Effects of Virtual Reality and Augmented Reality on Induced Anxiety

Shih-Ching Yeh, Yuan-Yuan Li, Chu Zhou, Pin-Hua Chiu, and Jun-Wei Chen

***Abstract*—To explore the effects of virtual reality (VR) and augmented reality (AR) in the treatment of claustrophobia, the potential effects of VR and AR on induced anxiety were investigated in this paper. During the experiment, 34 subjects were randomly selected and distributed in AR and VR scenes in a sequence. The skin conductance and heart rates of the subjects were measured throughout the entire process, and the anxiety scale was used to assess the subjective anxiety when the task in each scene was completed. The results showed the following: (1) AR and VR scenes led to feelings of discomfort, but the subjective anxiety scores obtained in the two scenes were not significantly different; (2) the skin conductance level of the subjects significantly increased from the baseline when the subjects entered the experimental scene but remained active in the two scenes without showing significant difference between the scenes; and (3) the heart rate index significantly increased from the baseline after the subjects entered the scene and then gradually decreased. The heart rates of the subjects significantly increased again when the anxiety-induced event was triggered. However, no significant difference was observed between AR and VR scenes. AR and VR have induced obvious anxiety, which was reflected in the subjective and objective physiological indicators. However, no significant difference was found in the effects of AR and VR on the induced anxiety. Considering the cost of building two scenes and other factors, AR was more suitable for the treatment of claustrophobia than VR.**

***Index Terms*—Anxiety, augmented reality, claustrophobia, virtual reality.**

I. Introduction

A. Phobia and Its Main Treatment Methods

PHOBIA is attributed to the anxiety disorders spectrum in DSM-5. The current main treatment methods for phobia include drug and psychological treatments. Several studies have reported that in drug treatment of phobia, tricyclic antidepressants, especially monoamine oxidase inhibitors, are more effective than placebos against social anxiety [1]. Paroxetine has been approved by the US Food and Drug Administration for social anxiety disorder [2]. Psychotherapy is more widely used for most phobias. Cognitive behavioral therapies for anxiety disorder mainly include exposure therapy (EX), cognition process therapy, systematic desensitization, and cognitive therapy [3].

Studies have shown that 5%–7% of the world's population suffer from claustrophobia, but most of them do not actively seek treatment [4]. With the introduction of new technologies, the efficiency of medical rehabilitation has been greatly improved. Virtual reality (VR) and augmented reality (AR) have been applied in several cases of phobia treatment. Several studies have achieved the treatment of some phobias using VR [5]–[9]. Several researchers have speculated that AR may be used to treat phobia [10]–[12]. However, studies on claustrophobia remain limited. Different from other phobias, claustrophobia is a kind of anxiety in a closed space. The closed space can be a variety of places, such as engine rooms, elevators, and closed rooms. This kind of anxiety comes mainly from imagining possible events in the claustrophobic space. Therefore, great differences may exist in establishing experimental scenarios for claustrophobia. This specificity requires experimental studies that are specifically conducted to address the anxiety-inducing condition of the phobia.

B. Application of VR in Phobia Treatment

VR is a type of advanced human–computer interface that allows users to interact with computers in real time and immerse themselves in the environment created by computers. In psychological treatment, VR technology can present audiovisual experiences more realistically than traditional therapy technology and provides a safe and controllable environment where patients can be treated. The scenario is customized according to the patient's condition, such that the patient's nervousness, fear, joy, and other emotions can be fully expressed. Various sensing devices are used to collect data and obtain feedback. Botella [13] exposed a participant to eight kinds of claustrophobic space for 35–45 min, and the therapeutic outcome was evaluated. The anxiety level and avoidance reaction decreased. Bruce and Regenbrecht [14] constructed a VR system for treating claustrophobia and included 18 subjects for the within-subject design experiment. Their result showed that these scenarios enabled the subjects to immerse in the VR environment, and the Subjective Unit of Discomfort scale (SUDS) score showed that the subjects felt discomfort. The two published study cases showed positive

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results. Some studies have proven that the construction of a closed room leads to subject discomfort. However, randomized controlled trials are required to assess the effectiveness of VR exposure treatment in the future.

C. Application of AR in Phobia Treatment

Another EX was gradually developed, namely, augmented reality exposure treatment (ARET). Azuma *et al.* [15] reported that AR must satisfy the following conditions: (1) combined real and virtual objects in real environments, (2) interactive and real-time implementation, and (3) associated real and virtual objects. One of the purposes of virtual elements is to deepen user experience and knowledge [16]. ARET is only suitable for small animal phobia [10]–[12], because the direction and position of the user relative to the screen are tracked through visual symbols in ARET. The virtual stimulus disappears completely when the user loses sight of the visual symbols. This detail hinders ARET from treating some phobias, such as large animal, public, and lightning phobias. The advantage of ARET is that the patient can be exposed to actual environments wherein he/she feels scared and anxious. The virtual object that the patient fears would be presented based on this environment.

D. Statement of the Problem

A review of related literature reveals that ARET may be as effective as VR EX for treating phobias. However, studies on the two therapies for treating claustrophobia are limited. This preliminary research on the effectiveness of the scenario aims to study the anxiety induced by the scenario in a healthy population. On this basis, researchers can further speculate whether this scenario is suitable for fear inducement in phobia patients. Cheng-Fang [17] conducted a related preliminary study and discovered that the scenarios established through AR and VR can cause physiological changes in the subjects, with AR bringing about changes. The Technology Acceptance Model (TAM) and self-made anxiety scales show that the anxiety of the subject in VR is significantly higher than that in AR. However, experimental control has several problems. The present study showed that the effect of AR is better than that of VR in the physiological index because different experiment environments were used, namely, a realistic environment for AR and an office environment for VR. A standing test was adopted in AR, whereas a sitting posture was adopted in VR. These differences affected the physical experience of the subjects. The subjective report result of VR was better than that of AR because the subjective reporting of subjects are conducted after the completion of all experiments, which may cause memory confusion. The deficiency of these controls may directly lead to error bias in the experimental results. Therefore, the differences between AR and VR should be studied further.

Several researchers have designed and evaluated scenarios for treating claustrophobia. Their results showed that complex scenarios are highly likely to cause anxiety in individuals [18]. This finding provides valuable information for the design of the current research. The elevator scenarios used in previous studies are monotonous. Bringing the subject into a closed-room scenario to which tasks are added may have an improved immersion effect.

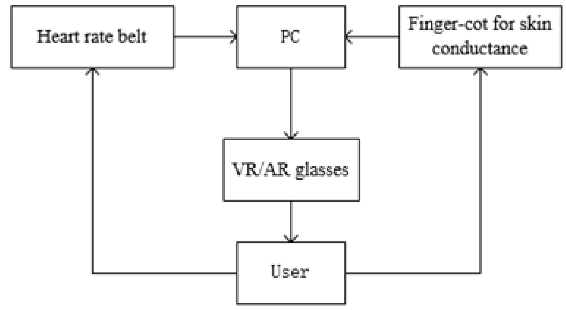

Fig. 1. System architecture.

II. Experimental Study

A. Subjects

A total of 43 subjects, which include 18 male students and 31 female students, with an average age of 23.3 years (± 4.12) and normal vision or normal corrected visual acuity, were recruited through the Internet. No trait anxiety was found through trait anxiety inventory [19] screening. The data of nine subjects were removed from the data preprocessing because the system encountered unexpected termination during testing, and part of the data was lost. Finally, valid data from 34 persons (11 males and 23 females) were obtained. Six of the subjects used a VR device.

B. System Design

1) System Architecture: VR hardware device: The VR device was equipped with HTC Vive. The device has a screen refresh rate of 90 Hz and two wireless controllers.

AR hardware device: For controlling variables, we directly modified HTC Vive with an added camera in 1080 P. Thus, the modified HTC Vive with the corresponding function of AR was used as the AR device in our experiment.

Scenario development: Unity3D5.3.x was used to implement VA and AR scenarios. The visual differences between AR and VR were minimized with an existing graphics technique in that AR and VR scenes look consistent and equivalent.

The data acquisition system was integrated with the VR/AR device to build the following system. The subject wears these devices, which constitute the entire system: heart rate belt, finger-cot for skin conductance, and VR/AR glasses. The system architecture is shown in Fig. 1. The scenarios of the AR and VR system are shown in Figs. 2 and 3.

The Grove-GSR skin current induction sensor kit developed by Seeed Studio was used to collect skin conductance information, and arduino-1.16.13 and Matlab coding were used to receive the data. A Polar H7 heart rate belt sensor was used to measure the heart rate. Windows' BluetoothGattHeartRate CPP sample and Python coding were used to receive the data. The experimental environment, temperature, light, postures

Fig. 2. Scenario of AR system.

Fig. 3. Scenario of VR system.

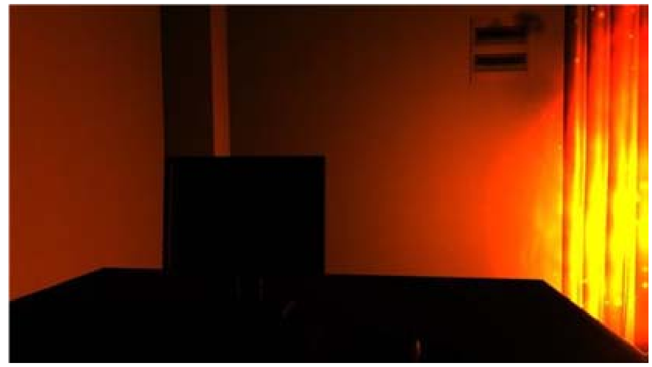

Fig. 4. Fire scene in VR.

Fig. 5. Fire scene in AR.

of subjects, helmet weight, and additional variables were controlled in the experiment.

2) Scenario Design: With reference to a previous study [17], two virtual scenarios designed as safe environments form physiological and psychological perspectives. The scenarios adopted different technologies but were the same, that is, a small closed room. The purpose of the experiment was concealed before the experiment and was only divulged at the end to obtain the true emotional feedback of the subject. First, a psychological experiment scenario was simulated at the beginning of the experiment. The subject sits in the room and completes a classic Stroop task [20] facing the computer. This is a pseudo task. The computer stops running after a period. A leakage fire occurs in the room, and events in the scenario would occur in turn with time. The events in the two scenarios occur at the beginning of the game in a fixed order. The trigger time of events in the two scenarios are consistent.

C. Research Procedure Design

The design was a single-factor within-subject design. Its independent variables referred to the experimental situations: VR and AR. Its dependent variables referred to the scores of the subject in two anxiety scales: SUDS and State Trait Anxiety Inventory (STAI) [19], which were subjective indicators; and skin conductance and heart rate in the experiment, which were objective indicators.

First, the selection and screening of subjects were carried out. The subjects were asked to fill out a screening scale by releasing the online recruitment information. After screening, the subjects who volunteered to participate in the study were subjected to the following experimental procedures after signing an informed consent form. The researcher helped the subjects use the experimental devices for the benchmark testing of the heart rate and skin conductance for 15 min. They entered Scenario 1 (half of the subjects entered AR, and half entered VR for a balanced sequential effect). The subjects listened to the instruction. They were informed of the content and operation method of the pseudo experimental task. The subjects repeated the experimental requirements to the experimenter after listening to the instruction. The subjects could enter the experiment after confirming the content and operation of the pseudo experimental task. The entire experimental scenario lasted for approximately 6 min. The scale test (SUDS\STAI-SAI) was conducted immediately, for a duration of approximately 3 min. The subjects were asked to rest for 5 min after the completion of the scale test. The subjects entered Scenario 2. The procedure for Scenario 2 was the same as that for Scenario 1 and lasted for approximately 6 min. Subsequently, the scale test (SUDS\STAI-SAI) was conducted, which took approximately 3 min. The entire experiment lasted approximately 50 min. Figs. 4–5 show the fire scenarios in VR and AR. Fig. 6 show the whole research procedure. Events were presented chronologically in the scenarios (Table 1).

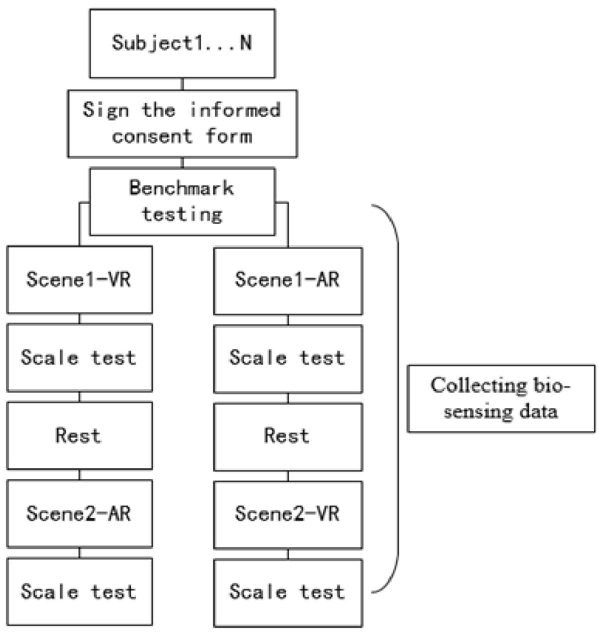

Fig. 6. Research procedure.

TABLE I
PROCESS OF EVENTS PRESENTED IN THE SCENARIOS

Time	Events
0 s	Display an audio of a listening task. The subjects must press the button on the controller. A "Pause" button is shown before the Stroop task begins to confirm that the subjects have understood the instruction.
60 s	Door slams, and footsteps are heard easing in the background). Lamp flickers for 15 seconds. Suddenly, the room turns dark. Approximately 5 seconds later, everything returns to normal. The blue screen with a disc error is seen, and fans are heard. Everything returns to normal again. The prompt "system returned to normal, please continue to test" appears on screen, and the experiment continues.
120 s	Lamp flickers. The blue screen shows a disc error. Subjects hear endless heart beats, fire and evacuation alarms, and banging on the door.
180 s	Lights are turned off. Heartbeats are heard. The switch sparks and smokes. The electrical socket sparks and starts to burn. Fire and evacuation alarms and banging on the door are heard.
240 s	The fire gets bigger and lights up the room. When the fire becomes fierce, screaming and crying are heard. Fire and evacuation alarms and bang on the door are heard.

D. Data Recording and Processing Method

1) Data Recording: The whole system recorded the following information. User's basic information included number, age, gender, and scenario. The time points of events in the scenario included the moment of entering the scenario, the formal start of the pseudo experiment after the subjects confirmed understanding of the instruction, the closing of the door, the first blue screen of the computer, the second blue screen of the computer, the lights going out, the sparking of the electric breaker on the wall, the fire breaks out in the room, the fire spreads in the room, the crowd screaming, and the end of the experiment. The scale information included the scores of the SUDS and STAI-SAI scales. The psychological information included skin conductance and heart rate during the entire course of the scenario.

2) Data Processing: The following approaches were adopted in processing the scale and psychological data. For the scale data, the questionnaire was given and answered via an iPad, and the results were uploaded to the Questionnaire Star Website. All the data were downloaded for processing using Excel 2016 after data collection was completed. For the psychological data, Matlab R2016a software was adopted after data collection was completed for data screening, data merging, filtering and noise reduction, and obtaining the peak value. The data were analyzed using SPSS Version 20 for the paired T-test.

TABLE II
SCORES OF SUBJECTS IN DIFFERENT SCALES

	N	SUDS	STAI-SAI
AR scenario	34	29.15(± 27.024)	44.50(± 11.968)
VR scenario	34	27.62(± 24.210)	44.15(± 12.997)

III. ANALYSIS OF RESULTS

The obtained results were analyzed in terms of subjective and objective indicators. After generating the descriptive statistics of the data, a paired t-test was conducted for the data results to determine the differences among the obtained means.

A. Analysis on Subjective Indicators of Anxiety

After experiencing all the scenarios, the subjects were asked to fill in a subjective scale. The scale score of each subject in each scenario was obtained, and the means of the two scale scores and the differences between them were added. Table 2 shows the results.

A paired t-test was conducted against the SUDS STAI-SAI scale results in the AR and VR scenarios to determine whether a difference exists between the subjective indicators of triggering anxiety in the AR and VR scenarios. The difference between AR and VR in the SUDS scale was 1.529, $t(33) = 0.847$, and $p > 0.05$. The difference between AR and VR in the SAI scale was 0.353, $t(33) = 0.306$, and $p > 0.05$, which means that no significant difference was found. This outcome indicates that the subjects did not feel any significant difference in the two scenarios.

B. Analysis on Objective Indicators of Anxiety

The results of the physiological data were divided into three parts. The first part is the baseline data (B_SCL), which were obtained by measuring the 15 min resting time from the beginning of the experiment. The data of subjects who were stable for 100 s before the experiment were obtained manually owing to the differences among subjects. The second part was obtained from the first scenario (AR/VR). The software was used to obtain the time points of the different events,

TABLE III
MEAN VALUE AND STANDARD DEVIATION OF SKIN CONDUCTANCE OF SUBJECTS IN DIFFERENT PERIODS (M ± SD)

	N	M (±SD)
B_SCL	34	184.68(± 67.01)
AR_SCL	34	142.73(± 50.04)
AREXP_SCL	34	141.86(± 49.14)
ARSCENE_SCL	34	143.98(± 54.69)
VR_SCL	34	143.35(± 51.92)
VREXP_SCL	34	141.45(± 50.20)
VRSCENE_SCL	34	146.00(± 58.28)

Note: B_SCL: mean value of skin conductance of baseline; AR_SCL: mean value of skin conductance in the whole AR scenario, including pseudo experiment and anxiety scenario; AREXP_SCL: mean value of skin conductance of pseudo experiment in the AR scenario; ARSCENE_SCL: mean value of skin conductance of anxiety scene in the AR scenario; three values of VR are the same as those of AR.

TABLE IV
T-TEST RESULT OF COMPARING THE BASELINE DATA OF SKIN CONDUCTANCE WITH THE VR/AR SCENARIO DATA

	t	df	p
B_SCL and AR_SCL	4.162	33	0.000**
B_SCL and VR_SCL	3.660	33	0.001**
B_SCL and AREXP_SCL	4.506	33	0.000**
B_SCL and VREXP_SCL	3.989	33	0.000**
B_SCL and ARSCENE_SCL	3.656	33	0.001**
B_SCL and VRSCENE_SCL	3.172	33	0.003**

Note: B_SCL: mean value of skin conductance of baseline; AR_SCL: mean value of skin conductance in the whole AR scenario, including pseudo experiment and anxiety scenario; AREXP_SCL: mean value of skin conductance of pseudo experiment in the AR scenario; ARSCENE_SCL: mean value of skin conductance of anxiety scene in the AR scenario; three values of VR are the same as those of AR.
* indicates $p < .05$, ** indicates $p < .01$

TABLE V
T-TEST RESULT OF COMPARING SKIN CONDUCTANCE IN THE AR SCENARIO WITH THAT IN THE VR SCENARIO

	T	df	p
AR_SCL and VR_SCL	−0.078	33	0.938
AREXP_SCL and VREXP_SCL	0.055	33	0.957
ARSCENE_SCL and VRSCENE_SCL	−0.210	33	0.835

Note: AR_SCL: mean value of skin conductance in the whole AR scenario, including pseudo experiment and anxiety scenario; AREXP_SCL: mean value of skin conductance of pseudo experiment in the AR scenario; ARSCENE_SCL: mean value of skin conductance of anxiety scene in the AR scenario; three values of VR are the same as those of AR.

which matched the psychological data. The third part was obtained in the second scenario (AR/VR). The software was used to obtain the time points of the different events, which matched the psychological data. The order of experience of the two scenarios was balanced among the subjects. It was divided into two parts in each scenario. The first part is the pseudo psychology experiment (EXP), and the second part is the anxiety-induced scene (SCENE), which was accounted for at the end of the psychological experiment (after the second blue screen).

1) Skin Conductance Data: The skin conductance data of subjects were collected during the whole experiment. Therefore, the mean value of the skin conductance of the subjects in different periods was obtained to generate the statistics. Table 3 shows the results.

The baseline data were used in the paired data to test the differences in skin conductance in different periods and the resting status among subjects to determine whether the scenario processing can lead to a change in the skin conductance of the subjects. Table 4 shows the result.

A significant difference in skin conductance existed between the experimental treatment and the baseline data. The difference in skin conductance between the baseline and AR scenario is 41.955, $t(33) = 4.162$, $p < 0.001$, and $d = 0.709$. The difference in skin conductance between the baseline and experimental data in the AR scenario is 42.824, $t(33) = 4.506$, $p < 0.001$, and $d = 0.665$. The difference in skin conductance between the baseline and scene parts in the AR scenario is 40.707, $t(33) = 3.656$, $p < 0.001$, and $d = 0.729$. The difference in skin conductance between the baseline and VR scenario was 41.337, $t(33) = 3.660$, $p < 0.001$, and $d = 0.690$. The difference in skin conductance between the baseline and experimental parts in the VR scenario was 43.238, $t(33) = 3.989$, $p < 0.001$, and $d = 0.62$. The difference in skin conductance between the baseline and scene parts in the VR scenario was 38.686, $t(33) = 3.172$, $p < 0.001$, and $d = 0.730$.

The data obtained from the scenarios were used in a paired t-test to test the difference in skin conductance change caused by the AR and VR scenarios (Table 5). No difference in skin conductance existed between AR and VR in the overall and partial scenarios.

2) Heart Rate Data: The heart rate data of the subjects were collected during the entire experiment. Therefore, the mean value of the heart rates of the subjects in different periods was obtained to generate the statistics. Table 6 shows the result.

The baseline data were used in a paired t-test with other data to obtain the differences in heart rates in different periods

TABLE VI
MEAN VALUE OF HEART RATES OF SUBJECTS IN DIFFERENT PERIODS (M ± SD)

	N	M(± SD)
B_HR	34	76.15(± 8.60)
AR_HR	34	77.50(± 9.80)
AREXP_HR	34	79.24(± 10.40)
ARSCENE_HR	34	75.81(± 9.82)
VR_HR	34	77.82(± 10.07)
VREXP_HR	34	79.85(± 10.75)
VRSCENE_HR	34	76.06(± 10.03)

Note: B_HR: mean value of heart rate of baseline; AR_HR: mean value of heart rate in the whole AR scenario, including pseudo experiment and anxiety scenario; AREXP_HR: mean value of heart rate of pseudo experiment in the AR scenario; ARSCENE_HR: mean value of heart rate of anxiety scene in the AR scenario; three values of VR are the same as those of AR.

TABLE VII
T-TEST RESULT OF COMPARING THE BASELINE DATA WITH THE VA/AR SCENARIO DATA

	t	df	p
B_HR and AR_HR	−1.614	33	.116
B_HR and VR_HR	−2.949	33	.126
B_HR and AREXP_HR	.444	33	.006**
B_HR and VREXP_HR	−1.569	33	.004**
B_HR and ARSCENE_HR	−3.095	33	.660
B_HR and VRSCENE_HR	.080	33	.937

Note: B_HR: mean value of heart rate of the baseline; AR_HR: mean value of heart rate in the whole AR scenario, including pseudo experiment and anxiety scenario; AREXP_HR: mean value of heart rate of pseudo experiment in the AR scenario; ARSCENE_HR: mean value of heart rate of anxiety scene in the AR scenario; three values of VR are the same as those of AR.
* indicates $p < .05$, ** indicates $p < .01$

and the resting status among subjects to determine whether the scenario processing led to a change in the heart rate of subjects. Table 7 shows the result.

The test indicates that a significant difference only exists between the heart rate in the pseudo experiment and the baseline heart rate. The difference in the heart rate between the baseline and experimental parts in the AR scenario is −3.082, t(33) = −2.949, p < 0.01, and d = −0.324. The difference in the heart rate between the baseline and experimental parts in the VR scenario is −3.695, t(33) = −3.095, p < 0.01, and

TABLE VIII
T-TEST RESULT OF COMPARING THE HEART RATE IN THE AR AND VR SCENARIOS

	t	df	p
AR_HR & VR_HR	−.272	33	.788
AREXP_HR & VREXP_HR	−.500	33	.621
ARSCENE_HR & VRSCENE_HR	−.223	33	.825

Note: AR_HR: mean value of heart rate in the whole AR scenario, including the pseudo experiment and anxiety scenario; AREXP_HR: mean value of heart rate of pseudo experiment in the AR scenario; ARSCENE_HR: mean value of heart rate of anxiety scene in the AR scenario; three values of VR are the same as those of AR.

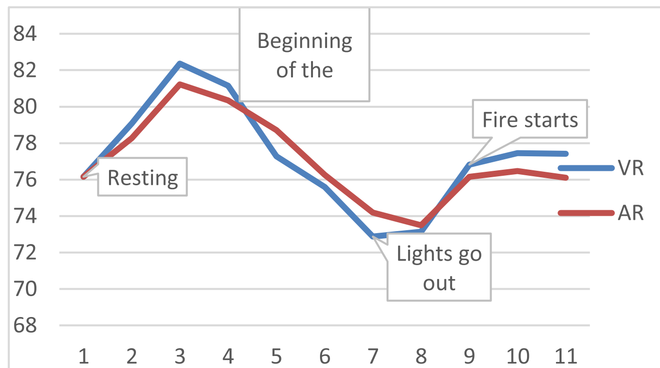

Fig. 7. Changes in the mean value of heart rates in the AR and VR scenarios.

d = −0.380. This finding means that no significant difference exists between the heart rates in the whole scenario and a claustrophobic scene and the baseline. The difference in the heart rate between the baseline and the AR scenario is −1.350, t(33) = −1.614, and p > 0.05. The difference in heart rate between the baseline and the scene in the AR scenario was 0.348, t(33) = −0.444, and p > 0.05. The difference in heart rate between the baseline and the VR scenario was −1.668, t(33) = −1.569, and p > 0.05. The difference in heart rate between the baseline and the scene in the VR scenario was 0.0864, t(33) = 0.080, and p > 0.05. The entire data indicated that the experimental treatment had no effect on the heart rate.

Moreover, to test the difference in heart rate changes caused by the AR and VR scenarios, the heart rate data obtained from the scenarios were used in a paired t-test (Table 8). The two experimental treatments did not have a significant effect on the heart rate.

For further analysis, the event nodes in each scenario were taken, and the mean value of heart rates after each event was calculated. The result is shown in Fig. 7.

Figure 7 shows that the heart rate of the subject undergoes two rising processes throughout the scene. First, the heart rate of the subject increases steadily from the resting state to the sound of the closing door in the scenario. The heart rate of the subject increases steadily and gradually decreases.

When the second anxiety event (fire starts) occurs, the heart rate of the subject increases again and reaches the highest as screaming finally occurs.

The pairwise comparison of the mean value of the heart rates of adjacent events in two scenarios shows that in the AR scenario, the heart rate significantly increased from the resting state to the experiment. The heart rate significantly increased from the resting state to the moment of wearing glasses with a difference of −2.118, $t(33) = -2.326$, $p < 0.05$, and $d = -0.229$. From the moment of wearing glasses to entering the pseudo experiment, the heart rate significantly increased again with a difference of −2.949, $t(33) = -3.592$, $p < 0.01$, and $d = -0.276$. The heart rate decreased and significantly increased again after the fire in the scene. The heart rate significantly increased from the occurrence of sparks on the wall to the fire in the scenario, with a difference of −2.658, $t(33) = -4.864$, $p < 0.001$, and $d = -0.273$.

In the VR scenario, the heart rate significantly increased from the resting state to the experiment. The heart rate significantly increased from the resting state to the moment of wearing glasses with a difference of −2.924, $t(33) = -2.637$, $p < 0.05$, and $d = -0.317$. The heart rate significantly increased again from the moment of wearing glasses to the moment of entering the pseudo experiment with a difference of −3.282, $t(33) = -4.066$, $p < 0.01$, and $d = -0.312$. The heart rate decreased and significantly increased again after the fire in the scenario. From the occurrence of sparks on the wall to the fire in the scenario, the heart rate significantly increased with a difference of −3.689, $t(33) = -4.940$, $p < 0.001$, and $d = -0.356$.

No difference was found between AR and VR for all indicators. This outcome may be related to the within-subject design. The subjects had psychological expectations when they experienced the second scenario. Therefore, the combination of the first and second statistics may conceal the effect of the experiment. Thus, we attempted to address this problem by taking the data obtained after each subject entered the first scenario. The subjects were divided into the AR and VR groups for comparison between subjects. No significant difference was found between them in the objective and subjective indicators.

IV. Discussion

A. Comparison of AR and VR: Subjective Indicators

The subjective scale data indicate that the subjects experience a certain degree of anxiety in the AR and VR scenarios [22], [23]. However, the comparison of the scores of the two scales in two scenarios shows no significant difference. This finding is inconsistent with the results obtained by Cheng-Fang [17]. The results of a previous study showed that the effect of VR is better than that of AR in the psychological indicators. Further comparison showed that the TAM and customized anxiety scales for the experimental scene were used in previous studies. Moreover, existing studies adopted SUDS and SAI. After the experiment, several subjects recounted that they did not see their legs as they bowed their heads in the VR, and thus, they knew they were in a built scene. This finding indicated the high reducibility of VR in this experiment, in that, several subjects could not tell at once if the scene is virtual or real. The score of VR was higher than that of AR in the TAM scale. Previous studies have adopted the self-made anxiety scale, but the general scale was used in this study. A great difference exists between the two in terms of questioning and wording. The previous scale was self-made and thus closer to questioning in the experimental scene. The scales adopted in this research focused on the current anxiety status. Several subjects felt nervous but did not believe they were anxious. This phenomenon also shows the effects of questioning and wording on the results obtained by the scales. The fire in the AR scenario was relatively direct with insufficient logic due to technical reasons, and the fire moved along with the head. However, the subjects were immersed in the real background scenes. Many subjects feared the two scenarios but speculated that these were simulations. This cognitive adjustment indicates the overall tension tendency of the subjects in the experiment when they entered the scenario, followed by gradual relaxation. Therefore, the subjective perception of the two scenarios tended to be similar at the end of each scenario.

B. Comparison of AR and VR: Objective Indicators

The skin conductance of the subjects greatly changed after entering the scenario. This change is constant and significant in the statistical result. The experimental treatment led to a psychological change in the subjects, and the reaction to this change is sensitive. The change in skin conductance is explained from the angle of sweat secretion [21]. When the subjects enter the experiment, their hands start to secrete sweat, and the sweat secretion is maintained throughout the experiment. A slight decrease occurs after resting, but the change is not obvious. Sweat secretion increases slightly after entering the second scenario. However, sweat secretion stabilizes after familiarity.

No significant difference exists between the heart rates of the subject in the resting state and in the experimental status, but a significant difference exists between the heart rates in the resting state and in the pseudo experiment. The heart rates of the subjects as they entered the scenario and in the pseudo experiment increase significantly possibly because this was the first time that most of the subjects wore helmets. The reason for the significant increase in the heart rate in the pseudo experiment may be the subjects' focus on the experimental task, which led to deeper immersion. This outcome is consistent with a previous study's result [18], as follows: more complex scenes and tasks easily lead to anxiety. No difference is found in subjects' heart rate. Therefore, we further analyzed and calculated the mean value of heart rates of the subject in all time points in the scenario. The subject experienced an increase in heart rate twice during the experiment. Moreover, the heart rate declined before the second heart rate increased, and the peak value of the second increase reached the mean value of the resting state. This discovery may be the reason that the mean heart rate did not increase. Thus, we conducted a paired comparison of the mean heart rate obtained from adjacent events and found that the differences in the two increases and the one decline are significant. We believe the first increase in heart rate may have been caused by the equipment and tasks, but the second one may have been the induced effect of the scene on anxiety.

On the basis of all dependent variables, the existing studies show that scenarios induce anxiety. This finding proves that scene construction is effective, which is consistent with results obtained in previous studies. Thus, scene construction can be applied to the EX of this population. However, previous studies cannot determine whether AR or VR is better based on any dependent variable. This finding is different from the results obtained by Cheng-Fang [17]. Previous studies have reported that the effect of AR is better than that of VR in terms of psychological indicators. This may be due to the following reason: by adopting the within-subject design, the subject develops an expectation of the latter experimental scenario after entering the first experimental scenario, which clouds the effect of the scene. To eliminate this possibility, the data obtained from the subjects after entering the first scenario are removed. The subjects are divided into AR and VR groups for comparison. The sample size of each group is small (less than 30). No indicator reaches a significant difference. Considering the psychological indicators, no difference exists between the AR and VR scenarios in anxiety inducement. Therefore, the existing study data are reliable, and the study result is true. The current research results differ from those obtained in previous studies because of the presence of a controlled variable problem in previous studies (i.e., the subject is in a real elevator scene in the AR scenario, and the subject is in a laboratory in the VR scenario). The experiment is completed in a standing posture in the AR scenario and is completed in a sitting posture at the computer in the VR scenario. These environmental differences may cause the subjects to be more anxious in the AR scenario. This kind of anxiety cannot be alleviated by cognitive adjustment. In the experiments conducted in the current study, the environment, the posture of subjects, and the variables are controlled strictly for all variables, except in the AR and VR scenarios, to ensure consistency. In addition to the realistic feeling caused by the VR scene construction, the subjects experience the same process. Thus, they do not feel significantly different. Another factor is the realistic VR scene, which weakens the real difference between the AR and VR scenarios; thus, the subjects show similar receptiveness to these two scenarios.

V. Conclusion

The study indicated that the proposed AR and VR systems effectively induced anxiety in subjects. Moreover, by measuring the subjective scale scores, skin conductance, and heart rate, no significant difference was found between the proposed AR and VR systems in terms of inducing anxiety. Future research will further quantify the contribution of each type of stimulus from human perceptions (visual, auditory, haptic, or smell) and investigate whether AR or VR system is more effective in inducing anxiety.

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