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Emotional effect of cinematic VR compared with traditional 2D film

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ABSTRACT

Virtual reality (VR) has been increasingly applied in filmmaking in recent years. The integration of film and VR is becoming an important breakthrough for traditional films. This new types of film, named cinematic virtual reality (CVR), provides immersive VR experience where individual users can immerse themselves in synthetic world experience in 360° (Mateer, 2017).

However, the characteristics and influence of this new digital media on human emotion is far from clear. In this study, we conducted an experiment to investigate the different emotional effects of CVR by comparing with a traditional two-dimensional (2D) film from two critical aspects: subjective emotional experience and real-time objective physiological reaction. Our results first revealed that the subjective experience and the physiological reaction showed significantly stronger emotional effect in the CVR condition than in the 2D condition. Upon further observation, we found that four emotions (excitement, nervousness, hostility, and jitteriness) are more closely correlated with the CVR than with the traditional 2D film. Real-time analysis of skin temperature shows a faster and steadier decline in the CVR group than in the 2D group. Finally, we summarized the causality of the effect by analyzing the characteristics of CVR. Our study suggests that CVR is an effective medium that induces stronger emotional experience and physiological reaction than traditional 2D film can. The design of the VR environment in CVR, as a key feature in the narrative of a film story, has an important influence on the emotional processing of the audience.

1. Introduction

Virtual reality (VR) has achieved impressing developments in recent years and is expected to make great improvements in education, therapy, media, medical training, and many other fields. In recent years, the application of VR in film has been attracting more attention from Hollywood studios. This new types of film, named cinematic virtual reality (CVR), provides immersive VR experience where individual users can immerse themselves in synthetic world experience in 360° (Mateer, 2017). In 2015, The Walt Disney Company led a $66 million investment in VR startup Jaunt VR. In 2017, 20th Century Fox created a new division called FoxNext, which focuses on location-based entertainment, VR, and augmented reality. A popular strategy among major film companies nowadays is to produce short VR trailers or VR games based on films, such as *The Jungle Book*, *Star Wars*, and *The Martian*. Cannes Film Festival and Sundance Film Festival have also handed out special awards for VR films in recent years. The integration of film and VR technique is becoming an important breakthrough for traditional screen films. CVR usually make people feel as though

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they are part of the story and let them experience the events in the movie.

The influence of new digital media on human beings needs to be explored because digital media has become a part of our life. Three-dimensional (3D) or called stereoscopic technique is a great development for traditional two-dimensional (2D) film over the last decade. Traditional 2D film, as the most common form of films, was usually presented in the cinema screen, computer or TV. The new 3D technique creates or enhances the illusion of depth in an image by means of stereopsis for binocular vision (Terlutter et al., 2013). In the recent studies, the effect of 3D in filmmaking on human attention, memory, and emotion processing were explored. Some researchers found that watching 3D films is a more realistic and immersive experience than watching 2D films (Ijsselsteijn et al., 1998; Ijsselsteijn et al., 2001). But some other studies showed that emotional experience during film viewing did not differ between 3D and 2D groups (Rooney and Hennessy, 2013) and 3D does not add an incremental benefit over 2D (Bride et al., 2014). Terlutter (Terlutter et al., 2013) compared the influence of 2D, 3D, and four-dimensional (4D) techniques on brand placement in movies. The result indicated that the viewer's memory of prominent brand placements benefits from 3D instead of 4D, and the viewer's memory of subtle brand placements is more negatively affected by 3D or 4D compared with 2D movies. These studies suggested that the application of a new technique in film did not always induce the anticipated effect.

Similar to the use of 3D and 4D, VR technique is usually considered to have a better effect than other forms of films on stimulating a more real and stronger sensory experience. On the basis of emotional gratification theory in media use, the desire to experience emotions is widely considered to be key motivation for the use of entertainment media, be it in the form of movies, TV, or computer games. The experience of emotions can be gratifying for media users because they help in attaining a pleasant state of arousal or because they give rise to novel, intense, and sensational experiences (Vorderer et al., 2004; Bartsch et al., 2006; Bartsch and Viehoff, 2010). Filmmakers primarily focus on evoking emotions in actors and viewers through an engaging story, sympathetic characters, and the presentation of a cinematic world by audiovisual means (Tarvainen et al., 2015; Plantinga, 2009). Film has been proven to be one of the most popular and effective methods of eliciting emotion. Given the brilliant emotional effect of films, researchers have established standardized film databases based on unified emotional criteria (Gross and Levenson, 1995; Schaefer et al., 2010).

With regard to the emotional effect of VR, previous studies mostly focus on the emotionally therapeutic effect of VR. VR exposure therapy for emotional disorders, such as phobia, anxiety, and pain, has been investigated for many years (Gorini and Riva, 2008; Daniel et al., 2016). Recent studies also found several key points of VR environment or technology, including the positive correlation of emotion and presence produced by VR condition (Riva et al., 2007), the different effect of virtual environment technologies (i.e., desktop, head-mounted display, or fully immersive platforms) on emotional arousal (Kim et al., 2014), and the relationship between different virtual scenes and specific affective state (Felnhofer et al., 2015). These results shed light on the important function of emotion in CVR. Will CVR produce a stronger emotional effect than other forms of film? What key factors in CVR will produce and influence emotion in users? Furthermore, what are the special characteristics of CVR compared with other forms of films? Few studies have explored the emotional effect of CVR. Determining the characteristics and influences of CVR on human beings is necessary because this new digital medium is becoming increasingly popular.

2. Research design

To answer these issues, we conducted an experiment to investigate the different emotional effects of CVR through a comparison with traditional 2D film. Normally, both CVR and traditional film have 2D edition and 3D edition. In order to strictly control the experimental conditions, we only chose the 2D editions of CVR and traditional film of a same film story. Four film clips, namely two CVR clips and two matched traditional 2D film clips, were edited from the same Disney animated film. It is a between-subject design. The participants were asked to watch CVR clips or traditional 2D film clips. The study focuses not only on subjective emotional experience of audiences but also their objective physiological reaction. Subjective experience and physiological reaction are key components in the process of emotion (Izard, 2009). According to the discrete emotion theory of Carroll Izard, subjective emotional experience is always accompanied with physical activities (neural, brain function, and physiological) and facial or body expressions. Physiological reactions always occur in the emotion process. Therefore, we measured self-reported emotional ratings with the Positive and Negative Affect Schedule (PANAS) before and after film watching. We recorded physiological reactions before and during film viewing. On the basis of the above analysis, we present two hypotheses.

H1: CVR clips will elicit a stronger emotional experience than traditional 2D film clips.

H2: The physiological reaction elicited by CVR clips will be significantly different from the reaction elicited by traditional 2D film clips.

3. Methods

3.1. Participants

Forty healthy Chinese college students (age: mean = 22.72, SD = 2.65, 19 males and 21 females) enrolled in universities in Beijing, China participated in this study. All Participants are randomly assigned to either the CVR group (N = 20) or the 2D group (N = 20) before watching the film clips. The CVR group watched two edited CVR clips, and the 2D group watched two edited traditional 2D film clips with the same story. Neither were participants previously exposed to the film nor they experienced VR before. They had normal or corrected-to-normal vision. All were paid after completed the experiment.

3.2. Stimulus materials

The Disney animated film *The Jungle Book* was selected. This movie tells the story of a little boy called Mowgli, who lived with animals in a jungle. All the animals and settings in the film were created by using computer-generated imagery. Two CVR clips were downloaded from the official website. One is a CVR monkey clip, and the other is a CVR snake clip. Two-dimensional film clips were edited from the normal version and are matched with the CVR version in scenes and sound. The CVR clips and traditional 2D film clips have the same content and duration. Films that have characteristics that all match is rare; thus, we matched along a few characteristics that have the highest priority (Gross and Levenson, 1995).

3.3. PANAS (the positive and negative affect schedule)

We used PANAS to measure the variability of emotion before and after watching the film clips (Watson et al., 1988). The scale is a reliable and valid tool for measuring positive and negative emotional states. Twenty adjectives are used to describe positive and negative feelings. The 10 items for positive affect (PA) are attentive, interested, alert, excited, enthusiastic, inspired, proud, determined, strong, and active. The 10 items for negative affect (NA) are distressed, upset, hostile, irritable, scared, afraid, ashamed, guilty, nervous, and jittery. Participants rated each item on a five-point scale, with 1 indicating “very slightly or not at all” and 5 indicating “extremely.” The total score of 10 positive items and 10 negative items was analyzed. Watson, Clark, and Tellegen suggest that the normal population will have a mean positive affective score of 29.7 (SD = 7.9) and a mean negative affective score of 14.8 (SD = 5.4) (Watson et al., 1988). The Chinese revised version of PANAS has good reliability and validity in the Chinese population (Lin, 2008). Previous studies proved that PANAS has good reliability and construct validity across countries, languages (Chinese, Dutch, English, French, German, Italian, Polish, Russian, and Spanish) (Quirin et al., 2016), and ages (adolescents and young adults) (Ortuñosierra et al., 2015).

3.4. Display equipment

The CVR stimuli were presented by Oculus Rift DK2 head-mounted display. The field of view of the display is 100°. The highest refresh rate is 75 Hz. The display size is 960 × 1080 pixels per eye. The support system of the computer is Windows 7 SP, and the graphics card is NVIDIA GTX 970/AMD 290. The traditional 2D film clips were presented on an integrated 22″ monitor connected with a personal computer in a psychological lab. The viewing distance is less than 100 cm.

3.5. Physiological recording

We recorded five original physiological signals based on previous emotional studies, namely, skin temperature A (SKTA), skin temperature B (SKTB), electrocardiogram (ECG), respiration (RSP), and photoplethysmography (PPG). These index are proven to be closely related to emotional processing (Kreibig, 2010; Stephens et al., 2010). All signals were simultaneously acquired using the BIOPAC MP150 wireless device (BIOPAC Systems, Inc.). The dual wireless skin temperature BioNomadix transmitter records two channels of temperature data with channel A named SKTA and channel B named SKTB. In practice, channel A is connected to index finger as a measurement for skin temperature and channel B to the ring finger. In physiological studies, skin temperature has been found to be correlated with emotion in general; higher SKT is related to positive emotion and lower SKT is related to negative emotion (Kreibig, 2010). ECG signals were recorded using an ECG100C-MRI amplifier, and three Ag/AgCl electrodes. ECG electrodes were attached to participants using the standard three-electrode lead-II configuration in which electrodes were placed on the right collarbone, and the lower left and right ribcage. RSP signals were using an RSP100C amplifier for direct physical measurement of respiratory effort. The RSP100C works with the TSD201 transducer to measure abdominal or thoracic expansion and contraction while breathing. The PPG channel was put on middle finger to measure Blood Volume Pulse (BVP) via optical plethysmographic methods. Before the electrodes were attached, the participants rinsed their skin and hands with distilled water. The signal was sampled at 200 Hz by using BIOPAC MP150 system connected to a data acquisition computer running the Acknowledge 4.2 software package. Baseline recordings were taken during a two-minute rest period before viewing the film.

3.6. Procedure

Before watching the films, the participants were asked to complete a pre-mood scale. The CVR group watched CVR clips through the Oculus headset, and the 2D group watched traditional 2D film clips on a computer screen. Physiological reaction was recorded by using BIOPAC MP150 for CVR and 2D conditions. After watching the film clips, all participants were asked to complete a post-mood scale. Two clips with the same condition were randomly presented (Fig. 1).

4. Data and results

4.1. Subjective experience analysis

PANAS was measured twice to record the present mood. The pre-test was measured before viewing the film, and the post-test was measured after viewing the film. We calculated each item score of the pre-test and the post-test. Then, we calculated the total score of

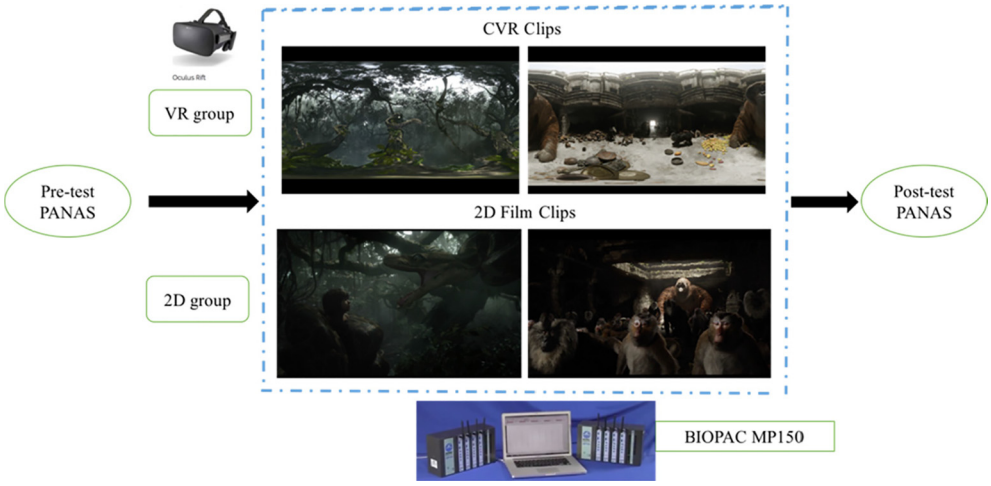

Fig. 1. Procedure of the experiment.

10 NA items and 10 PA items.

First, we compared the subjective experience differences between the VR and the 2D groups. After the baseline was reduced (post-pre), we obtained the index of subjective experience difference. One-way ANOVA between the VR and the 2D groups revealed a significant difference in the NA experience between groups ($F = 4.895$, $p = 0.033$). The VR group experienced stronger negative emotions than the 2D group did when they watched the film clips. However, we did not find any significant difference in the PA experience between the two groups ($F = 1.425$, $p = 0.24$) (Table 1).

Second, we compared each item's scores in the pre-test and the post-test for the CVR and the 2D groups. In the CVR condition, mean scores of six emotions (excited item $t = 3.489^{**}$, scared item $t = 3.684^{**}$, hostile item $t = 2.932^{**}$, nervous item $t = 2.998^{**}$, jittery item $t = 2.127^{*}$, and afraid item $t = 3.249^{**}$) have significant differences between the pre-test and the post-test. However, in the 2D condition, only two emotions (scared $t = 4.025^{**}$ and afraid $t = 2.882^{*}$) are significantly different based on a comparison of the mean scores of the pre-test and the post-test (Fig. 2).

4.2. Physiological data analysis

Five physiological indexes were analyzed, including four original indexes (SKTA, SKTB, ECG, and PPG) and one translated index from ECG (heart rate; HR). We set 60 s as the baseline before each film clip. The mean value of each index for the CVR and traditional 2D clips was calculated. After the baseline was reduced, we obtained the index of physiological reaction difference.

The main experiment results are summarized in Table 2. The mean values of SKTA, SKTB, and HR have significant differences between the CVR and the 2D groups when the participants watched the snake film clip. The mean values of SKTA and SKTB are significantly lower in the CVR condition than in the 2D condition. The HR is greater in the CVR condition than in the 2D condition. When the participants were watching the monkey film clip, only the mean value of SKTB has a significant difference between the CVR and the 2D groups, and the mean value of SKTA has a marginally significant difference between the two groups. The difference also showed that the mean values of SKTA and SKTB are lower in the CVR condition than in the 2D condition (Table 2, Fig. 3).

An analysis of finger SKT before and during the film viewing indicate a faster and steadier variety in the CVR condition than in the 2D condition (Fig. 4). Fig. 4 shows that the mean finger temperature declined rapidly after the CVR clips started. This decrease remained steady as the film played. In the 2D condition, the change in the finger temperature did not show these features; it was slow and unsteady.

Notes: The variety of SKT before and during film viewing. The first six points for each figure are data for the baseline (from B01 to B06). The seventh point is the start time of the video. We record the mean of SKT every 10 s. A: The data of SKT collected for video Monkey-CVR is analyzed in Figure A. The length of this video is 60 s. We obtain the data collected among the viewers at six time

Table 1
Emotional experience: ANOVA between CVR and 2D groups.

	CVR group		2D group		One-way ANOVA	
	Mean	SD	Mean	SD	F	Sig.
Negative Affect	4.8	6.57427	0.6316	5.04657	4.895	0.033*
Positive Affect	2.35	6.65918	0.0526	5.23316	1.425	0.24

Notes: The stars indicate that the differences are statistically significant. ** means $p < 0.01$.
* Means $p < 0.05$.

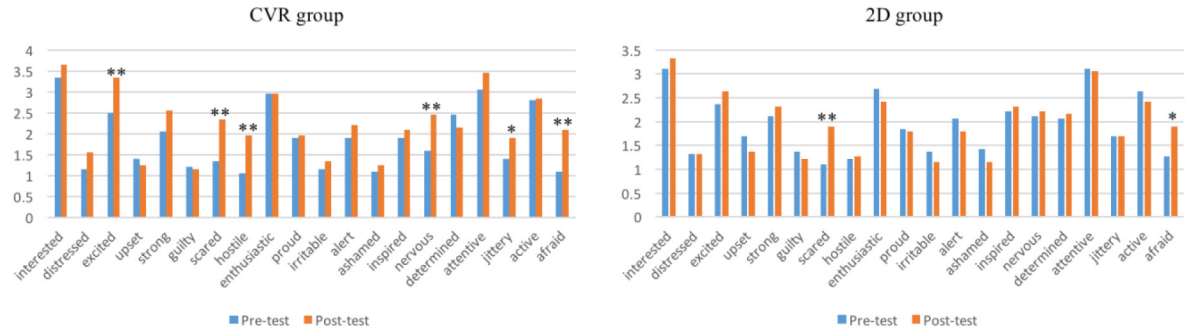

Fig. 2. Emotional variability in the pre-test and the post-test.

Table 2
Physiological reaction of CVR and 2D groups.

Film Clips	Physiological Index	CVR group			2D group			AVONA analysis	
		N	Mean	SD	N	Mean	SD	F	Sig.
Snake Clip	SKTA (°C)	21	−0.3466	0.59159	19	0.1913	0.45099	10.285	0.003**
	SKTB (°C)	21	−0.2744	0.51233	19	0.3356	0.67479	10.487	0.002**
	ECG	21	−0.0002	0.00107	19	0	0.00127	0.169	0.684
	Rate (BPM)	20	4.4958	6.91174	15	−1.0205	3.13496	8.235	0.007**
	PPG	21	−0.0008	0.00214	15	0.0024	0.01397	1.09	0.304
Monkey Clip	SKTA (°C)	21	−0.2583	0.81607	19	0.1669	0.51228	3.798	0.059+
	SKTB (°C)	21	−0.3241	0.64929	19	0.0977	0.44692	5.605	0.023*
	ECG	21	−0.0003	0.0012	19	0.0001	0.00075	1.062	0.309
	Rate (BPM)	19	0.7094	7.72006	16	0.1846	3.08082	0.065	0.8
	PPG	21	−0.0003	0.00149	15	0.0016	0.00619	1.977	0.169

Notes: The stars indicate that the differences are statistically significant.
** Means $p < 0.01$.
* Means $p < 0.05$.
+ Means $p \approx 0.05$.

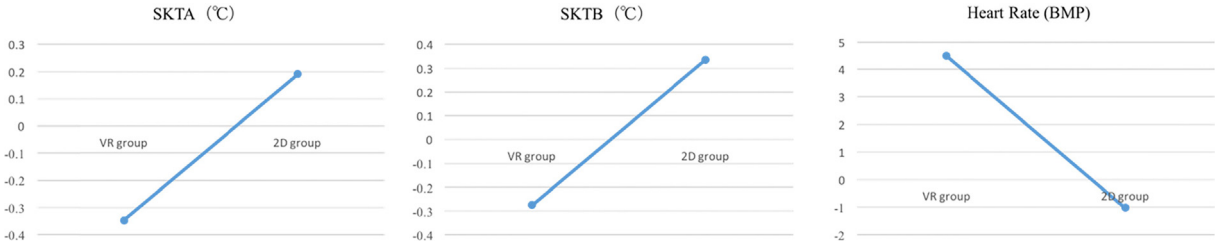

Fig. 3. Physiological reaction of CVR and 2D groups (snake clip).

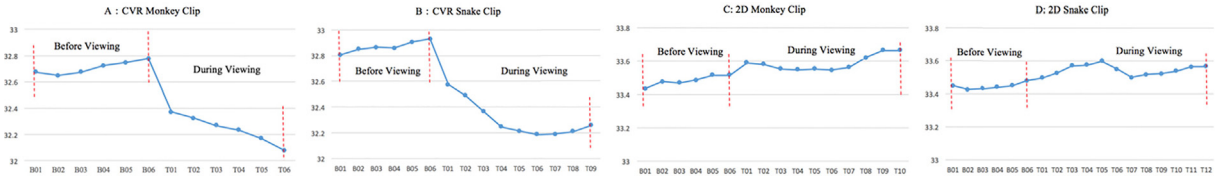

Fig. 4. Real-time physiological reaction while viewing CVR and 2D clips.

points (from T01 to T06). B: The data of SKT collected for video Snake-CVR is analyzed in Figure B. The length of this video is 86 s. We obtain the data collected from the viewers at nine time points (from T01 to T09). C: The data of SKT collected for video Monkey-2D is analyzed in Figure C. The length of this video is 99 s. We obtain the data collected from the viewers at 10 time points (from T01 to T10). D: The data of SKT collected for video Snake-2D is analyzed in Figure D. The length of this video is 120 s. We obtain the data collected from the viewers at 12 time points (from T01 to T12).

5. Discussion

We analyzed two components of emotional processing in film viewing: subjective experience and physiological reaction. An overall analysis of these two aspects revealed several important features of CVR compared with traditional 2D film.

5.1. Stronger emotional effect of CVR

First, the analysis of the subjective experience data of the CVR showed stronger emotional effect than the traditional 2D film. This result supports the first hypothesis that the CVR clips elicited stronger emotional experience than traditional 2D film clips. The PANAS result shows a significant difference in the NA factor between the CVR and 2D groups. The average scores of the NA factor in the CVR group are significantly higher than those in the 2D group. The NA scale in PANAS reflects a general dimension of unpleasant engagement and subjective distress that includes a broad range of aversive affects, including fear, nervousness, guilt, and shame (Schaefer et al.,2010). This finding reveals that the CVR clips in our study induced a stronger emotional experience in viewers compared with the traditional 2D film clips.

Second, the physiological data analysis, including the mean values of SKTA, SKTB, and heart rate, showed a significant difference between the CVR and the 2D conditions when watching the snake film clip. The mean values of SKTA and SKTB are lower in the CVR condition than in the 2D condition. The HR is greater in the CVR condition than in the 2D condition. This result supports the second hypothesis that the physiological reaction elicited by CVR clips is significantly different from the reaction elicited by traditional 2D film clips. According to previous studies, a lower finger temperature and faster HR may reflect more negative emotional reaction. In the Ekman's study (1984), the result showed that left and right finger temperatures increased more in anger than in happiness. The author concluded that the autonomic activity produced distinguished not only between positive and negative emotions, but also among negative emotions (Ekman et al., 1983). A review of 134 physiological studies concluded that a lower finger temperature is related with fear, sadness, crying, and anger. A faster HR is related with fear, sadness, anger, anxiety, happiness, and surprise (Kreibig, 2010). About the emotion of anger, the results in two papers are contradictory. We think it is related with specific tasks and individual differences between participants. Furthermore, a number of studies report increased HR together with indicators of decreased finger temperature (Ekman et al., 1983; Kreibig et al., 2007, Prkachin et al., 1999, Sinha, 1996). According to the scenes in the present study, a lower SKT and a faster HR in the CVR condition are correlated with negative emotional reactions, especially fearful emotion. Therefore, the physiological result also showed the stronger emotional effect of the CVR. We did not find the same significant difference in the monkey clip possibly because of the content of the film clip. The scenes and the characters are less frightening in the monkey clip than in the snake clip. The results also showed differences only in negative emotions and not in positive emotions, which is consistent with the film's story. The scenes showed a little boy attacked by a python and threatened by a monkey. Hence, the scenes were expected to elicit negative emotions.

Our study is the first to prove that the application of VR in filmmaking has a stronger effect on human emotional processing than traditional 2D films do. This result is consistent with the findings of Riva, who confirmed the efficacy of VR as an affective medium in eliciting specific emotions of anxiety and relaxation (Riva et al., 2007). Felnhofer's findings also showed that almost all five virtual park scenarios were able to elicit the intended emotion, such as joy, sadness, boredom, anger, and anxiety (Felnhofer et al., 2015). Furthermore, studies on 3D effect in filmmaking shed light on this issue because 3D is largely applied in CVR (Terlutter et al., 2013; Price et al., 2015). These results suggested that the emotional effect of 3D film on viewers is not always obvious. For VR, we should also take note of this issue because the effect of the new digital technique depends on the degree of agreement between media content and media types. In our study, the steady effect in both the self-report experience and physiological response suggests that the application of VR in filmmaking should have more specific features than other techniques. Thus, we further analyzed special features in CVR on the basis of an analysis of the self-report and physiological data. The causality of this effect will be discussed later.

5.2. Special features in CVR

The emotional effect shows special features in CVR and 2D conditions on the basis of an analysis of specific emotions. In the CVR condition, the mean scores of six emotions (excited, scared, hostile, nervous, jittery, afraid) have significant differences between the pre-test and the post-test. However, in the 2D condition, only two emotions (scared and afraid items) are significantly different when the mean scores of the pre-test and the post-test are compared. This result also supports the first hypothesis that the CVR clips elicit more emotional experience than traditional 2D film clips. This finding means that CVR and traditional 2D film evoked fearful emotions, which are closely correlated with the scenes of the film clips. Furthermore, some special emotions were observed in the CVR condition, including excitement, nervousness, hostility, and jitteriness. Excitement and nervousness are closely related with the VR environment. When people experience VR for the first time, they would be nervous about being isolated from the real world and also excited about the new technique. With regard to hostility and jitteriness, we think such emotions are correlated with the first-person viewpoint in the CVR, which made participants feel as though they themselves were attacked by the python and threatened by the monkey. This feeling is weak in the 2D condition. Thus, hostility and jitteriness showed significant differences in the CVR condition and not in the 2D condition. A previous survey found that three factors (fun, thrill, and being moved) are associated with emotional experiences while watching movies and TV serials (Bartsch and Viehoff, 2010). Although that study is different from ours, the findings of both studies suggest that a special emotional experience is closely correlated with the use of specific media.

The physiological reaction also showed several different features in the CVR condition compared with the 2D condition. An analysis of finger temperature during the film viewing showed that the temperature varied more quickly and steadily in the CVR

condition than in the 2D condition. This result also supports the second hypothesis that the physiological reaction elicited by CVR clips is different from the reaction elicited by traditional 2D film clips. The finger temperature decreased evidently only after the film has played for several seconds and continued to decrease steadily as the film played. The change in finger temperature did not show these features in the 2D condition and was slow and unsteady. This result is important for understanding the VR digital environment. CVR provides a full viewpoint, which is more similar to the real environment. In a CVR, the design of CVR scenes will significantly affect the audience's experience because it differs considerably from traditional films, in which narrative structure and technique play a key role in producing the audience's affect and resonance.

5.3. Causality of the effect

The issue that needs to be addressed now is why the same story had a different emotional effect in the VR environment. We summarized four factors of the VR technique that are crucial for producing a different emotional effect.

The most important factor is the presence in the VR environment. Immersion and presence are two crucial features of VR. The degree of immersion is viewed as an objective property of a system. It is related to many parameters, including the extent of field of view, the number of sensory systems that the system simulates, the rendering quality in each sensory modality, the extent of tracking, the realism of the displayed images, the frame rate, and the latency. These parameters could be measured independently of the human experience that it engenders. The concept of 'presence' refers to the phenomenon of behaving and feeling as if we are in the virtual world created by computer displays (Sanchez-Vives and Slater, 2005). It is usually defined as the "sense of being there" or the "feeling of being in a world that exits outside the self" (Riva, 2003; Riva et al., 2004). Presence is the human response to the system. CVR usually makes people feel as though they are part of the story and are physically present in the scene. Emotion is related to the degree of presence. Physiological responses are correlated with presence (Riva et al., 2007; Meehan et al., 2001). Given the higher degree of presence in CVR, the participants experienced stronger emotions and different physiological responses to the CVR clips compared with the traditional 2D film clips.

The second factor is the wide viewpoint in the VR environment. VR offers a 360° viewpoint, which is considerably different from traditional films. People can choose where to watch and what to see by themselves. The field of view is an objective parameter of immersion, along with other parameters such as the number of sensory systems and the realism of the displayed images (Sanchez-Vives and Slater, 2005). Although the parameters of immersion in Maria's paper were considered as objective factors and not directly correlated with subjective feelings, the 360° viewpoint in a CVR actually has a crucial influence on the audience's feeling. The 360° viewing point in the VR environment is similar to the real field of view in the real world, which is why the participants experienced more complicated emotions in the VR environment than in the 2D environment.

The third factor is the new VR technique. People are excited and nervous about this new interactive media. According to uses and gratifications theory in media effect, the media and their content are sources of influence, among other potential sources (Rubin, 2009). Thus, the participants experienced more emotions (e.g., excitement and nervousness) while watching the CVR. Such emotions were not found with traditional 2D films.

The last factor is the first-person viewpoint in CVR. CVR seems to include the viewer in the film, thereby strengthening the interactive effect. For example, in the traditional 2D film, the main character is the little boy. In the CVR version, the main character is the participant. The python was talking to and approaching the participant in the CVR. The first-person viewpoint made the participant feel more real and stronger emotions. For example, in the traditional 2D film, the main character is the little boy. In the CVR version, the main character is the participant. The first-person viewpoint—the core design of the CVR version—made the participants feel more real and stronger emotions. Both the python and the monkey are created to face, approach and talk to participants so that they are seen as a part of the movie. Of course, There are also possible other viewpoints such as the spectators' viewpoint. Other viewpoints are also created to induce the feeling of participants' presence in the scenes.

5.4. Concluding remarks and limitations

This study explored the different emotional effect of CVR through a comparison with traditional 2D film from two critical aspects: subjective experience and physiological reaction. This is the first study to prove that the application of VR in filmmaking has a stronger effect on human emotional processing during subjective experience and physiological reaction compared with traditional 2D films. Our results suggest that VR effectively induces moods. We found that four emotions are closely correlated with the CVR, namely, excitement, nervousness, hostility, and jitteriness. Real-time analysis of SKT showed a faster and steadier decline in the CVR group than in the 2D group, thereby suggesting that the design of the VR environment in CVR, which is as important as the narrative, has an important influence on the emotional experience of the audience. The characteristics of VR, especially the feeling of presence and the 360° viewpoint, have a crucial effect on emotions.

The film clips in our study were edited from the Disney animated movie *The Jungle Book* and were expected to produce negative emotions. Hence, our analysis and conclusion are based on this specific genre of film. Further studies need to be conducted using other genres. Second, a comparison between CVR and traditional 2D films is risky because of the great differences between such movies. The story and the scenes are the most important aspects that influence the audience's feelings. We exerted our best effort to match and control these two aspects. Further study is needed to verify the emotional effect of CVR in different stories or scenes. Given the application of VR in filmmaking or other fields, the influence of this new digital technique on the cognition and emotions of people needs more research attention. Will this new technique lead to great improvements in emotional experience in all conditions? What film genres are suitable for CVR? Many unanswered questions remain in this field.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tele.2018.04.003.

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