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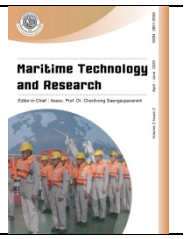

Research Article

A study of the suitability of marine transportation personnel using brainwave analysis and virtual reality technology

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Abstract

This work aims to investigate the possibility of reducing the occurrence of marine accidents by avoiding the unsuitability of marine transportation personnel. Recognizing that a majority of marine accidents arise from the improper reactions of transportation workers, we propose to evaluate the suitability of transportation personnel with the aid of brainwave analysis and Virtual Reality (VR) technology. By analyzing the brainwaves of a person facing operation situations simulated via VR, it may be possible to predict his/her responses in the situations and, thereby, determine if he/she is suitable to be involved in transportation work. Our preliminary experiments show that the brainwave analyses do have the capability of evaluating the appropriateness of the decisions made by a person when he/she faces operation situations.

1. Introduction

According to statistics from Allianz Global Corporate & Specialty (2019), one of the major causes of marine accidents comes from human error and, more specifically, from immediate decisions made during emergencies. Although the capability for handling emergencies can be improved after training or accumulating experience, it is sometimes costly and time consuming. Thus, appropriate selection of personnel could be crucial in helping to reduce marine transportation accidents. In other words, if we could choose suitable people and avoid unsuitable people to work in marine transportation, then a certain level of accidents may be prevented.

For the purpose of people selection, we propose to evaluate the suitability of transportation personnel with the aid of brainwave analysis and Virtual Reality (VR) technology. By analyzing the brainwaves of a person facing operation situations simulated via VR, it may be possible to predict his/her responses in the situations and, thereby, determine if he/she is suitable to be involved in transportation work.

The rest of this paper is organized as follows. Section 2 Materials describes the concepts of Brainwave Analysis and Virtual Reality (VR). Section 3 presents the methodology. Section 4 shows our results and a discussion. Then, Section 5 presents our conclusions.

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2. Materials

We use virtual reality (VR) technology to simulate 4 emergency scenarios. When a subject is watching a video from VR, his/her brainwaves are recorded and then analyzed. The analysis results are then used as bases for determining his/her suitability for working on marine transportations.

2.1 Brainwaves analysis

Brain functioning involves the transferring of electrical signals, leading to so-called "brainwaves." The Brainwave-Reading Headset device (Chalakorn & Kochiu, 2019) used in this study, shown in **Figure 1**, can read the brainwaves Delta, Theta, Alpha, and Beta; each wave has different characteristics (Methee, 2014; Walter, 1964).

Figure 1 Macrotellect BrainLink Lite EEG Headset.

Brainwaves are measured in Hertz (Hz), in cycles per second. The frequency ranges of brainwaves depend on an individual's activity. In addition, we found that brainwaves are related to what a person is facing in a situation. There are 4 brainwaves considered in this study.

2.1.1 **Delta**, as shown in **Figure 2**, is the slowest brainwave. The wave appears when people feel relaxed, or in a deep sleep or meditation. However, if a person on duty has this brainwave in the surveillance period, it is assumed that this person is not suitable for this position.

2.1.2 **Theta**, as shown in **Figure 3**, is the slower brainwave, inferior to Delta. Nevertheless, this brainwave is linked to the acquisition of knowledge, recognition, and visualization, including finding solutions. If this brainwave occurs in an on-duty person, it is reasonable to deduce that he/she is thinking about his/her work.

2.1.3 **Alpha**, as shown in **Figure 4**, is the brainwave which shows a balanced mental state. This brainwave state represents systematic thinking, or long-time activity concentration in a period. If a person on duty in the surveillance period and is highly focused, it is supposed that they have this brainwave dominant in his/her mental state.

2.1.4 **Beta**, as shown in **Figure 5**, is the fastest brainwave. This state of mind will have a lot of thoughts, and be chaotic, confused, or muddled, with unsystematic brain commands. This state always occurs in a person who is very stressed, hurried, oppressed, excited, or frightened.

If a person on duty in the immediate decision-making period has high beta brainwaves, there may be a risk of causing an accident.

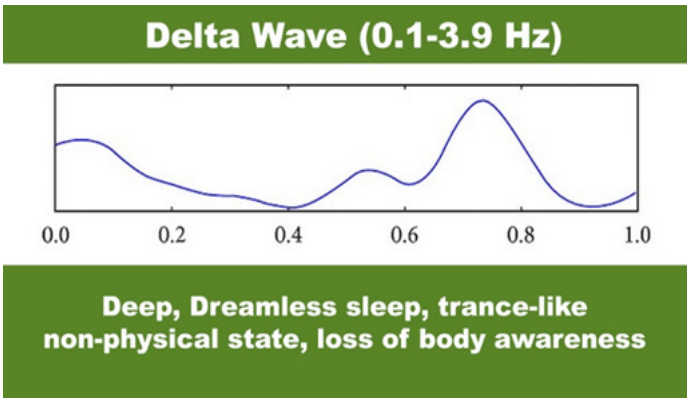

Figure 2 Delta wave.

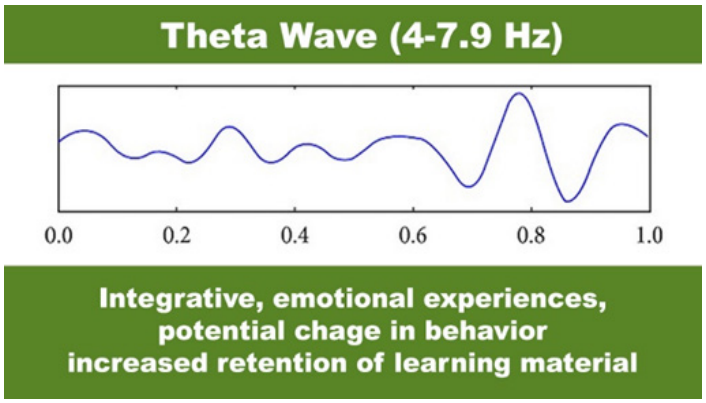

Figure 3 Theta wave.

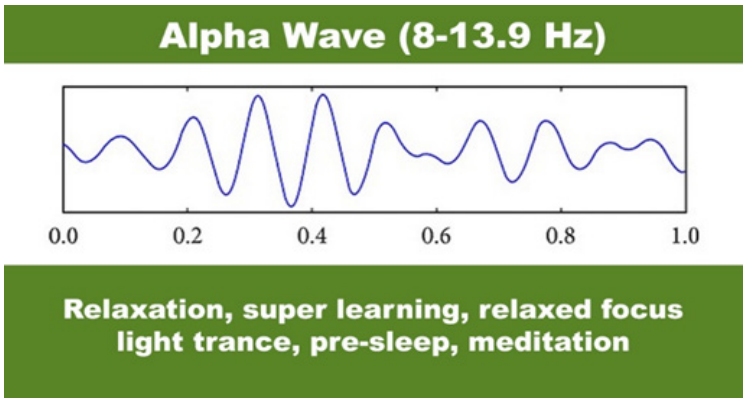

Figure 4 Alpha wave.

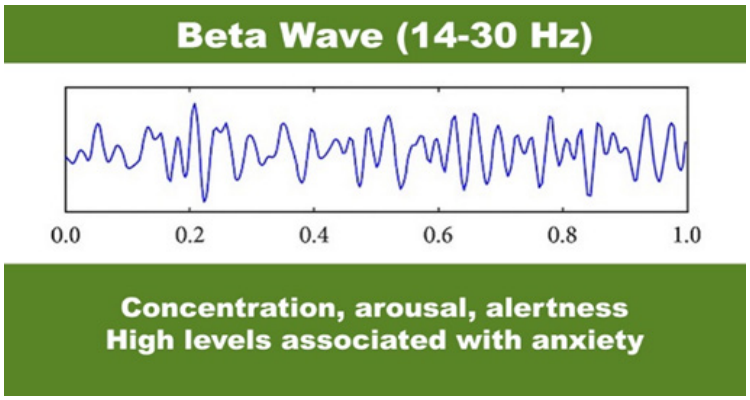

Figure 5 Beta wave.

2.2 Virtual Reality (VR)

Virtual Reality is a utilization showing mixed reality, and creates a 3D environment by using specialized equipment, such as virtual reality glasses, while receiving information about movement (Dan et al., 2009). It can be used to simulate some scenarios and interact with users. Users can experience something close to a real case. The system can inspect the users' movements, and evaluate and show the results to users in the simulated world. Moreover, it might add more feeling as a response or as a change of the environment. By all of the elements, it can allow users to feel something similar to true reality (Surasachai & Varinya, 2019). VR systems also allow an individual or group to interact with an environment which is reproduced by a computer (Basu & Johnsen, 2014). When referring to virtual reality, "immersion" is regularly used, with the more restricted definition "spatial immersion". Spatial immersion into virtual reality is an understanding of being physically sudden in a nonphysical world (Howard-Jones et al., 2014; Jennett et al., 2008). Insight is created by surrounding the user of the Virtual Reality system regarding images, sound, voice, or other stimuli that provides very interesting and absorbing environments (Huang & Han 2014). Spatial immersion occurs when a player or participant feels the simulated world is perceptually convincing, and looks real and authentic (Webster, 2014).

Immersive VR can contribute great advantages for training: it provides a direct feeling of events and objects that are physically out of an experiment, it encourages training in a safe environment, avoiding potential real dangers. and also increases the participant's involvement and impulsion while widening the range of knowledge styles supported (Freina & Michela, 2015). For our experiment, we used Oculus Quest, a new Virtual Reality device of 2019, as shown in **Figure 6**.

Figure 6 Oculus Quest All-in-One VR Gaming Headset.

3. Methods

3.1 Simulated scenarios by using Virtual Reality

We designed 4 simulated situation videos using Virtual Reality. Each video was divided into 4 sections. Each section involved a specific situation, and a question followed each section, shown in **Figures 7 - 10**.

- **Section 1. Observation**

Meaning: The action or process of observing or monitoring something or someone.
Situation: To avoid an accident, the staff needs to keep their eyes peeled. The video shows people passing the camera. The subject has to answer the following question about what the video shows.
Question: How many people walked pass the camera just now?
Choices A: 1, B: 2, C: 3, D: 4.

Figure 7 Example of a scene in Section 1- Observation.

- **Section 2. Discussion**

Meaning: An activity where people talk about something and share their ideas or opinions with each other.
Situation: During training, conferences, and meetings, all staff must keep their eyes peeled to avoid confusion on the operation steps. The video shows that the boss is teaching the steps of doing Cardiopulmonary Resuscitation (CPR). The subject has to answer the following question about what the video shows.
Question: What is the first step of doing CPR?
Choices A: Checking for normal breathing.
B: Waiting for the arrival of an ambulance.
C: Giving 30 presses on the chest.
D: Shaking and shouting.

Figure 8 Example of a scene in Section 2- Discussion.

- **Section 3. Decision making**

Meaning: A statement about what should be done when facing an accident.
Situation: To prevent accidents, the subject has to make a decision. The video shows 2 boats are going to collide. The subject must find a way to avoid the accident.
Question: What are you going to do in this situation?
Choices A: Warn people to stay in a safe place.
B: Call 911.
C: Find a safe place for yourself.
D: Call your mom.

Figure 9 Example of a scene in Section 3- Decision Making.

- **Section 4. Rescue**

Meaning: An action that helps someone or something out of a dangerous, harmful, or unpleasant situation.
Situation: A shipwreck happens.
Question: What are you going to do in this situation?
Choices A: Scream.
B: Jump into the sea.
C: Cry.
D: Guide people to a lifeboat.

Figure 10 Example of a scene in Section 4- Rescue.

All the 4 sections were designed as random pop-up videos. Then, we could measure brainwaves to select suitable personnel.

3.2 Equipment

All the subjects were asked to wear both a VR Headset and a Brainwave headset, as shown in **Figure 11**. The captured brainwaves are shown in **Figure 12**.

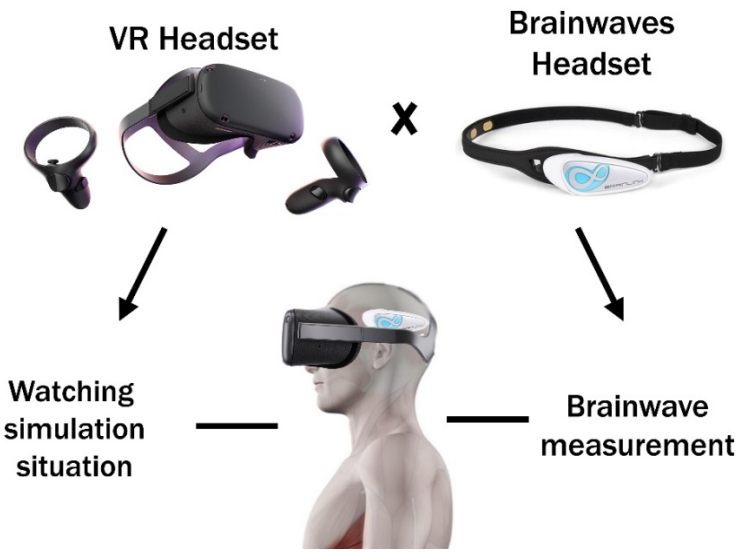

Figure 11 Devices used in our experiments.

Our test criteria are listed as follows.

- Section 1 Observation: Alpha wave is evaluated. If the average value is between 0.1 - 3.9, then the result is “pass”.
- Section 2 Discussion: Theta wave is evaluated. If the average value is between 4.0 - 7.9, then the result is “pass”.
- Section 3 Decision making: Alpha wave is evaluated. If the average value is between 8.0 - 13.9, then the result is “pass”.
- Section 4 Rescue: Beta wave is evaluated. If the average value is between 14 - 30, then the result is “pass”.

A subject is considered to pass only if he/she passes 4 sections.

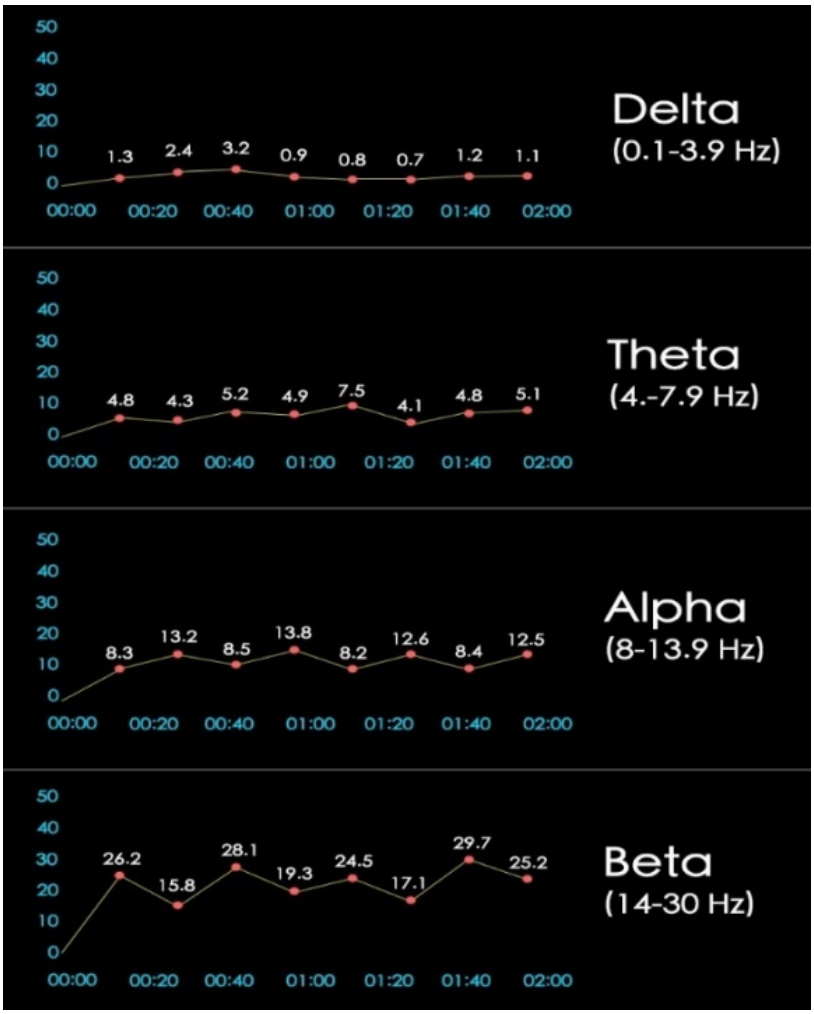

Figure 12 Captured brainwaves.

3.3 Experiments

We invited 8 people, as shown in **Figure 13**, to participate in this experiment. The assessment function was that each person must pass every section. A block diagram showing the relationship of Simulation Videos by Using Virtual Reality Section and Analysis Brainwave Charts is shown in **Figure 14**.

Figure 13 8 participants.

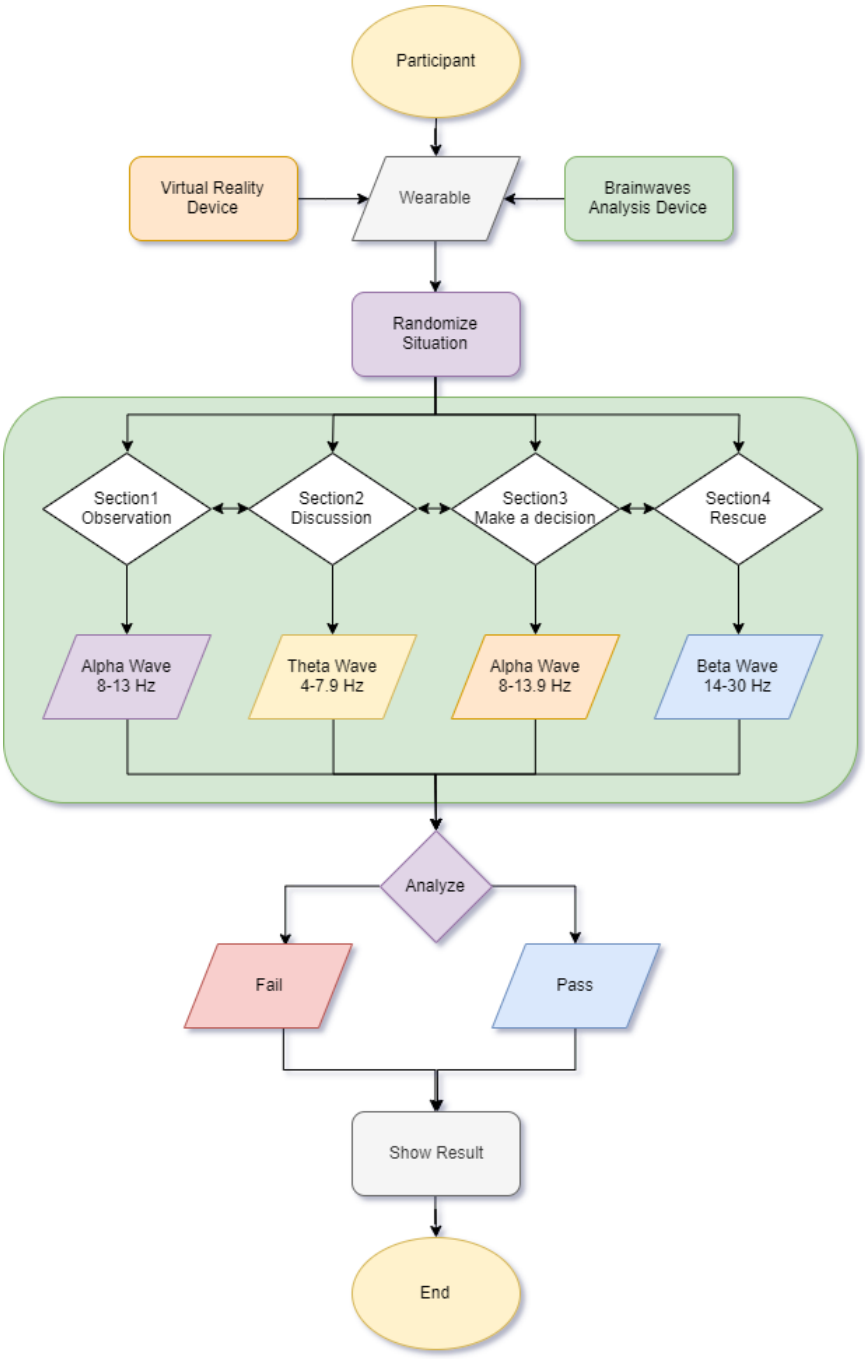

Figure 14 Block Diagram showing the relation of Simulation Videos by Using Virtual Reality Section and Analysis Brainwave Charts.

4. Results and discussion

By using the Virtual Reality section and brainwave analysis chart, it was found that, among the 8 people, 5 passed and 3 failed, detailed as follows:

- The randomly-selected videos are arranged in the following sections for Participant #1:

Section 3 Decision making; Passed
Section 4 Rescue; Passed
Section 1 Observation; Passed
Section 2 Discussion; Passed

- The randomly-selected videos are arranged in the following sections for Participant #2:

Section 2 Discussion; Passed
Section 4 Rescue; Failed
Section 1 Observation; Passed
Section 3 Decision making; Passed

Participant #2 did not pass because the Beta wave point was lower than the standard average, which means his/her brainwaves matched only 3 sections. She was too nervous to be ready to stand by to help people.

- The randomly-selected videos are arranged in the following sections for Participant #3:

Section 1 Observation; Passed
Section 3 Decision making; Passed
Section 4 Rescue; Passed
Section 2 Discussion; Failed

Participant #3 did not pass because the Theta wave point was lower than the standard average, which means his/her brainwaves matched only 3 sections. He was not enthusiastic enough to discuss with other people.

- The randomly-selected videos are arranged in the following sections for Participant #4:

Section 4 Rescue; Passed
Section 2 Discussion; Passed
Section 3 Decision making; Passed
Section 1 Observation; Passed

- The randomly-selected videos are arranged in the following sections for Participant #5:

Section 1 Observation; Passed
Section 4 Rescue; Passed
Section 2 Discussion; Passed
Section 3 Decision making; Passed

- The randomly-selected videos are arranged in the following sections for Participant #6:

Section 3 Decision making; Failed
Section 4 Rescue; Passed
Section 2 Discussion; Passed
Section 1 Observation; Passed

Participant #6 did not pass because the Alpha wave point was higher than the standard average, which means his/her brainwaves matched only 3 sections. He was too panicked to make a decision.

- The randomly-selected videos are arranged in the following sections for Participant #7:

Section 2 Discussion; Passed
Section 3 Decision making; Passed
Section 4 Rescue; Passed
Section 1 Observation; Passed

- The randomly-selected videos are arranged in the following sections for Participant #8:

Section 3 Decision making; Passed
Section 1 Observation; Passed
Section 4 Rescue; Passed
Section 2 Discussion; Passed

Table 1 Details of the experiment results.

Number of participant	Section	Average point pre-experiment	Average point post-experiment	Result of each section		Result	
				Passed	Failed	Passed	Failed
Participant#1	Observation	7.8	8.3	✓		✓	
	Discussion	4.3	4.9	✓		✓	
	Decision	7.9	8.2	✓		✓	
	Rescue	13.6	14.4	✓		✓	
Participant#2	Observation	8.6	8.9	✓			✓
	Discussion	5.2	5.8	✓			✓
	Decision	7.3	7.6	✓			✓
	Rescue	10	12		✓		✓
Participant#3	Observation	9.5	9.9	✓			✓
	Discussion	2.9	3.8		✓		✓
	Decision	5.3	5.7	✓			✓
	Rescue	16.6	16.9	✓			✓
Participant#4	Observation	10.5	10.8	✓		✓	
	Discussion	6.2	6.7	✓		✓	
	Decision	9.4	9.9	✓		✓	
	Rescue	15.3	15.7	✓		✓	
Participant#5	Observation	8.2	8.6	✓		✓	
	Discussion	3.9	4.3	✓		✓	
	Decision	7.8	8.3	✓		✓	
	Rescue	15.6	15.9	✓		✓	
Participant#6	Observation	7.7	8.4	✓			✓
	Discussion	3.8	4.2	✓			✓
	Decision	10.6	14.4		✓		✓
	Rescue	13.9	14.6	✓			✓
Participant#7	Observation	7.4	8.1	✓		✓	
	Discussion	3.8	4.4	✓		✓	
	Decision	10.6	11.1	✓		✓	
	Rescue	16.3	16.9	✓		✓	
Participant#8	Observation	8.6	8.9	✓		✓	
	Discussion	5	5.5	✓		✓	
	Decision	9.4	9.9	✓		✓	
	Rescue	16.4	17.2	✓		✓	
Total						**5**	**3**

However, the fluctuations in brainwaves may be due to many factors, such as excitement or pressure. The subjects can be consulted for improvement in the next experiment. For example, person A only passed 3 sections, failing Section 1- Observation, because he displayed Delta waves which should not appear in this section; person B did not pass in Section 4- Rescue because he displayed beta waves of more than 30 Hz, causing too much panic and preventing them from assisting anyone.

5. Conclusions

We have proposed a method for evaluating the suitability of transportation personnel with the aid of brainwave analysis and Virtual Reality (VR) technology. The method is on the basis of analyzing the brainwaves of a person facing operation situations simulated via VR. Our experiments provide evidence of using brainwaves to predict peoples' responses when facing emergency situations. Although this paper presents a preliminary study, the results lay a good foundation for the future development of an assistant system for marine transportation.

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