Effects of Guided and Unguided Style Learning on User Attention in a Virtual Environment

Jayoung J. Goo[1], Kyoung S. Park[1], Moonhoen Lee[1], Jieun Park[1], Minsoo Hahn[1], Hyungil Ahn[2], Rosalind W. Picard[2]

[1] Digital Media Lab, Information and Communications University, 517-10
Dogok-dong, Gangnam-gu, Seoul, 135-854, Republic of Korea
[2] M.I.T. Media Laboratory, E15-020a, 20 Ames Street, Cambridge, MA 02139, USA

Abstract. In this paper, we investigated the effects of guided and unguided style VR learning on user attention and retained knowledge. We conducted a study where users performed guided or unguided style learning in the virtual environment while user attention was measured through an eye tracking system and physiological sensors. The virtual environment contained the five specific events associated with different stimuli, but the guided task was designed to provide the specific goals whereas the unguided task asked the user to actively search for the interesting items. The results showed that the unguided task followed by the guided task made a considerable learning effect by giving a preview to the user. In addition, tactile feedback, sudden view point change, unique appearance and behavior, and sound stimuli played an important factor in increasing human attention states that also induced enhancing human memory about VR experience.

1 Introduction

Virtual reality is an immersive technology that allows students into a three-dimensional interactive environment. It places students inside of a simulated environment, which looks and feels like the real world. It affords opportunities to experience environments in which time, distance, scale, and safety would not otherwise be accessible. Virtual reality allows students to create their own experiences and the types of knowledge that has so far only been possible through direct experience with the world. For example, a child will best learn about the ocean not from reading or listening to a lecture, but by exploring the virtual ocean space and becoming a part of it.

Due to this fact, virtual reality has been used in various education applications, such as geology, biology, chemistry and industrial simulations [2,3]. It is largely because VR has positive influence on education by giving students immersive feelings and interactivity through visual, audible, and tactile feedback [2,3,5]. Nevertheless, there has been ongoing research on investigating learners' attention to educational contents in a virtual learning environment, to design effective VR education systems [1].

There are specific aspects in the mediated information that capture and hold student's attention, which can direct students to become actively involved with their learning process. The identification of these aspects may be of particular importance in the design of interactive learning virtual environments. We can vary color, location, scale, movement, density of information, interactivity and responsiveness, time, and degree of participation in the presentation of learning materials. However, the challenge is to place learning materials in a natural, although virtual, context to make learning a real experience.

The goal of this research is to design and develop an interactive virtual environment that can hold student's attention and encourage them to be actively involved in their learning process. There has been much work done on user visual attention, but little is known about the actual engagement of users. While eye tracking data may tell where users look at, they cannot provide enough information about whether the user is simple liking at an object or actually engaged in focused activity with it. Hence, we attempt to investigate the factors that affect user attention state in an interactive learning virtual environment and the retention of the learning materials, i.e. how a student's engagement affects actual learning.

In this paper, we describe a study conducted on users in an interactive virtual learning environment to evaluate the effects of guided or unguided style VR learning on user attention. We have used the eye-tracking system and various physiological-sensors (such as, EEG, ECG, and GSR) to detect the level of user attention state. All eight subjects were given the unguided and the guided VR task (i.e., within-subject study) where the virtual environment contained five specific events associated with different stimuli such as color, movement, lighting visual cues, audio cue, and tactile feedback. This paper will first present related work on detecting and analyzing user attention. It will then describe a study to explore the effects of the VR learning style and a variety of stimuli on user attention. Finally it will highlight some of important results, lessons learned and ideas for future exploration.

2 Detection and Analysis of User Attention

Eye tracking has been used in visual attention research such as usability evaluation of web or other media [29]. Attention can be determined through where the user's gaze falls and for how long (location and duration of gaze) [18,19] and search patterns can be determined through the number and duration of fixations and the scan paths. The pupil of the eye varies in size depending on several internal (e.g., emotional state) and external factors (e.g., light). A number of studies have suggested that the pupil dilation is a sensitive measure of attention workload [20]. The pupil size would enlarger when the subject faces exciting and interesting events or objects [20]. Also, it has been shown that the number of eye blinks is smaller and their fixation duration is longer as more attention is needed [28]. Recently, physiological measures (such as EEG, ECG, and GSR) have been used to determine emotional response, such as stress and mental workload [30]. The advantage of using physiological measures is that they are continuous and relatively unobtrusive. They provide measures, which do not require overt behavior of user, such as mouse/control actions or subjective ratings. It is found that high frequency range (e.g., beta rhythm) of brain wave is amplified during highly focused attention period for daily office work [14]. During this attention period, sweat comes out from the skin of human hands, and heart rate change occurs.

EEG (electroencephalogram) signals have been used to measure user attention, such as event-related potentials (ERPs) and P300 [11]. ERPs are changes in the brain's activity in response to stimuli. The P300 is a large brain signal that is evoked by task relevant stimuli. The beta rhythms (13 30 Hz) are associated with an alert state of mind, such as during general daily office works. The alpha rhythms (8 13 Hz) are usually associated with a relaxed state. The gamma rhythm (30 50 Hz) is usually appeared during stress or intense mental activity. The ratio of beta to alpha rhythm is used to measure mental workload associated with task difficulty.

In the Brainball game, the players attempted to roll a ball into the opponent's goalmouth by achieving a higher state of relaxation. The relaxation was measured as the ratio of beta to alpha rhythm (beta/alpha) of EEG [26]. From our preliminary user experiment, we found that SEF50 (Spectral Edge Frequency 50 of EEG) can be used as an index for human awakening state. In this experiment, the subjects played 3D computer game tutorials, and the results showed higher SEF50 value in a more difficult task.

Heart rate variability (HRV) from ECG (electrocardiogram) has been used as an index for measuring user attention, and it has been shown that HRV decreased with increased task demands [12]. R-R interval variability (RRV) is also corresponded with user attention. That is, sustained attention states gradually reduce RRV. Low frequency (LF) of RRV is in the range of 0.04 0.15Hz and it is related with the response on exterior stimulation, such as sounds and visual objects [14]. High frequency (HF) is in the range of 0.14 0.4 Hz. The ratio of LF to HF represents the arousal of a human sympathetic nervous system [13].

Moreover, it is known that skin conductivity responds (SCR) to things that grab user attention such as significant thoughts, exciting events, and pain [30]. The GSR (galvanic skin response) sensor was used to measure when the skin momentarily becomes a better conductor of electricity when internal or external stimuli occur that are physiologically arousing. The SCR value was evaluated by the number of startles. More number of startles means more arousals of excitement. It can be well representative and intuitive data for human event related attention state [12].

3 Method

We evaluated student's attention states during their interactive learning in the ocean virtual environment by using an eye-tracking system and EEG, ECG, and GSR physiological sensors. We provided the guided- and unguided-style virtual

Fig. 1. The Ocean virtual environment, populated with fish, corals, rocks and vents.

environment. Both have the same contents during the 5-minute VR exploration except that the guided style has given the subjects the guided questions and cues whereas the unguided style asked subjects to find the objects of their interest.

Fig. 1 shows the Ocean virtual environment populated with a variety of fishes, corals, rocks and vents. It is originally developed at Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago, designed to support children engaged in inquiry-based science learning activities. This environment simulates underwater exploration in a shallow coral reef, along an undersea cliff, and deep ocean region off the coast of Florida. Students can learn a wide variety of unique sea creatures by actively exploring their fields of interest in the Ocean.

At ICU Digital Media Lab, we repopulated the ocean objects to add more areas of interest (such as several coral reef zones for angel fish habitat) and five specific fish behaviors (such as a herd of angle fishes, a flat fish with an interactive sound, a ray fish with a tactile feedback, a giant squid moving away extremely fast, and an angler fish luring and eating a lantern fish), to study user attention in the virtual environment. We provided a joystick for user's submarine navigation and tactile feedback. We also provided a spot light for user's deep ocean exploration where the lighting level was extremely low and a snapshot camera for taking snapshots of interesting objects.

The Ocean has been written in using a high-level VR toolkit called Ygdrasil [31]. Ygdrasil is a set of C++ classes built around SGI's Performer graphics library, CAVElib VR library, and CAVERNsoft networking toolkit. Ygdrasil is designed to simplify the construction of behaviours for virtual objects using reusable components; and on sharing the state of an environment through a distributed scene graph mechanism. Ygdrasil focuses on constructing dynamic, interactive, collaborative virtual worlds, so its scene graph nodes can have behaviours attached to them. Individual nodes are compiled into dynamically shared objects (DSOs), so that they can be rapidly added to a world. The system includes a number of pre-made classes that implement common capabilities in VR, such as audio, avatars, navigations, and triggers that detect when a user enters an area.

3.1 Subjects

Eight students from the ICU Digital Media Laboratory volunteered as subjects in this study. The average age of the subjects was 24.5 years. The subjects composed of 3 female subjects and 5 male subjects. As part of the demographic data survey, students were asked to rate their prior experience with VR, video games, and physiological sensors as well as daily computer usages They were also asked about any experience with the undersea ocean ecosystem. All students had a high level of experience with computers. Most of them had experience with games and VR systems, but none of them had prior experience with the physiological sensors and the Ocean virtual environment used in this study. Most students had little to moderate experience with the ocean ecosystem. All students expressed fairly high interests in exploring the virtual environment.

3.2 Tasks

We evaluated two different learning-style VR tasks: the unguided search task and the guided search task where the unguided task is more student's self-explorative learning whereas the guided task has provided more specific goals and cues. In both cases, the same contents and the exploration time (approximately 5 minutes) were given to the subjects.

In the unguided search task, students were asked to freely explore the ocean virtual environment and find five fish of their own interests. In the guided search task, students were given five questions about a specific fish (i.e., an angel fish, a flat fish, a ray fish, a giant squid, and an angler in order every minute). When given the questions in this guided task, we also provided the text and the photograph of the five specific fish to help user easy identification. Furthermore, subjects were automatically dragged from their present location to the habitat of the fish being asked for the question in the environment.

3.3 Experimental Design

Each subject was randomly assigned to complete the two tasks (i.e., a within-subject study). That is, four subjects were given the guided task followed by the unguided task, and the other four subjects were given the unguided task followed by the guided task. The purpose of this experimental design was to evaluate learning effects by the task order.

Subjects would experience the same events occurred in every minute during the VR exploration. There are five distinguishing events to draw their attention

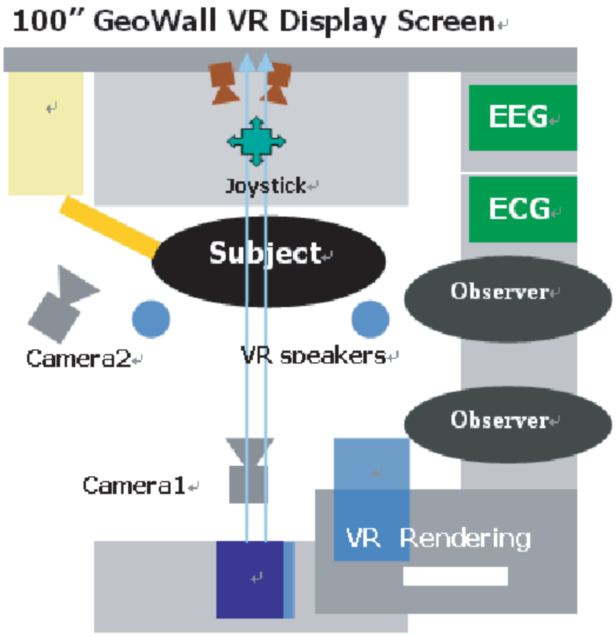

Fig. 2. The layout of the experiment set up

in the virtual environment. First, the subject would see fog off and fish gradually appeared in the ocean. Then, after a minute, the subject would meet an angel fish (with the colorful and moving element) nearby the coral reefs passing along left side to right side. Next, the subject would face a flat fish (with the sound stimulation which makes the sound of water bubble burst) rising from the bottom of the sands. Next, a ray fish would move fast heading toward the subject. When the subject is close to the ray fish, it would make a collision and so the subject would feel the vibration tactile feedback via a joystick. This event represents an electronic ray fish's self-protection.

After that, the subject would be automatically dragged to fall down to the deep ocean. In this event, the view point is dramatically changed which would also affect subject's attention state. Next, a giant squid would run away from the subject and scatter its own dark inky water. After that, the subject would face an angler fish passing along right side to left side and luring a lantern fish with a luminescence and then eating it. Finally, the subject would be automatically moved up to the shallow ocean.

3.4 Apparatus

Fig. 2 illustrates the layout of the experiment apparatus in ICU Digital Media Laboratory. The system consisted of a 100-inches front-projection GeoWall virtual reality system, a Laxtha Inc.'s 8-channel EEG and a 3-channel ECG measuring device, a HandWave skin conductance response device. Our GeoWall system provides a high quality three-dimensional graphic image to give users vivid immersiveness. It uses two DLP projects and circular polarization filters and a polarization preserving screen to generate 3-dimentional stereoscopic images, and users wear polarization glasses to see the 3D effects. Subjects were given a vibration feedback enabled joystick device for navigating the virtual environment and they heard a variety of interactive sounds through the stereo speakers.

A HandWave bluetooth skin conductivity sensor is developed by MIT media laboratory. It is a small, wireless skin conductance sensor for affective computing applications. The sensor consists of a 16-bit analog to digital converter which covers 10 meter ranges, and generates approximately 30 Hz rate (i.e, it can be used as real-time data input).

Two video cameras were used to record all subjects' body posture, movements, and physical and psychological conditions during the experiment. In addition, two observers took notes to record the subject's behaviors and detail conditions occurred during the experiment.

3.5 Procedure

The subjects were given a pre-test survey about technology familiarity and previous experience with 3D game, VR, and physiological sensors. The pre-test survey also asked for subject's demographic information, such as age, sex, interest on marine creatures and ecosystem. All subjects were asked to complete the two VR tasks: unguided and guided search task.

The experimental procedure included (1) 10 minutes of pretest survey of collecting subject's demographic data and user comfort with the devices (such as VR and physiological sensors); (2) 20 minutes of experiment set up (such as calibrating the eye tracking system and attaching various physiological sensors on the subject); (3) 5 minutes of relaxation; (4) 5 minutes of unguided or guided VR task; (5) 10 minutes of post-test survey of answering what are factors that draw the subject's attention during the VR experience and what the subject remember after the VR exploration; (6) 5 minutes of relaxation; (7) 5 minutes of unguided or guided VR task; and (8) 10 minutes of post-test survey of answering the questions after the VR exploration.

The post-test survey asked for subject's memory about VR contents, such as the most memorable thing in the Ocean virtual environment, the ecosystem for five fish given in the guided task or for the fish of their interests given in the unguided task. The main focus was to evaluate subject's memory affected by the learning style as well as to find a correlation between subject's attention during the VR exploration and their retained knowledge after VR.

We provided the 5 minute-long relaxation period before the VR exploration to reinitialize human physical and mental state. During this relaxation period, subjects closed their eyes and no body movements were allowed.

3.6 Evaluation

First, we analyzed the whole range of EEG, ECG, and GSR data for each task (i.e., relax before the guided task, the guided task, relax before the unguided task, and the unguided task). We calculated the spectral edge frequency analysis (SEF50) and the ratio of beta rhythm to alpha rhythm (beta/alpha) of EEG, heart rate variability (HRV) and R-R interval variability (RRV) of ECG, and skin conductance response (SCR) of GSR for each subject during the task.

SEF50 has been used as an index for human awake state, indicating how much a subject's brain was active during the task. During sleep, human brain signals record very low range of frequency, such as delta wave (0 4Hz). Human brain signals during dynamic thinking activities make high propositions of high frequency, such as beta wave (13 30Hz) and gamma wave (30 50Hz). Hence, high SEF50 indicates that a subject is highly awakened [27]. In addition, we used the ratio of beta rhythm to alpha rhythm (beta/alpha) of EEG to measure mental workload.

We also analyzed R-R interval variability (RRV) and the ratio of LF to HF (LF/HF) of RRV for detecting human attention states. LF/HF is the ratio of human sympathetic nervous system to the para-sympathetic nervous system [13,16]. In particular, we verified RRV value at the event related stimulus occurred, such as the ray fish vibration tactile feedback. In addition, we analyzed overall GSR data to calculate skin conductivity responds (SCR) to measure the number of startles and the amplitude of startled point.

Moreover, we performed the event region analysis of EEG, ECG, GSR, and eye tracking data for the guided or unguided task, such as angel fish, flat fish, ray fish, moving to the deep ocean, giant squid, and angler fish. In this analysis, we first classified the points where the SCR value is startled. Then, we verified whether HRV is accompanied with the GSR startles. Next, we collected the moments matched with the startles and used the video analysis to figure out any event or stimulus associated with these moments. Then, we analyzed the post-test results about user attention, interest and memory to find any correlation with the events or stimuli.

4 Results

4.1 Effect of guided or unguided learning

Contrary to our expectation, the subjects generally showed more SEF50 in the guided search task than in the unguided search task regardless of the task order. Most subjects had higher SEF50 in the guided task except that one subject showed slightly lower SEF50 in the unguided task. We believe this result indicates that users pay more attention when the specific guided goals are given in the interactive learning virtual environment.

We extracted the distribution of subject's eye gaze movements by calculating the standard deviation of eye movement locations during the task. In this analysis, four subjects recorded higher standard deviation of eye movements in the guided task than in the unguided task, one subject recorded nearly same value of the standard deviation between the two tasks, and one subject recorded higher standard deviation value in the guided task than in the unguided task. With the detail video analysis, we found that the subjects moved their eye more frequently in the guided task to search for the answer to the question whereas they tended to follow a certain object of their interest in the unguided task.

There was a distinct difference between the tasks in the subject's navigation trail patterns in the Ocean virtual environment. It was shown that most subjects widely explored the virtual environment during the unguided task. The subjects moved mostly within the predefined navigational trails during the guided task.

In the post-test analysis, we found that there was no significant difference between the two tasks in the amount of memorable items by the subjects (total 18 items in the guided task; total 20 items in the unguided task). However, the subjects after the guided task remembered mostly the lesson objects/events (i.e., angel fish, flat fish, ray fish, squid, angler fish) (15 items) whereas the subjects after the unguided task remembered mostly the other interesting objects/events than the lesson objects (13 items).

The memorable items that the subjects wrote after the guided task were ray fish (5 subjects), squid (4 subjects), angler fish (3 subjects), angel fish (2 subjects), sea snake next to flat fish (2 subjects), flat fish (1 subject), and spot light (1 subject). On the other hand, the memorable items that the subjects wrote after the unguided task were sea horse (5 subjects), ray fish (3 subjects), coral reefs (2 subjects), sea spider (2 subjects), angler fish (2 subjects), and squid (1 subject).

Table 1. The number of startles on the GSR

Subject	Task Order	Guided Task	Unguided Task	More Startled
1	U - G	5	12	U
2	G - U	6	3	G
3	G - U	25	23	G
4	U - G	2	Error	Error
5	U - G	-	4	Error
6	G - U	40	24	G
7	U - G	7	10	U
8	G - U	23	16	G

4.2 Effect of task order

We found that the sequence of the two tasks (i.e., task order) was the most significant influence on the GSR value. For many subjects, the first task in the sequence tended to have a larger skin conductance response (SCR) value than the second task. The skin conductance response was evaluated by the number of startles. It appeared that there was more "downward sloping" or "relaxation" in the second task. Table 1 shows the number of startles on the SCR. In particular,

Table 2. The mental workload (beta/alpha) of EEG

Subject	Task Order	Guided Task	Unguided Task	More Startled
1	U - G	3.815	3.917	U
2	G - U	5.23	2.94	G
3	G - U	1.596	1.615	U
4	U - G	4.436	2.88	G
5	U - G	1.85	1.989	U
6	G - U	2.694	2.305	G
7	U - G	1.483	1.61	U
8	G - U	8.09	7.62	G

all subjects with the G-U task order have clearly shown a large SCR in the guided task.

Likewise, the EEG data analysis results also revealed that the task order was considerable influence on mental workload (i.e., beta/alpha). As shown in Table 2, the subjects in the first task in the sequence tended to have a larger mental workload than in the second task. The subjects who had completed in the U-G task order showed lower mental workload (Unguided 2.896, Guided 2.599, and Total 2.747) on average than the subjects with the G-U task order did (Guided 4.4025, Unguided 3.62, and Total 4.011).

In addition, we found the learning effect by the task order. It seemed that the unguided VR learning gave our subjects the preview effect by giving a chance to actively explore their fields of interest without any clear goals. The post-test survey results also revealed that the subjects with the U-G task order wrote down 8 more items for the most memorable item/event question (Unguided 12, Guided 11, and Total 23) than the subjects with the G-U task order did (Guided 7, Unguided 8, and Total 15).

As mentioned in the above section, the subjects remembered mostly the lesson items after the guided task. The subjects with the G-U task order wrote down 5 items that were related to the lesson items and 2 items other than the lesson items after the guided task. Similarly, the subjects with the U-G task order wrote down 10 items that were related to the lesson items and 1 item other than the lessons items after the guided task.

Interestingly, the subjects with the G-U task order remembered mostly other interesting objects/events (7 items) than the lesson items (1 item) after the unguided task, whereas the subjects with the U-G task order remembered the lesson items (6 items) and the other interesting items (6 items) equally after the unguided task. It seems that the subjects with G-U task order were affected by the guided cues so that they would pay more attention to the unexplored items.

4.3 Effect of stimulus

Tactile feedback With the stimulus based analysis, we found that tactile feedback plays an important role in drawing user attention in this interactive learning virtual environment. We designed the ray fish event which generated vibrations on the joystick to represent the electronic self-defense when the subject collided

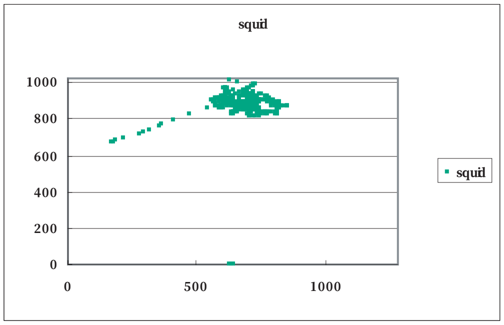

Fig. 3. The eye-gaze traces of a subject during the squid event.

with the ray fish. Half subjects (i.e., four subjects) recorded the highest startle point of SCR value at the time when the vibration event occurred regardless of the task.

Moreover, we found the strong correlation between tactile feedback and memory enhancement - i.e., evidently, many subjects wrote down the ray fish (that is associated with the tactile feedback) as the most memorable item in the post-test (In total, ray fish 8 subjects, squid 5 subjects, angler fish 5 subjects, and sea horse 5 subjects).

In addition, we asked our subjects to rank a variety of factors that may draw their attention (such as size, moving, vivid color, sound effect, brightness, unique appearance or behavior, vibration, and so on) in five level weighted sum (1:low - 5:high) in the post-test. The results showed that the vibration factor ranked the second highest stimulus (60 points) where the light in the dark factor and the moving factor ranked the highest (61 points).

View point change We also found that the view point change (i.e., the event when the subjects automatically dragged down to the deep ocean) affected our subjects arousing user attention. Using the ECG and GSR startle integration analysis, four subjects showed the highest SCR startle and the high ECG amplitude at this event.

Chaser situation We also observed the effect of goal oriented attention by guidance at the chaser situation in a giant squid event in the guided task. Many subjects showed high attention states when the fast moving giant squid was appeared. The subjects showed higher SEF50 in the guided task than the unguided task at the squid event. In the guided task, we gave the subjects a question about searching for the squid's hiding method. The video analysis confirmed that most subjects tried to chase the fast moving squid. The subjects also showed high fixation (in terms of the duration and the location) on eye-tracking data indicating that the subjects were highly focused on the squid event.

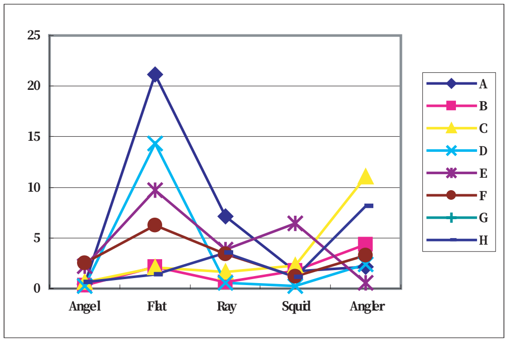

Fig. 4. LF/HF of RRV in the guided task

Fig. 3 shows one subject's eye-tracking data that also depicts the squid movement trajectory. The subject clearly paid attention to the squid. We found that many subjects showed this eye-tracking data pattern during this squid event. In the post-test analysis, the squid event was ranked as the second highest items for the question about ”What is the most memorable thing in the VE?”

Unique appearance and behavior It seemed that a unique appearance also slightly affected to the subject's attention and memory in the virtual environment. We designed the angler fish event as an index for unique appearance and behavior, and as mentioned in the above section, 5 subjects wrote this down in the post-test. Unexpectedly, we also obtained an interesting result - i.e., 5 subjects wrote down the sea horse as one of the most memorable items from their VR experience. Especially, 2 (out of 5) subjects described the sea horse as a floating, immovable object. Using the ECG and GSR startle integration analysis, we confirmed that some subject's ECG and GSR arousals were observed at the angler fish event and the sea horse.

Bright color We observed some effects of bright color in orienting user attention. We noticed 5 GSR startles associated with the angel fish event from the ECG and GSR startle integration analysis.

Sound We found a very subtle effect on sound stimulus. In Fig. 4, four subjects showed an increased LF/HF of RRV at the flat fish event where it was coupled with the water bubble burst sound. LF/HF is the subsidiary index for detecting human attention state. However, unlike this physiological arousal, a few subjects wrote down the flat fish in the post-test survey, and most subjects quoted the background sound effect had no significant influence on their attention.

5 Discussions

The study results revealed that the first experience of VR task played a vital role in drawing user attention and interest to the virtual environment overall. It was shown that the first task in the sequence tended to have higher number of startles on GSR data and mental workload (measured by beta/alpha of EEG) than the second task.

Interestingly, there was a considerable learning effect by the task order. In particular, the U-G task order was more effective than the G-U task order in terms of the amount of subject's memory about VR contents after the VR experience. It seemed that this unguided VR learning gave users the preview effect during the second task - i.e., it helped them experience more the future learning items by encouraging them to actively explore their field of interest in the first time unguided task.

On contrast, the subjects who already experienced guidance seemed to be more interested in searching for new objects/events rather than the lesson items during the second unguided task. They remembered mostly other interesting items whereas the subjects without previous experience remembered lesson items and other interesting items equally after the unguided VR exploration.

It also confirmed that the guided VR task was strongly related with slightly increased mental workload and awakened states due to the goal-oriented learning method as compared to the unguided task, regardless of task order. However, there is a trade off between selecting either one of learning style in VR education. In this study, the guided task was more effective on teaching the focused learning contents. However, we also found a positive effect of using the unguided task, i.e., the preview effect while user's active explorations in the virtual environment, making them get more experienced with future lessen contents.

In addition, we found that tactile feedback, sudden view point change, fast moving object, unique appearance and behavior, vivid color, and sound stimuli were the most important factors for increasing user attention during VR exploration and enhancing user memory about the contents after VR experience. In this study, vibrations and view point changes had been a great influence on drawing user attention in a virtual learning environment.

We plan on conducting this study with more subjects for statistically valid evaluation. We will also include the analysis of the subject's activities during the VR exploration, such as navigation log file and snapshot images. This will allow us to understand the relationship between user activity in the virtual environment and user attention and interest. Moreover, we will investigate whether the subjects' emotional states before the task may affect to their attention states during the VR learning task and memory retention after the task.

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