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Virtual Reality System as an affective medium to induce specific emotion: A validation study

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Abstract

Negative emotions can lead to emotional stress, and people in a negative state for a long time would easily have physiological and psychological diseases. Virtual reality technology could generate a lifelike high immersion simulated environment may relieve the emotional stress. The main purpose of this paper was to verify effectiveness of the virtual reality system to induce an emotional change. A multi-channel VR system was built to create the fear scene and elicit subjects' fear sense. Four different type of fear scenes: the Imagine fear scene, the Unknown fear scene, the Threatened fear scene and the Height fear scene were tested in experiment and subject's emotion change would be recorded by ways of subjective and physiological parameters, such as the subject's subjective feelings, heart rates and behavior performance etc. 15 subjects participated in experiment. The experiment result showed that VR system can induce subject's emotion change and the Threatended scene more easily induces responsive change in four different fearful scenes. In addition, the correlations between the visual, tactile and auditory stimuli of a VR system and emotion induced was also analyzed and the result showed that the correlation of visual stimulation was stronger than tactile and auditory.

1. Introduction

Emotions can be broadly divided into positive emotions and negative emotions (anxiety, fear, sad, disgust,etc). People exposed in negative emotions are prone to have emotional stress, which can affect the physical and physiological health. The common mental disorder caused by emotional stress are depression, anxiety, sad and paranoia, etc.[1] With the continuous development of virtual reality technology, the virtual reality system maybe be used to create a virtual environment to relieve emotional stress.Using the VR system to carry out the psychological relief for patients with negative emotional pressure by follows:

(1) Verify the virtual reality system can induce emotional change;

(2) Whether there is difference between the virtual reality system and the real environment in inducing emotion;

(3) To set up a soothing virtual environment for patients with negative emotions;

Psychological relief makes the patient's emotional adjust to the normal state by generating a similar "safe island" simulated environment in a VR system to relieve the psychological stress. In this paper, the only first step was finished and in order to verify the virtual reality system can induce patient's mood changes, a reverse study will be conducted. Creating a pessimistic mood scene to verify the virtual reality system can induce negative emotions. If people really feel fear in this VR scene, this VR system can be considered as an effective system for inducing emotional change.

There are many ways to induce mood change in psychology, the main way is using emotional materials and situations and many studies have confirmed that with emotional concerned films, pictures, sounds as well as emotional scenes can elicit emotions.[2][3][4] VR system first used in psychology was that treating different phobias,, such as acrophobia, fear of flying, fear of spiders, PTSD, duo to the traditional real scene evoked not convenient, highly cost, risk and the unreliability of imagine scene evoked, so the virtual reality technology as emotion evoked medium is applied more and more widely. Dong P. Jang [5] develop an inexpensive and more realistic stimulus environment to perform exposure therapy for acrophobia and results showed that the VE seemed to evoke more fearful feelings than the real situation. Cavrag. M [6] explored that combining virtual terrorist spider with real tactile spider can induce a more disgust sense and patient could interact with the spider. The result showed that when the degree of patient's fear and disgust sense decreased, the spider fear was relieved in a certain degree. Pertaub[7] designed an experiment to compare the stress level of the speakers under three kinds of virtual human. Through the helmet monitor, speaker entered into a conference room with 8 virtual spectators and made a 5 minute speeches. The result of the experiment showed that the negative audience could obviously stimulate the speaker's anxiety. These studies provide some evidences that the VR system is helpful in the treatment of psychological phobias, therefore, there need some experiments to verify that the VR system can relieve psychology stress. This is the point for us to make this study.

In VR system, presence is an important criterion for evaluating the validity of the system. Presence of a VR system can be defined as the subjective feeling of people in the virtual environment generated by computer. The main factors that affect presence are immersion of VR system, scene content and the user's own background. Villani. D[8] studied the possible use of VR as an affective medium and analyzed the relationship between presence and emotions through three different virtual environments by the subjective questionnaire. In addition, the interaction of the VR system and dynamics of virtual environment will also affect the effectiveness of emotion induced. Courtney C G [9]compared the real static International Affective Picture System images and computer generated dynamic virtual pictures as stimuli to elicit fear, and the result shows that the dynamic virtual graph induced fear is more effective than static real map.

In measurement of presence of the VR system and emotion, the related researches mainly adopt two ways: subjective evaluation and objective physiological measure. Winter[10][11] had analyze the necessary conditions and contributing factors for the presence and designed the Presence Questionnaire and Immersive Tendency Questionnaire to test the presence in virtual environments in 1998. For the measurement of emotional changes, under inspiration of the James Lange and Cannon theory [12], researchers pay more attention to the link between emotional changes and physiological responses. People's emotions are controlled by the Autonomic Nervous System (ANS), and emotions changed will cause varying degrees of physiological reaction [13], such as changes on the Heart

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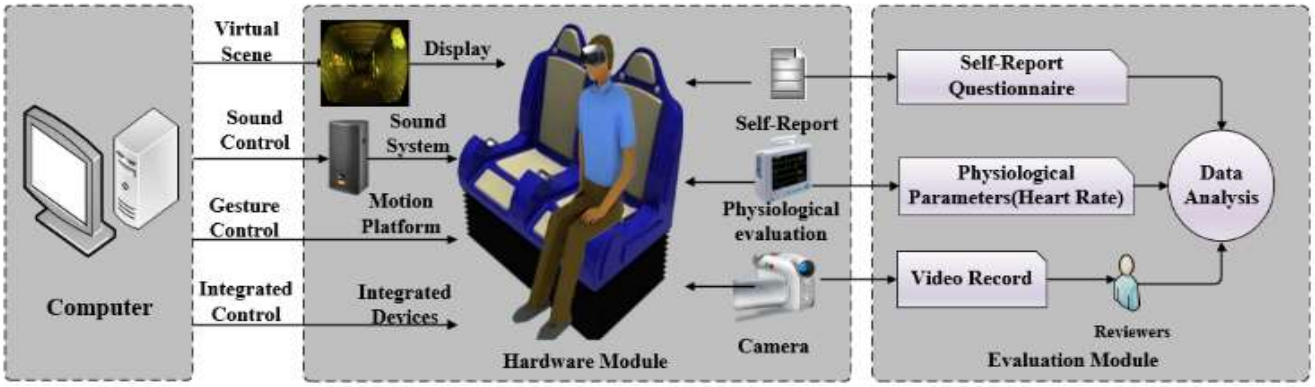

Figure.1 *The structure of the multi-channel VR system and evaluation methods*

Rate, galvanic skin response (SCR), finger pulse volume, blood pressure etc. These indicators can be as effective emotional change measurements. In this paper, the heart rate was chosen as the primary emotion measurement.

2. Methods

In this paper, a multi - channel virtual reality system was built(Figure1), which indicates the effectiveness of the virtual reality system induced by the change of emotion in two aspects. The first is the virtual reality system to the subjects of the visual, auditory, tactile and other sensory stimulation effect on mood induced, the correlation with the system of three sensory stimulation of the sense of presence, the hypothesis of sensory stimulation and the sense of presence is positively related to sensory stimulation, enhance, enhance the sense of existence, emotional arousal. The second is through research comparative virtual reality system and calm state, subjects using virtual reality system to observe the virtual scene, to record the participants' physiological responses to different scenarios (such as ECG data), through the analysis of heart rate variability compared to observe the end scene and the quiet state of heart rate variability degree the. In the experiment, four kinds of different types of scenes were analyzed to verify the difference between the four different types of scenarios.

2.1 Hardware System

Our system is a set of multi-channel roaming VR system (Figure.2), contains two computers and a Helmet Mounted Display (Oculus rift DK2), six degree of freedom dynamic seat (integrated sweep leg device, air injection equipment) and 5.1 channel sound systems. One computer provides a virtual scene for Helmet Mounted Display, and another computer controls the movement of the dynamic platform. Subjects can freely rotate head to observe different directions of the scene, and the dynamic seat has two seats can satisfy two persons observe at the same time, but in the experiment we just used one. 5.1 sound system was used to provide a more realistic sound field. When the scene of helmet mounted display changed, the dynamic seat will complete the corresponding action according to the computer signals. This system did not provide interaction devices, and the subjects can only observe the virtual scene through the helmet, can't interact with the scene.

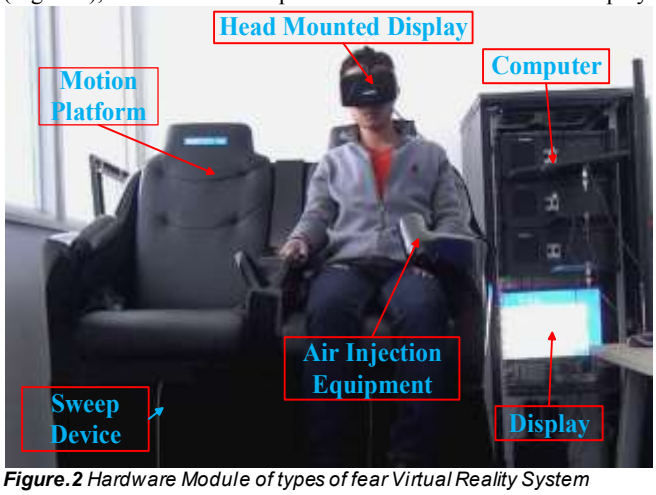

Figure.2 *Hardware Module of types of fear Virtual Reality System*

2.2 Virtual Scene

In this paper, a complete set of fear scene is used as the stimulus source. For the convenience and representation of the experiment, the fear scene is abstracted into four different types: the imaginary fear scene, the unknown fear scene, the threatened fear scene and the height fear scene. (Figure 3) The subjects wore a helmet mounted display to observe the virtual scene and the camera in the scene was equivalent to the human eye.

In an imaginary fear scene (Figure3-1), the virtual camera moves along a dark corridor simulate person's walk and the sound system provides the background sound of terror and the footsteps etc. Under the fear of a terrorist's sound and the visual stimulation, the subjects would have a kind of imagination fear. In an unknown fear

Figure.3 *Four different fear scene.*

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scene (Figure3-2), In front of the subjects will suddenly appear terrorist objects, such as crows, zombies, running past rats etc. Dynamic seat will have jet and leg sweep special effects, the unknown fear scene would be evoked by a combination of unknown visual and tactile stimuli; In threatened fear scene (Figure3-3), subjects will saw a ghost just like "Sadako" slowly climb out from well and hordes of zombies run towards the observers, dynamic seat will have the escape action, through the threatened visual stimuli and tactile stimuli evoke the person's fear sense; In the height fear scene (Figure3-4), Observer would fall into a downward curved tunnel, the dynamic seat will control the observer's body tilted forward, achieve a sense of fear of falling.

3. Experiment Design

3.1 Participants

15 students participated in the experiment, including 12 males and 3 females aged 22-27 years (M=24.47, SD=0.91), all of them didn't observe this scene before and experience the system. All of the subjects completed the observation of four different fear scenarios through the virtual reality system and recorded the physiological information, but two of them were not completely filled in the subjective scale.

3.2 Measures

In this paper, we mainly use the subjective and physiological parameters of the two evaluation methods, as follows:

3.2.1 Subjective scale

Presence Questionnaire Witmer[10]designed a subjective assessment scale to measure the presence of the virtual reality system. The PQ scale contains 32 questions, which contain the influence of vision, hearing, touch and interaction. We designed the virtual reality system has no interaction, the subjects can only observe the virtual scene, we according to the system and the virtual scene to modify the Witmer's PQ scale, the modified scale contains 12 questions, including the sense of touch, hearing, vision and the overall feeling of the system.

The Positive and Negative Affect Schedule is a 20-item self-report measure of positive and negative affect developed by Waston in 1988[14]. It contains 20 words describing 10 positive emotions and 10 negative emotions, this paper chooses four negative emotions to describe the feelings of the system's emotional change, namely Rejected, Nervous, Scared, Frightened, and subjects will select one of the words to describe emotional feelings induced by the system induced.

Fear scale. The scale (Table 1) is designed for four different kinds of virtual scenes, for each scenario corresponding to two problems. In order to achieve the purpose of evaluation, the scale of the design for the 7 level: 1 indicated that the degree of fear was the lowest, and 7 was the highest. The reliability analysis of the scale was carried out by SPSS, and the Cronbach's alpha was 0.804. The scale was credible.

Behavior scale. In the process of the test, the subjects may have physical or behavioral response, the statistical analysis of behaviors can better explain the emotional change, therefore, this paper designs 5 kinds of behavior to let subjects to choose according to their own subjective feelings.

- Rapid heartbeat ;
- Dodge eyes and don't dare to look;
- The mouth opens out a cry;
- Breathing faster;
- Body (arms or legs) have avoid or evade action;

Table.1 Fear scale about different scenes.

Imaginary fear scene	1. How many degrees of your fear cause by the dim corridor and background sound? 2. How many degrees of your fear when you walk or run across the corridor?
Unknown fear scene	3. How many degrees of your fear caused by the sudden appeared crows or bloody mural? 4. How many degrees of your fear cause by the suddenly jumped out of bloody zombies?
Threatened fear scene	5. How many degrees of your fear when the "Sadako" climbed out and ran to you? 6. How many degrees of your fear when the hordes of zombies ran to you?
Height fear scene	7. How many degrees of your fear when you fell into the tunnel? 8. How many degrees of your fear when zombies and monsters in tunnel jumped on you?

3.2.2 ECG physiological parameters measurement- Heart Rate

In the experiment, the ECG signal was recorded by the MP150 physiological parameter recorder and connected with the way of limb lead. The left leg, right leg and right hand of the subjects was pasted on the three electrodes. The physiological parameter recorder can record the ECG data in the test process, and measure the ECG data. This paper uses the Kubios software to analyze the heart rate variability.

Time domain, frequency domain and nonlinear analysis are the main methods for the analysis of heart rate variability. In this paper, we used time domain and frequency domain. In the time domain analysis, the standard deviation (SDNN), the HRV triangle index, SDANN, RMSSD the commonly used feature values. SDNN and HRV triangle index was used to measure the overall change. SDANN was used to evaluate long-term changes in heart rate, and RMSSD was used to reflect the change in heart rate.

In addition, Kubios provides two methods of frequency spectrum analysis, classical FFT spectrum analysis and AR auto regressive parametric model spectrum analysis. The normal heart rate spectrum curve is between 0-0.4Hz, 0.0030 is a super low frequency (VLF), 0.04~0.15Hz is a low frequency (LF), 0.15~0.4Hz is a high frequency range (HF)[16]. LF is a double regulation of sympathetic nerve and the vagus nerve, and HF is only regulated by vagus nerve. LF/HF is a balanced state of the autonomic nervous system, which represents the level of sympathetic nerve tension. LF, HF and LF/HF three data can be used for the analysis of short time ECG signal [17]. In this paper, we analyze the ECG data between the calm state and using a VR system.

3.3. Procedures

Prior to the experiment, all the participants filled out the questionnaire: the Survey Schedule Fear, which was proposed by Wolpe[15] in 1963, which contained a variety of different types of fear scene or vocabulary, we chose 12 specific words as the evaluation of the subjects' self-Fear Questionnaire. This parameter will be used as a reference for data statistics. Before experiment,

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experimenter explain the purpose and requirements of test and method of wearing and using a helmet. Test procedure is divided into baseline stage and testing stage:

Baseline stage: the subjects wear HMD and the ECG measuring instrument for 3 minutes, and recorded the ECG data in the calm state of the subjects.

Test stage: the subjects wear HMD to observe the virtual scene, and the test time was 5 minutes, and the ECG data of the subjects was recorded. After the completion of the test, the subjects completed the subjective scale.

4. Result

The PQ, Fear, behavior questionnaires and ECG data of 13 subjects were recorded in this paper and used the correlation analysis, hypothesis test and analysis of variance and SPSS software in data analysis. After the experiment, we had a return visit to the subjects. The result showed that 4 subjects have experienced similar systems before and 4 subjects felt uncomfortable in the process of experiment, 77% of the subjects thought that this VR system was able to induce their fear sence in some extent, and all of them wanted to experience the system again, but 85% of them believed that the degree of fear sense would reduced due to the familiarity of scene.

4.1 Validity analysis of induce emotion changes using VR system

4.1.1 From the statistical results of the scale

From the statistical results of PANAS(Figure.4), Five subjects felt nervous when they finished experiment which is more than the numbers who felt threatened and scared, and only two thougth that they would never experience this system any more. The result showed that most subjects felt nervous after experiment ,which in some extent indicated that the degree of fear sense induced by the VR system is not strong enough, just made subjects feel nervous. But The difference of the subjects' fear degree has a greater impact . on the results. And from the Survey Schedule Fear, subject who has a lower degree of fear is more likely to feel fear. But the system is capable of inducing a change of emotion in some intent.

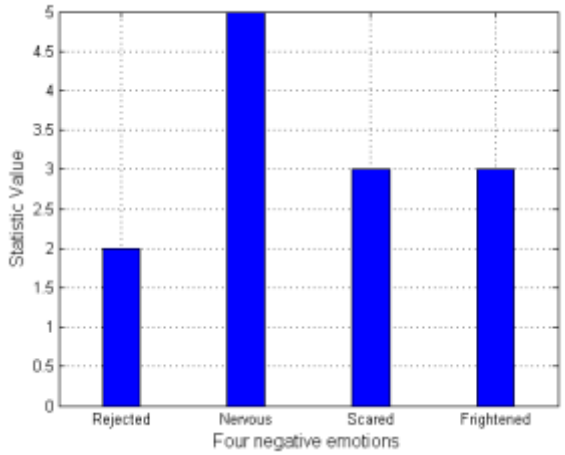

Figure.4 The Statistic result of FANAS

4.1.2 From the results of ECG data

Physiological signals can reflect the inherent emotional state changes of the subject through characteristics of physiological responses.[18][19] Figure.5 shows the change of Heart rate with time extracted from a subject's ECG data. The first 180 seconds is the Baseline stage, the change of heart rate fluctuations is not great; 180 seconds~240 seconds is testing stage, and the heart rate of subjects was strongly changed in different scenes. The time domain and frequency domain feature information of all subject's ECG data could be obtained by Kubios software and utilizing MATLAB analyze the characteristics of the time domain and frequency domain. The noticeable change of all characteristics is: the mean value of heart rate (mean RR) and RMSSD; in frequency domain are LF and HF.

The statistical result of heart rate characteristics of the 13 subjects is shown in Figure.6.And from the statistical results (Figure.6)in the time domain analysis, the mean heart rate of 70 percent subjects (nine persons) was higher than the calm state, the RMSSD value of 77 percent (10 persons) were reduced; Bong-song Zheng[1] found that most of subjects HR during negative emotions are higher than positive emotions through comparison of the HR between negative emotions,positive emotions and neutral

In the frequency domain analysis, the frequency spectrum of low frequency components (LF) and high frequency components of (HF) have been reduced, very low frequency components (VLF) has increased.

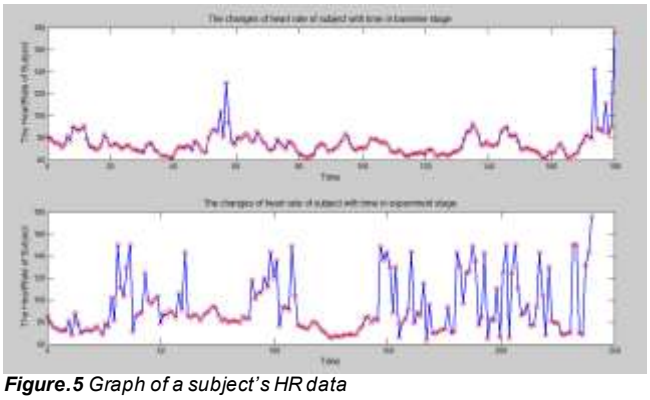

Figure.5 *Graph of a subject's HR data*

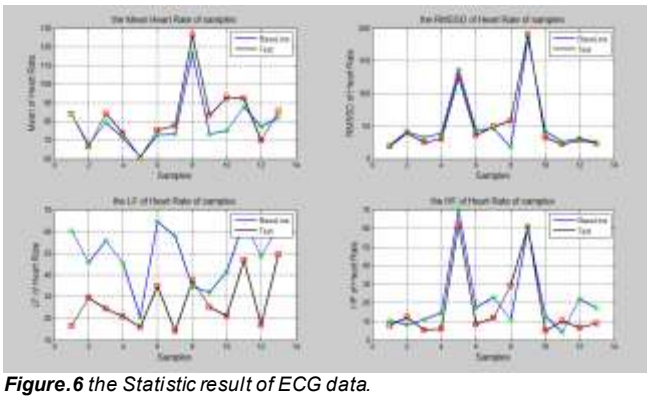

Figure.6 *the Statistic result of ECG data.*

4.2 Analysis of differences about fear scenes

In this paper, a single factor analysis of variance was used to analyze the influence of the four different kinds of fear of subject's fear degree. Single factor analysis of variance was required to meet the normal distribution and homogeneity of variance. Normality test using K-S (Kolmogorov-Smirnov) test method for non-parametric estimation, four different levels of progressive significance of 0.850, 0.541, 0.910, 0.954, four kinds of scenes satisfy normal distribution.

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On the basis of Levene's test, the statistical value is 0.565, and significance level is 0.641 which is more than 0.05. It is considered that the level of fear in the four scenarios is homogeneous. The condition of analysis of variance is satisfied. Table.2 is the result of variance analysis.

Table.2 Single factor analysis of variance

	SS	df	MS	F	Sig
Between	1.192	3	0.397	0.254	0.858
With-In	75.202	48	1.567		
Total	76.394	51			

From Table.2, we can see the sum of squares with-in groups are bigger than the sum of squares between groups. This is shows that the difference was mainly derived from the random factors in the group, and significance is 0.858, greater than 0.05. We could consider that difference of fear scenes had no significant effect on the emotion. Results of multiple comparison tests also showed that there is no meaningful difference between the two levels. The reason for this result may be explained by the samples is small and the scene is continuous, so subjects didn't feel the difference of scenes. But in the mean of subjective feeling about four fear scenes (Figure.7), we can see that the threatened fear scene is strongest and imaginary fear scene is weakest.

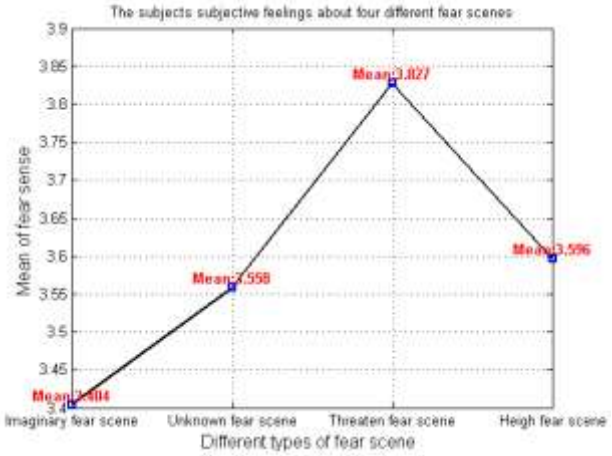

Figure.7 *Mean of subjective fear tester's about four fear scenes.*

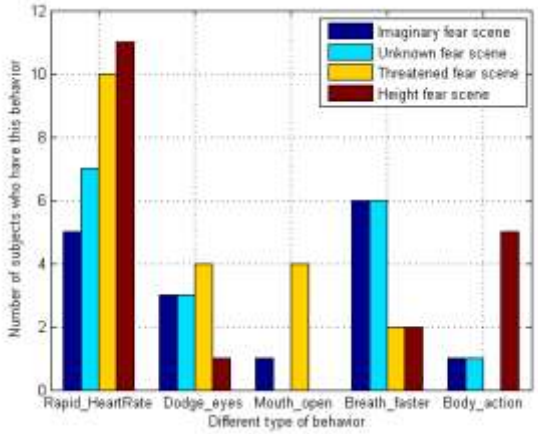

Figure.8 *The statistic result of behaviors in four scenes.*

In addition, the behavior of subjects can see the impact of scenes on emotion induction. From statistical results (Figure.8)found that subjects in four scenes are clearly feeling the heartbeat speed and acceleration of respiration, especially in Height fear scene, due to greatly movement of dynamic seats, the number of subjects who feel rapid heartbeat is most. Subjects had eyes dodge and mouth open behavior in threatened fear scene is more than other three scenes, and in imaginary fear scene and unknown fear scene makes it easier for the subjects to speed up breathing.

4.3 Influence of VR system presence on the emotion evoked

The factors that affect the virtual reality system in PQ scale are divided into three aspects: vision, hearing and touch. In this paper, we analyze the relationship between the three factors and emotion, and determine which factor has most impact on emotion induced. The simple Pearson correlation coefficient and the method of bilateral test were used to calculate the correlation of visual stimuli, auditory stimuli, tactile stimuli and emotion in virtual reality system.

Table.3the result of correlation statistics

	Visual stimuli		Sound stimuli		Tactile stimuli	
Presence	Pearson	Sig	Pearson	Sig	Pearson	Sig
	0.707**	0.007	0.571*	0.041	0.647*	0.017

** At 0.01 level (Two-tailed) was significant correlation.
* At 0.05 level (Two-tailed) was significant correlation.

As can be seen from Table.3, the visual, auditory and tactile stimuli in the virtual reality system are positively related to emotion induced. When the stimulus is enhanced, the effect of emotion induced is better. Visual stimuli were significantly associated with emotion at 0.01 levels, and the auditory and tactile were significantly correlated with emotion at the level of 0.05. Therefore, in virtual reality system, the influence of visual stimulation on emotion is better than that of auditory and tactile. Tactile stimuli were greater than the correlation of auditory stimuli. Virtual reality system requires a strong presence to induce emotional change, and in the design process can strengthen the system of visual and tactile stimulation, increase the sense of reality.

5. Conclusion

In this paper, we built a multi-channel virtual reality system and four kinds of different fear scenarios. The validity of the VR system as an affective medium is verified by the method of subjective and objective measurement. In the follow-up study, in order to verify whether there is difference between the virtual reality system of inducing emotional change and the real environment, there will be a comparative study. In addition, this paper has some defects and shortcomings: the sample size is small, the evaluation method is the lack of depth, and the ECG data are only done by statistical analysis, we will improve in the next paper. In the future, the factors that affect the emotional changes of the virtual reality system will be considered more, such as the resolution of the scene, the view angle, and the interaction of system, etc.

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Author Biography

Di Wu was born in China in 1990, and now studys in Beijing Institute of Technology for a Master degree, mainly engaged in virtual reality technology and Human-computer Interaction technology research work, and will be about to graduate in 2016. He participanted in the Psychological relief project based on Virtual Reality Technology in 2015

Dongdong Weng was born in 1979 in China, obtained Doctor's degree from Beijing Institute of Technology in 2006, and now is a deputy researcher at Institute of optical information technology and color Engineering of Beijing Institute of Technology, master's tutor, engaged in virtual reality and augmented reality technology research work for more than 10 years. He has been involved in the project of national high tech Development Program, national outstanding youth fund projects, the national key basic research development plan sub topics, provincial-level research projects, including more than 20 provincial and ministerial level projects. In recent years,he has published more than 30 papers and ten patents,etc.

Song Xue was born in China in 1990, and now studys in Beijing Institute of Technology for a Master degree, mainly engaged in virtual reality technology and Human-computer Interaction technology research work. He participanted in the Psychological induce and relief project based on CAVE virtual reality Technology