel high tension at a time of actually encountering the accident, and then we measure the brain wave to avoid the accidents. Subjects perceived themselves as a brain wave around the unusual circumstances of the surrounding environments. It was possible for them to respond quickly to take action of avoiding crisis at least about 1.0 second before the piece of building materials dropped from the construction site overhead. If no action was taken for the response to the piece of iron material dropping overhead, the subject might be unsafe. In order for them to let the piece of construction materials falling overhead before a marginal time of at least 2.5 seconds, they were never to hit overhead by taking any action of instantaneous avoidance. So, it was required that the brain wave will function at least 2.5 seconds at this time.

When the authors interviewed subjects, who were saved in a safe range not encountered fatal injuries, every subject testified that "I felt a sign of tension, so I clicked the mouse". To support the testimony, when the authors measured brain waves under circumstances in safe life status, a beta waves showing tension was remarkably observed immediately followed the alpha wave.

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How to Activate Brain Sensor

We supposed each subject might feel a stimulus in a little bit from the pressure sensor (tactile) by the pressure form the wind or something was sensed when any material was started to falling from the construction site at 45 m above the ground. The subject might sense whose skin unconsciously feeling on his/her skin surface tensely. In accordance with supporting this phenomenon in interview, the subject every time testified "I clicked the mouse because I felt a sign tensely." Alpha waves (8 to 13 Hz) and beta waves (14 to 30 Hz) conspicuously was output at the brain waves (see Figure 7) viewed at that time. It was said to be output at alpha wave when relaxed. In virtual reality, reported is an alpha wave suppressed before and after the image of actually moving or in the meantime of moving image. If one has conceived those feelings, and they are after the alpha waves increase when this sequential motion has been completed [11]. Presence or not of the beta wave influenced by strains depends on the applied mental burdening to the biological load. According to the subject's past experienced, the brain waves were sensed in a psychological manner by skin surface sensor [12,13]. Based on the testimony of the subjects and the above research reports, stimulation of pressure sensor (tactile) was enabled to sense the dangerous accident and to avoid the accident. That is to say "suddenly caused by falling of the construction steel, from the construction site of 45 meters above the ground, is enabled psychologically escaped from the subject's past learning." It was to say judged by the way of skin felt and the brain thought.

Condition of experiment might be clear, provided that specs of displays, audio equipment and tactile device might be as described in Table 1. Size of display, observation distance and scale factor of display is also important.

To summarize the above, when the subject's brain sensor tends to reach its climax at once, which implies the whole-body area of the various sensors consisting of merging of visual, auditory and pressure (tactile) sensors together whose stimuli are at maximum.

Video setup	
Frame size	60 inches
Backlight	Edge LEDs
Resolution	1,920 × 1,080
Aspect Ratio	16:09
Audio setup	
Practical maximum output	40 W+40 W
Frequency characteristic	10 Hz-100 kHz
S/N Ratio	100 dB
Brain wave sensor	
Alpha wave output	8~13 Hz
Beta wave output	14~30 Hz

Table 1: Specifications for display, audio equipment, and brain wave sensors (tactile). NOTE: The video setup and audio setup were commercially available, and the brain sensors were not available, but this hardware were homemade versions.

The subject feels a message conveying the deadly danger from the surrounding environment at this time. At that time, the brain sensor functioned that the subject might reflexively clicked the mouse and immediately took avoidance action. Seeing such a simulated three-dimensional moving image in Figure 1 at the building construction site on a large 60-inch screen area of Figure 5, together with a large crashing cut-off noise at on-site, hearing form a loud speaker in real time, establishes the subject in a circumstance of virtual reality for occurring an accidental possibility. When the subject become aware of unconscious feeling in view of apparent tension applied to the whole-body (whole body) skin of arms and/or feet, the subject tends to click the mouse. Figure 6 shows the function of the brain sensor yielding from a merging sensor consisting of visual, auditory, and pressure (tactile) sensors whose stimuli at maximum, together for providing stimuli of deadly danger to protect one's body itself immediately.

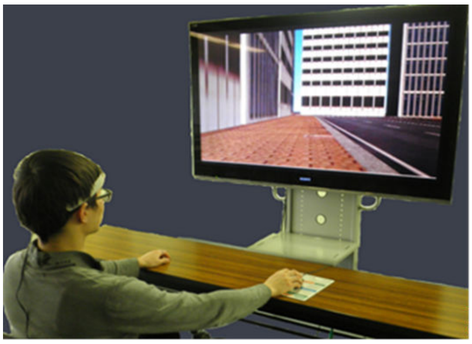

Figure 6: Generation of brain sensors stimulus by merging together the visual, auditory, and tactile sensors whose stimuli are at maximum.

Model of Experiment Results for Avoiding Accident

The model of experimental status for avoiding accident is shown in Figure 7. Measurement data acquired from 100 subjects were classified into the four categories; "The crisis avoidance behavior was taken by function of bran sensor". "The brain sensor was too strong to take the crisis avoidance behavior", which means such that "The brain sensor worked after the accident". And "The brain sensor could not work in the accident".

These four categories of classes depend on mutual comparison of the timings between the brain wave works, which imply the timings the subject clicked the mouse, with respect to occurring time of data, together with the brain sensor worked by the action of the various sensors merged of visual, auditory and pressure sensors (tactile) stimulated [14]. The occurring time of data was acquired by the timing from the start to the fall down until the mouse was clicked.

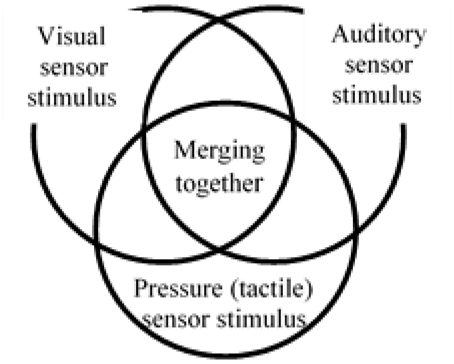

Figure 7: Model of experiment status for the subject to take action of avoiding accident immediately. NOTE: For further information on the unconscious feeling, see the APPENDIX "What about brain sensor responded to accident."

Action of avoiding crisis taken by function of brain sensor

Among the total of 100 subjects, only six subjects were felt the surrounding environment unusual immediately after the time the brain sensor had functioned. They clicked the mouse in 1.0 seconds before the construction material dropped over the head. Figure 7 shows an example of brain wave data of a subject who clicked the mouse in 0.53 seconds after a piece of the building material started to drop. Subjects who obtained such measurement data are evaluated as having taken actions to avoid crises. With seeing the measurement data in Figure 8, we can see at first alpha wave (8 to 13 Hz) group to have appeared "while relaxing generally," and then beta wave (14 to 30 Hz) appearing at tension at 18 Hz at its peak. One momentary tension runs at a peak of one sharp beta wave seen at 18 Hz, of which one started behavior of avoiding crisis taken reflexively (see Supplementary Figure S1). Among 6 subjects with sharp beta wave peaks, there were 2 persons at 18 Hz, 3 persons at 20 Hz, and only 1 person at 22 Hz [15].

When a single sharp beta wave peak has appeared, the subject can observe the image visually, hearing the work sound from the construction site, together with sounds of the surrounding environment. Then, the subject can take an action of avoiding crisis by virtually seeing the big accident scenes with big sound. By using the brain sensor combined together the virtual pressure sensor (tactile) stimuli, we felt stimuli of the virtual wind pressure from learning psychologically skin of the subject would like to be nervous. As a result of the merging interaction of these three stimuli of Figure 5 reaching its climax, it seems that the brain sensor functioned effectively. For referencing the brain sensor of subjects taken by behavior of avoiding crisis, the time from starting the piece of construction material to fall until the mouse was clicked was 0.53 seconds (2 persons), 1.41 seconds, 1.60 seconds, 1.84 seconds, and 1.87 seconds, respectively. The falling distance of construction materials was 1.39 to 17.13 m.

Talks of "functioning brain sensor" also experienced many cases by the old, experienced engineering personals in the construction field were hired many times from the authors.

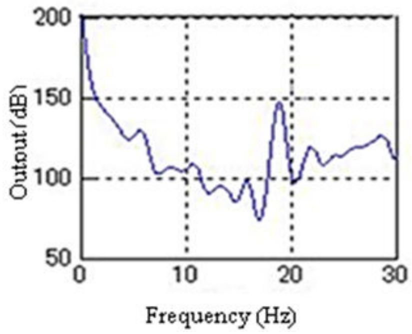

Figure 8: Crisis avoidance behavior was taken by the function of brain sensor.

Prototype of virtual reality in experimental system model

Figure 9 shows the subject felt an unusual circumstance, under the condition that the brain sensor was too strong to indicate that substrate could not take action to avoiding crisis. In addition, an alpha wave (8 to 13 Hz) group had appeared while relaxing, and the peaks of sharp beta wave (14 to 30 Hz) appearing at the time of tension greater were seen at 15, 17 and 21 Hz. The same results were seen in 6 subjects [15].

While multiple peaks of beta waves appear simultaneously, it was presumed that the tensile strength was felt too strong so that one's body was stiffened, and the action of avoiding instantaneous crisis was difficult to do.

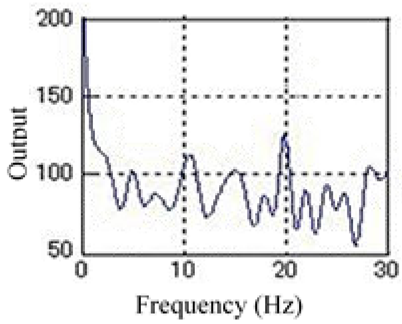

Figure 9: Brain sensor was too strong to take action of avoiding crisis.

Brain sensor functioned after the accident

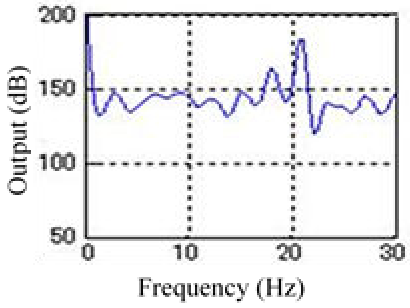

Figure 10: Brain sensor functioned late after the accident.

Figure 10 shows that the brain sensor of the subject functioned late the accident, not useful for behavior of avoiding crisis. One peak of beta wave has appeared in an alpha wave group, which was the same result as "Behavior of avoiding crisis by the function of brain sensor". However, after the piece of construction material had struck directly above the subject's head and a fatal accident had occurred, the subject was clicking the mouse. It was excluded from the function of the brain sensor. These results were seen in 9 subjects [14].

Brain sensor did not function in the accident

Figure 11 shows that visual stimulation, auditory stimulation, and pressure sensor (tactile sense) stimulation were temporally disjointed, nor integrated, but only elapsing time has passed. There were 79 subjects who suffered from functioning the brain sensor to the experiment of falling down piece of construction materials on the human head [14,15].

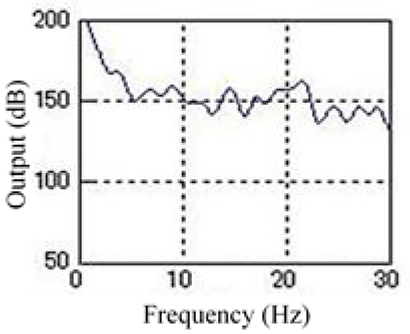

Figure 11: Brain sensor did not function in the accident.

Summary of brain sensor function for avoiding accidents

Based on the results of above-mentioned study by 100 subjects, the relation between falling down a piece of construction materials and avoiding human head of accidents was classified as "Action of avoiding crisis was taken by the function of brain sensor", "Brain sensor was too strong to take avoiding crisis action", "Brain sensor functioned late after the accident has occurred", and "Brain sensor did not function during the accident".

"Action of avoiding crisis was taken by the function of brain sensor" and "Brain sensor was too strong to take action of avoiding crisis" was 6% respectively. "Brain sensor functioned late after the accident" was 9%. On the other-hand, "Brain sensor did not function during the accident" was 79%. The relationship between the functions of the brain sensor expressed by the above four items and the occurrence rate for avoiding crisis is summarized in Table 2.

Function of Brain sensor	Appearance rate to avoid crisis
Action of avoiding crisis was taken by the function of brain sensor.	6%
Brain sensor was too strong to take action of avoiding crisis	6%
Brain sensor functioned late after the accident	9%
Brain sensor did not function during the accident	79%

Table 2: Relationship between function of brain sensor and appearance rate to avoid crisis.

Conclusions

The usage of the flat panel display is new, evolutional because of the real and fake images are mixed together with the real use of the display in order to simulate the big accident, for the purpose of forecasting a big accident before damage has occurred. Assume that a high tall building is under construction for repair, a pedestrian is assumed to be walking under such building underground while thinks of what a dangerous site it is. An alarm to notify the pedestrian to dangerous status is onsite issued to the pedestrian through the high-definition display used with a signal signage.

The authors created a new model of experimental system realizing virtual reality on the high-definition display. Conducted is a virtual experiment to investigate the elapsing time from the starting to the safety ending of travel when each substitute encountered an unexpected accident. Let us work the function of brain sensor so as taking the action of the avoiding crisis. The results are as follows:

The brain sensor of the substitute functioned, among those totally 12% of the subjects felt the surrounding environment unusual. However, only 6% of the subjects were highly evaluated so as having avoided behaviors satisfactorily. Even though the other 6 subject functioned with satisfaction, the peak of the beta wave was repetitively output, due to the reason that the tension was too strong to their body stiffened. In this case, it was difficult to take action of avoiding the crisis. In addition, there were further other 9% of subjects showed the same electroencephalograms, as those who were highly evaluated as having done of satisfactory behaviors. However, the piece of construction material has already fallen overhead, and thus a mouse is clicked late after a fatal accident has occurred. Then, it was excluded from the functional classification of the brain sensor worked. The reminder 79% of the subjects, excluding the above 21%, was such that the brain sensor did not function at all because neither alpha nor beta wave was detected. It implies the substitute have had no experience at all.

Therefore, citizens and workers may use the highly evaluation results of 6% of subjects. Saying that "Avoiding crisis of behavior was taken by the functioning the brain sensor." Seeing the fake big accidental scene on high definition image display was striking to the functioning of the brain sensor. This display system alarms on time the dangerous accident for avoiding human damages by viewing scenes.

This technology will be more useful if 4 K, 8 K technology will be more commonly used in a digital signage. However, this technology might belong to reliability engineering or safety engineering, and high vision is strongly related to the display engineering.

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