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Better than the real thing: Eliciting fear with moving and static computer-generated stimuli

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ABSTRACT

As the popularity of virtual reality as an exposure therapy increases, it is important to validate the use of computer-generated stimuli in comparison to standardized images of "real" phobic objects, such as those of the International Affective Picture System (IAPS). The present study examined physiological and subjective measures of negative affect when viewing static IAPS images, static computer-generated images and moving videos of computer-generated images of feared stimuli and other negative stimuli which were not specifically feared. For example, a picture of a spider would be a "feared" stimulus for a spider fearful participant, whereas a picture of a snake would be categorized as a "negative" stimulus for that participant. Eighteen participants scoring high (high fear (HF) cohort) on questionnaires assessing specific fears of spiders or snakes and 20 participants scoring low (low fear (LF) cohort) on the questionnaires viewed the stimuli. The computer-generated videos elicited greater physiological (skin conductance and startle eyeblink potentiation) and self-report arousal responses than the IAPS images and the computer-generated static images. Computer-generated stills and IAPS images did not differ in eliciting emotional responses. Additionally, HF participants showed greater heart rate acceleration and larger skin conductance responses to their feared stimulus than to the negative stimulus, especially when viewing computer-generated moving videos. The results demonstrate the importance of motion in eliciting fear and the usefulness of computer-generated stimuli in the study of emotion.

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Virtual Reality (VR) has recently become an increasingly popular form of exposure treatment for various clinical populations (Parsons and Rizzo, 2008). It is an especially useful treatment modality when real-world exposure would be too inconvenient, costly, or dangerous. Additionally, VR affords the capability to create a virtual environment specifically suited to the needs of multifarious projects or treatments of persons from various clinical groups. For instance, Rothbaum et al. (2001) found VR exposure to be an effective treatment for patients suffering from post-traumatic stress disorder (PTSD), in a study where Vietnam veterans were exposed to VR scenarios that included flying in a helicopter over a virtual Vietnam. In vivo exposure therapy of this sort would have been extremely costly and dangerous and, although exposure was experienced only in a virtual environment, all participants reported significantly fewer PTSD symptoms at 6 month follow-up. Other studies have reported positive outcomes for VR exposure in reducing phobic symptoms, including acrophobia (Emmelkamp et al., 2002), arachnophobia (Carlin et al., 1997; Garcia-Palacios et al., 2002; Renaud et al., 2002), fear of flying (Hodges et al., 1996), fear of public speaking (Anderson et al., 2005), and social phobia (Klinger et al., 2005). A recent meta-analysis of VR exposure therapy outcomes concluded that this form of treatment can be effective in reducing phobia and anxiety symptoms (Parsons and Rizzo, 2008).

1. Moving versus stationary images

VR may be advantageous in comparison to "real" static images at least in part because use of VR media allows visual images to move. Motion in the visual field has been shown to have strong effects on skin conductance, heart rate, and self-report measures of arousal, with weaker effects on valence (Detenber et al., 1998; Simons et al., 2003). Detenber et al. (1998) recorded skin conductance and heart rate while subjects viewed moving video clips taken from television and film, as well as still-framed pictures taken from these videos. Participants exhibited larger skin conductance and heart rate responses to moving rather than static images. Moreover, the moving images elicited greater late heart rate deceleration (i.e. toward the end of the 6 s

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stimulus presentation), indicative of greater sustained attention. These results were replicated by Simons et al. (1999).

Moving images may be more physiologically arousing because humans have an innate tendency to attend to moving over stationary objects. In support of this view, McKenzie and Day (1976) found that infants merely two months of age would fixate on moving objects longer than stationary ones. Moreover, research has shown that moving stimuli capture attention as strongly as abrupt onset visual stimuli that were not previously in the visual field (Franconeri and Simons, 2003; Thomas and Luck, 2000). This finding indicates that moving objects are of relatively high priority in demanding attentional processes. Franconeri and Simons (2003) postulated that motion may capture attention because it potentially represents “behaviorally urgent” stimuli. That is, humans may have an innate tendency to attend to moving stimuli because they signal an event that could require urgent action. Thus, moving images would have significantly greater effectiveness at tapping into the participant's fear structure, or the memory structure that guides fear behavior (Foa and Kozak, 1986).

2. Applications for emotional stimuli in the laboratory

The study of emotion elicitation in the laboratory has often relied on the use of emotion laden pictures, such as those from the International Affective Picture System (IAPS; Lang et al., 2005). The IAPS consists of a large number of photographs of real objects selected to evoke negative, positive, or neutral affect. This collection of images has been widely employed and has become a standard way of eliciting affect in psychological studies of emotion. Considerable stability of affective evaluations of the IAPS slides has been exhibited across laboratories in different countries (Hamm et al., 2003). Although the IAPS has been instrumental in the study of affect, VR, using computer-generated (CG) stimuli, may be more effective at eliciting emotional responses, particularly because of image movement. However, to our knowledge no studies have used CG videos in emotion elicitation, which provide the possibility of using three-dimensional presentations as is the case in fully immersive virtual environments. This study provides a direct comparison between responses elicited by moving CG video clips and the widely-used IAPS images.

In the current study, we assessed whether CG still images and moving videos of virtual spiders and snakes are threatening enough to elicit fear responses that are similar to or greater than those elicited by photographs of real spiders and snakes. IAPS slides were used as comparisons because they are well-validated and widely-used in the study of human affect. VR systems are typically equipped with head tracking capabilities to allow the participant to explore his or her environment. However, IAPS slides do not lend themselves well to this type of presentation. Thus, immersive virtual environments were not used in this study. Instead, CG stimuli that could be used in a virtual environment were projected onto a screen to achieve greater control of what the participant was viewing, and to prevent the CG stimuli from having an advantage in creating an arousing situation due to the novelty of the head tracking capabilities. We hypothesized that moving CG stimuli would be more effective than IAPS images or CG stills in eliciting fear responses.

3. The use of fearful participants for increased clinical relevance

The current study also aimed to understand how IAPS, CG still and moving video stimuli affect participants who are high in fear of a specific stimulus, and to assess which type of stimulus presentation works best for differentiating between feared stimuli and other negative stimuli that are not specifically feared. More specifically, this study used CG and IAPS stimuli depicting snakes and spiders. A group of participants scoring high (high fear (HF) cohort) on scales assessing fear of spiders or snakes, but not both, was compared to a control group (low fear (LF) cohort) made up of persons that scored in the low range on the scales. Öhman and Soares (1994) reported findings of increased skin conductance responding when fearful participants viewed static images of their specifically feared objects compared to other negative and neutral objects. Hamm et al. (1997) found that participants endorsing high levels of animal fears also exhibited an accelerative heart rate response to their feared stimuli compared to a decelerative response when viewing other negative stimuli. For example, a “negative” stimulus, in this context, referred to a picture of a snake for a spider-fearing participant, while a picture of a spider was referred to as a “feared” object for that participant. The inclusion of fearful participants allows for examination of which stimulus presentation type is most efficacious for targeting emotional responses to a specifically feared stimulus.

In measuring fear responses, it is important to consider both subjective and psychophysiological indices to obtain a more complete understanding of the fear response. Self-report data, when used in isolation, are highly susceptible to extraneous influences (Schwarz, 1999). The item's wording, context, and format are all factors that may affect self-report responses, as is gender or cultural restrictions on reporting of fear. Psychophysiological indices are less susceptible to demand characteristics and responder bias.

Additionally, the psychophysiological measures used in the current study provide the advantage of having three systems of response that can be used to target understandings of various emotional states. Emotional responses are typically thought to be composed of two primary dimensions: valence and arousal. In this study, we use skin conductance responses and subjective ratings as indices of arousal. Skin conductance responses are phasic changes in electrodermal activity, and are innervated solely by the sympathetic nervous system, providing a direct measure of sympathetic activity (Dawson et al., 2007). Electromyographic (EMG) recording of the startle eyeblink reflex is a widely-used psychophysiological index of valence, as participants' blink amplitudes are potentiated when subjects view more negative images (Vrana et al., 1988). Heart rate responses are useful in differentiating between an orienting response and a defensive response. Heart rate will accelerate during a defensive response, but will decelerate when orienting occurs (Graham and Clifton, 1966; Öhman and Mineka, 2001). Utilizing these three measures gives the current study insight into understanding how participants' responses relate to the “defense cascade” discussed by Lang et al. (1997). They suggest that as stimuli become sufficiently aversive, the participant becomes defensively primed, resulting in increase in skin conductance response amplitudes, increased eyeblink amplitudes, and heart rate acceleration. We hypothesized that the pattern of autonomic responses seen in the defense cascade would occur when HF participants viewed their feared objects.

4. Hypotheses

In summary, our primary objective was to examine the effectiveness of IAPS slides, CG stills, and CG moving videos in eliciting subjective and psychophysiological fear responses. We expected that CG videos would elicit the highest levels of arousal and unpleasantness. We further hypothesized that CG still images would be as effective as IAPS slides in eliciting fear responses. Additionally, we expected that HF participants would show significantly stronger responses to their feared stimulus (e.g., snake) than to a negative stimulus (e.g., spider), and would show greater differential responding to CG videos than to static images.

5. Methods

5.1. Participants

Thirty-eight participants (76.3% female, mean age = 20.6, range = 18 to 23) were selected based on a questionnaire screening

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of 407 college students. Participants were selected based on their scores on the Spider Questionnaire (SPQ) and Snake Questionnaire (SNAQ) developed and tested by Klorman et al. (1974).

Participants were selected for the HF group if their scores were above the 90th percentile on either the SPQ or the SNAQ and below the mean on the other. The HF group consisted of 18 participants (11 spider-fearing and 7 snake-fearing). The spider-fearing participants had a mean score of 23.89 on the SPQ and 8.11 on the SNAQ. Snake-fearing participants had a mean score of 20.75 on the SNAQ and 6.00 on the SPQ.

The LF group consisted of 20 participants and was selected to match the range of the HF group's scores regarding the negative objects that were not specifically feared. Thus, selected participants had to score in the 7 to 10 range on both questionnaires. The mean scores for the control group were 7.65 on the SPQ and 8.40 on the SNAQ.

5.2. Stimuli and design

Participants viewed snakes and spiders using three different media types, including pictures taken from the IAPS, CG videos, and CG still pictures. Each stimulus was projected onto a screen (84 cm high, 104 cm wide) for 5 s. Participants were seated approximately 150 cm from the screen.

Four IAPS pictures of both snakes and spiders were selected that were the highest in arousal that could be obtained consistent with equating the snake and spider pictures. IAPS pictures for the two animal types did not differ on valence, $F\,(1, 7) = 0.357$, $p = 0.551$, or arousal $F\,(1, 7) = 0.060$, $p = 0.807$, according to data reported by Lang et al. (2005). The IAPS snake images used in the current study were numbered 1051, 1070, 1090, and 1113. IAPS numbers 1200, 1201, 1205, and 1220 were used for the spider images.

Video clips with 3D graphic virtual reality content of four snakes and four spiders were first storyboarded and designed on paper, and then models were built in Maya before being converted to OpenGL models. Though the computer-generated stimuli utilized in this study were created for use in a VR setting, they were displayed as two-dimensional videos and still images on a screen for greater control of the stimulus presentation, as mentioned above. Spiders and snakes varied in shape, form, and size. Clips also differed in background environment. Four CG still-framed pictures of spiders and four CG still-framed pictures of snakes representative of the CG videos were taken from the CG videos. Examples of CG still-framed pictures and IAPS images used are shown in Fig. 1.

The experimental test session consisted of 48 trials divided into 8 blocks of 6 trials each. Block presentation order was counter-balanced across participants. Each block consisted of one snake and one spider from each of the three media types. Each stimulus was presented for 5 s, with 15 and 20 s intertrial intervals. Participants were instructed to view each stimulus for the entire time it appeared on the screen.

An acoustic startle-eliciting stimulus was presented during 3 of the 6 trials of each block. The same type of stimulus was never startled on consecutive blocks and no more than three consecutive trials included a startle probe or were absent of a startle probe. A total of 24 startle probes were presented in the experiment, 4 probes for each of the 6 types of stimuli. Optimal modulation of the startle reflex created by affective valence occurs after a lead interval of at least 3 s and continues beyond 5 s (see Bradley et al., 1999); thus startle probes were presented at 3 and 4.5 s lead intervals following stimulus onset in order to increase the participants' perception that startle probes were presented at random.

The startle-eliciting stimulus was a 110 dB white noise burst 50 ms in duration with a near instantaneous rise/fall time presented binaurally through Telephonics TDH-50P headphones. Decibel levels were measured with a Realistic sound level meter using a Quest Electronics earphone coupler.

5.3. Dependent variables

Electromyographic (EMG), electrocardiographic (ECG), and electrodermal activity (EDA) were recorded simultaneously throughout

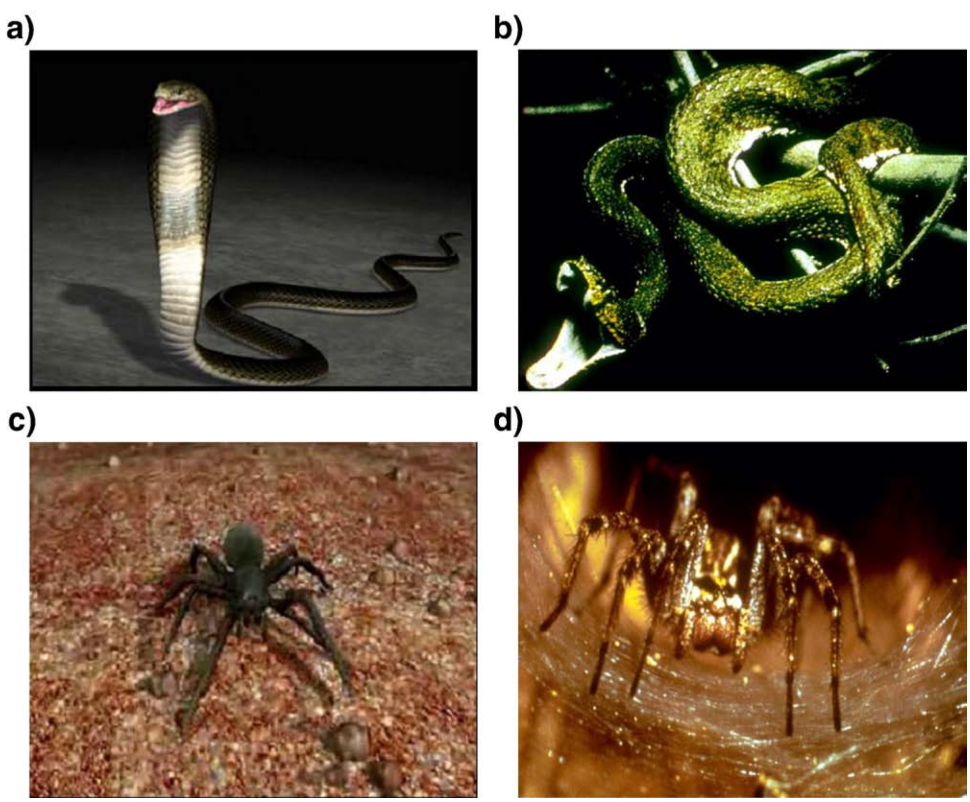

Fig. 1. Examples of computer-generated and IAPS images. a) Computer-generated snake. b) IAPS snake. c) Computer-generated spider. d) IAPS spider.

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the experiment using Contact Precision Instruments equipment and a computer running SAM1 software.

5.3.1. Skin conductance response

EDA was measured with the use of 8 mm silver-silver chloride electrodes placed on the volar surface of the distal phalanges of the index and middle fingers of the non-dominant hand. Electrodes were filled with a 0.05 molar isotonic NaCl paste to provide a continuous connection between the electrodes and the skin.

Skin conductance responses were scored as the largest amplitude response beginning in a window of 1 to 3 s following stimulus onset. A response was defined as having amplitude greater than 0.01 μS. Only those trials that did not include a startle probe were scored for skin conductance responding.

5.3.2. Cardiovascular responding

ECG was recorded with use of a Lead 1 electrode placement. Electrode sites were cleaned with alcohol prep pads in order to improve contact.

Inter-beat Intervals (IBIs) were scored as the time difference between successive R waves in the ECG signal. IBIs were used as the dependent variable analyzed instead of heart rate because of a lowered susceptibility to artifact due to differences in baseline values (Stern et al., 2001). A window of 3 s pre-stimulus onset to 5 s beginning at stimulus onset was scored. Instantaneous IBIs were recorded at half second intervals during the pre- and post-stimulus time windows. A difference score between the average pre-stimulus IBI for each trial and each post-stimulus IBI value was computed for each trial. Only those trials which did not include a startle probe were scored for IBI responding.

5.3.3. Startle eyeblink response

EMG startle eyeblink responses were recorded using two miniature silver-silver chloride electrodes (4 mm in diameter) placed over the orbicularis oculi muscle of the left eye. One electrode was placed directly below the pupil in forward gaze while the other was placed about 1 cm lateral to the first. Both electrodes were placed as close to the eye as possible while still allowing the participant to close his or her eyes comfortably. Impedance between the two electrodes was measured and deemed acceptable if below 10 kΩ. A large silver–silver chloride electrode (8 mm in diameter) was placed behind the left ear to serve as a ground. The raw EMG signal was recorded at a rate of 1000 Hz throughout the experimental session using a 10 Hz high pass and 200 Hz low pass filter. Raw signals were stored and exported for analysis in microvolt (μV) values. Startle responses were rectified and integrated for analysis using a 20 ms time constant. In order to be scored, the onset of the blink response had to occur within a window of 20 to 100 ms following the startle probe. The blink response had to reach peak activity within a window of 20 to 150 ms following the startle probe. Amplitudes were recorded as the difference between the peak activity value and the baseline level that was present immediately preceding onset of the blink response. Participants who failed to reach 1 μV amplitudes on more than 50% of probed trials were considered non-responders and were excluded from further EMG analyses. Two participants from the LF group reached this criterion, leaving 18 LF participants to be included in EMG analyses. If the participant was blinking during the onset of the startle probe, the blink response for that trial was removed from scoring due to artifact. These blinks were replaced with the average of that participant's blinks to the other three probed trials of that stimulus type (i.e. the same animal and modality). Outliers were defined as being three standard deviations above the mean for each participant as well as being two standard deviations above the next largest response from that participant. Only one response from one participant was determined to be an outlier in the current study and was replaced using the same methods used to replace blinks removed due to artifact.

Due to the high levels of variability between participants in EMG responses, all blink amplitude values were standardized using a z-transformation (i.e. the difference between each participant's rectified EMG amplitude value on each trial and that participant's mean value across all trials was divided by the standard deviation of all values). Scores were then subjected to a linear T-transformation resulting in a mean of 50 and a standard deviation of 10 for each participant. This helped to ensure that all participants contributed to group means equally.

5.3.4. Affective ratings

Following the 8 blocks of the experimental test session, all stimuli were presented again, and participants were asked to rate the pictures and videos on scales of both valence and arousal. A 9 point Likert scale was used for assessing both valence and arousal, following a similar rating system used by Lang et al. (2005) for the IAPS.

5.4. Statistical analyses

Each dependent variable was analyzed using a repeated measures analysis of variance (ANOVA) with a three-level media within-participants factor and a group (HF vs. LF) between-participants factor. This ANOVA was performed to determine whether the media manipulation had an effect on participants in general, and if it affected the groups differently.

A second ANOVA was performed for each dependent variable on the HF group only to examine differences in responding to feared stimuli compared to negative stimuli. Responses among the HF group were examined using a 3 (media) by 2 (feared stimulus vs. negative stimulus) within-participants design. Though spider-fearing and snake-fearing participants were expected to have differing responses to spiders and snakes, it was expected that their responses to their specifically feared stimuli would not differ in a meaningful way, nor would their responses to negative stimuli. Combining the spider-fearing and snake-fearing participants into one high fear group was helpful in creating a larger sample size with which to determine differences in response created by varying levels of fear relevance and different media types.

All significant media main effects and interactions were followed with paired samples t-tests in order to identify the precise nature of these effects. All reported significant t-test results are Rom corrected to prevent inflation of type 1 error rates (Rom, 1990). Additionally, a Greenhouse–Geisser correction was used for all reported main effects and interactions with greater than one degree of freedom.

6. Results

6.1. Skin conductance responses

In the media by group ANOVA performed on all participants, there was a significant media main effect, F (2, 35) = 16.88, p<0.001. As shown in Fig. 2a, SCRs elicited during CG video presentations were significantly greater than those elicited during IAPS presentations, t (37) = 4.05, p<0.001, d = 0.66, as well as those during CG still presentations, t (37) = 3.165, p<0.01, d = 0.56. SCRs elicited during IAPS and CG still presentations did not differ significantly (p = 0.55). There was no group main effect or media by group interaction.

In the analysis of the HF group, a significant media main effect, F (2, 18) = 8.46, p<0.01, was found again. Larger responses were elicited by CG videos than IAPS images, t (17) = 3.28, p<0.01, d = 0.77, or CG still images, t (17) = 3.15, p<0.01, d = 0.74. Additionally, a significant stimulus main effect was evidenced, in which participants responded with greater intensity to feared stimuli, F (1, 17) = 5.08, p<0.05, d = 0.53. There was also a stimulus by media interaction, F (2, 16) = 3.817, p<0.05. This interaction was the result of greater

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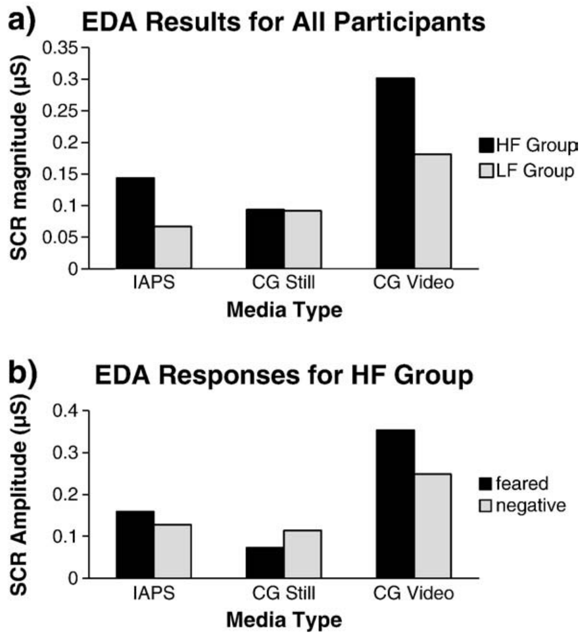

Fig. 2. a) Skin conductance responses for high and low fear participants. b) Skin conductance responses for high fear participants. All responses are reported in μS.

responding to feared stimuli only when viewing the CG videos, t $(17) = 2.67$, $p < 0.05$, $d = 0.63$, as can be seen in Fig. 2b. There was no significant differential responding to feared and negative stimuli in the other two media types.

6.2. Heart rate responses

Analysis of heart rate is more complex than the other two psychophysiological metrics employed in this study because skin conductance responses and startle responses are unidirectional, whereas heart rate can accelerate due to defensive responses or decelerate due to orienting. In general, participants in both groups responded with an overall deceleration to stimuli in each media type. One-tailed t-tests confirmed that these decelerations were significant (t-values ranged from 2.30 to 7.31). However, the responses of the HF group differentiated between feared and negative stimuli, such that decelerations were not significant when participants viewed feared stimuli, due to accelerative components, which is clearly apparent in their response to the CG Videos (Fig. 3a). In order to better understand the nature of the differences in responding in the HF and LF groups and in the HF group to the feared and the negative stimuli of the different media types, analyses were conducted examining the differences in responding over the last second of stimulus presentation. This time window was thought to reflect the most complete development of the heart rate response across all conditions. There was no significant media or group main effect nor was there a media by group interaction in the ANOVA involving all participants.

In the HF group, a significant stimulus main effect was found, F $(1, 17) = 6.68$, $p < 0.05$, $d = 0.61$, which was the result of heart rate acceleration in response to the feared stimuli and deceleration in response to negative stimuli. Additionally, a stimulus fear level by media interaction was uncovered in the HF group, $F\ (2, 16) = 4.65$, $p < 0.05$. As is evident in Fig. 3b, this was a result of significant differential responding between feared and negative stimuli only in response to the CG videos, $t\ (17) = 4.93$, $p < 0.001$, $d = 1.16$.

6.3. Startle responses

In the media by group ANOVA involving all participants, an overall media main effect was found, $F\ (2, 36) = 33.94$, $p < 0.001$. This effect was the result of larger eyeblink responses during CG video stimuli. As can be seen in Fig. 4a, responses during CG video presentations were significantly larger than those during IAPS presentations, $t\ (35) = 5.95$, $p < 0.001$, $d = 0.99$, and likewise were greater than responses during CG still presentations, $t\ (35) = 7.31$, $p < 0.001$, $d = 1.22$. Responses made during IAPS and CG still presentations did not differ significantly ($p = 0.73$). No group main effect or media by group interaction was found.

In the media by stimulus ANOVA performed on the HF group, a significant media main effect was found, $F\ (2, 16) = 10.21$, $p < 0.001$. As shown in Fig. 4b, participants responded with greater eyeblink amplitudes when viewing the CG video stimuli than the IAPS, $t\ (17) = 3.56$, $p < 0.01$, $d = 0.84$, or the CG stills, $t\ (17) = 3.90$, $p < 0.01$, $d = 0.92$, as was the pattern described in the ANOVA involving all participants. There was only a trend of responding with greater intensity to feared stimuli than to negative stimuli, $F\ (1, 17) = 3.97$, $p = 0.063$, $d = 0.47$. No media by stimulus interaction was found.

6.4. Arousal ratings

All means and standard deviations for subjective ratings of low and high fear participants are reported in Tables 1 and 2, respectively. Subjective arousal ratings revealed a significant main effect of media in the total sample, $F\ (2, 38) = 14.18$, $p < 0.001$. IAPS slides were rated as less arousing overall than CG videos, $t\ (37) = 5.98$, $p < 0.001$, $d = 0.97$, or CG stills, $t\ (37) = 3.44$, $p < 0.01$, $d = 0.56$. Ratings of CG videos and CS stills did not differ significantly ($p = 0.33$). There was no group main effect nor was there an interaction between media and group.

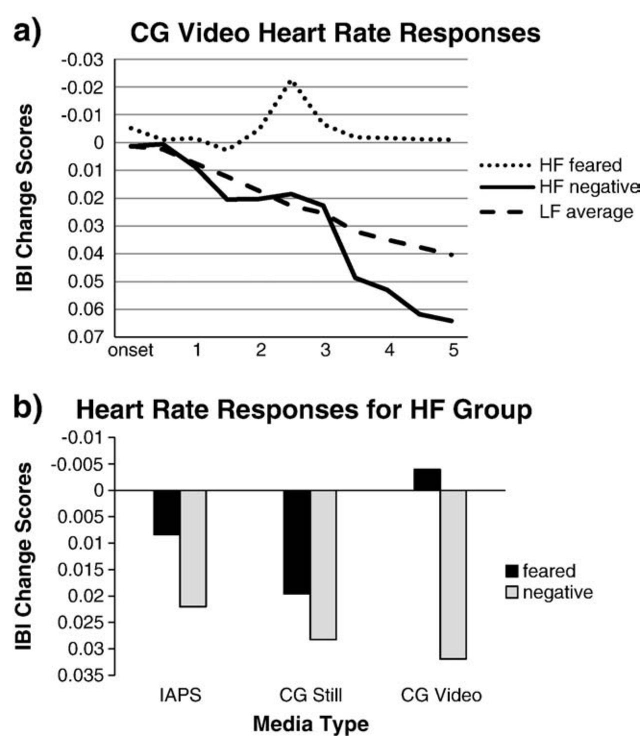

Fig. 3. a) Heart rate responses (in IBIs) among high fear participants when viewing to CG videos. Responses of the low fear group to CG videos are also included for comparison. Values along the y-axis have been reversed for display purposes, so a deceleration appears as a downward deflection. b) Heart rate responses (in IBIs) in all participants beginning at stimulus onset and continuing until stimulus offset. Again, values along the y-axis have been reversed for display purposes, so a deceleration appears as a downward deflection. When viewing negative stimuli, high fear participants had similar responses to the low fear group.

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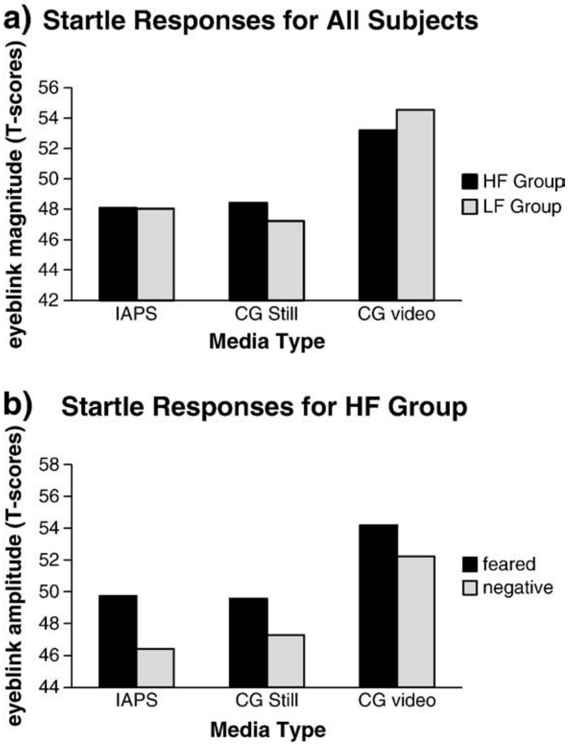

Fig. 4. a) EMG eyeblink response amplitudes for high and low fear subjects. b) EMG eyeblink response amplitudes for high fear subjects. All amplitudes are reported as t-scores.

A media main effect was also found for HF group, $F\ (2, 16) = 3.91$, $p < 0.05$. Participants rated CG stills, $t\ (17) = 3.44$, $p < 0.01$, $d = 0.56$, and CG videos, $t\ (17) = 5.98$, $p < 0.001$, $d = 0.97$, as more arousing than IAPS slides. A stimulus main effect was revealed, in which participants rated feared stimuli as more arousing than negative stimuli, $F\ (1, 18) = 8.65$, $p < 0.01$, $d = 0.69$. There was no stimulus by media interaction.

6.5. Valence ratings results

There was no media or group main effect, nor was there a media by group interaction for valence ratings when the entire sample was analyzed.

In the HF group, there was a significant main effect of stimulus fear level, in that participants rated feared stimuli as being more unpleasant than negative stimuli, $F\ (1, 18) = 24.73$, $p < 0.001$, $d = 1.17$. There was no media by stimulus fear level interaction.

7. Discussion

7.1. Effects of media type

Consistent with our hypotheses, CG video moving stimuli, compared to CG and IAPS still images, elicited larger skin conductance responses and greater negative affect as indicated by potentiation of the startle eyeblink reflex. Moreover, only for the CG video stimuli did high fear subjects exhibit a heart rate accelerative response. As hypothesized, startle eyeblink responses, skin conductance and heart rate responses did not differ when participants viewed IAPS and CG still images, supporting the conclusion that motion was the key factor in eliciting increased responding. These findings also lend credence to the notion that VR type stimuli can be as effective as still images of real stimuli, such as the pictures of the IAPS, when instigating fear responses. Although the moving CG stimuli used in the present study were not presented in an immersive virtual environment, they were still able to elicit stronger emotional responses than IAPS or CG stills.

Table 1
Subjective ratings for low fear participants.

Media	Valence ratings		Arousal ratings	
	Mean	Std dev	Mean	Std dev
IAPS images	2.93	1.22	3.01	1.47
CG stills	3.18	1.74	4.35	1.76
CG videos	3.09	1.72	4.26	1.55

Note. Smaller valence values are indicative of more negative valence, while larger arousal values indicate greater levels of arousal.

Table 2
Subjective ratings for high fear participants.

	Valence ratings		Arousal ratings	
	Mean	Std dev	Mean	Std dev
Negative				
IAPS images	3.93	1.81	3.00	1.40
CG stills	3.81	1.52	3.25	1.64
CG videos	3.85	1.64	3.79	1.57
Feared				
IAPS images	2.14	0.99	4.53	2.33
CG stills	2.15	1.02	4.97	2.32
CG videos	1.78	0.76	5.53	2.54

Note. Smaller valence values are indicative of more negative valence, while larger arousal values indicate greater levels of arousal.

Although the psychophysiological measures were consistent with our hypotheses, the subjective ratings were not entirely consistent. Despite the fact that CG videos elicited greater physiological response than CG stills, the two did not differ in arousal ratings, though both were rated more arousing than IAPS slides. The lack of differential ratings of the CG stills and CG videos could be due to the fact that the CG stills were taken directly from the CG videos. Participants may have been primed to feel an increased sense of arousal because the CG stills were components of the CG videos. In future research, the use of CG stills with features independent of the CG videos may elucidate this effect. It is also possible that the differences in physiological responses evoked by the moving images may arise from activation of a variety of brain structures, creating responses of which the participants are not necessarily consciously aware. Research using fMRI has suggested that viewing moving emotional stimuli, when compared to static emotional stimuli, create an enhanced activation pattern in specific brain structures, such as the amygdala, parahippocampal gyrus, and the orbitofrontal cortex, thought to be involved in emotional processing and memory encoding (Trautmann et al., 2009). Such activation may affect psychophysiological response to moving stimuli in ways of which the participant is not fully consciously aware, as reflected in the ratings.

Ratings of valence were not affected by the media manipulation in this study. Detenber et al. (1998) and Simons et al. (1999; 2003) also found that moving pictures strongly increased arousal, but had little impact on valence, compared to still pictures of the same image. Results of other studies support this finding (e.g. Dillon et al., 2002).

Though seemingly contradictory to subjective valence ratings, startle eyeblink responses, which are thought to be a sensitive psychophysiological measure of valence (Vrana et al., 1988), were affected by the media manipulation in this study. Thus, the startle potentiation measure appears to provide a more sensitive measure of varying degrees of valence than the self-report measure.

7.2. Effects of the feared stimulus

Support was found for the hypothesis that participants would have stronger emotional responses when viewing feared stimuli than

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negative stimuli. Participants rated feared stimuli as more arousing and more unpleasant. Participants also evidenced heart rate acceleration in response to feared videos and a decelerative orienting response to the negative stimuli (Fig. 3a). They had larger skin conductance response amplitudes when viewing feared items and showed a trend toward increased eyeblink amplitudes in response to feared stimuli. Previous studies have shown that feared stimuli produce more pronounced psychophysiological responses than negative or non-feared stimuli (e.g. Cook et al., 1988; Geer, 1966; Globisch et al., 1999; Hamm et al., 1997; Öhman and Soares, 1994). This effect is especially pronounced in participants with simple phobias in comparison to participants with other fear related disorders such as social phobia and agoraphobia (Cook et al., 1988; Cuthbert et al., 2003). This is thought to be due to increased avoidance motivation in simple phobics, which leads to heart rate acceleration. Heart rate responses provide a useful measure for differentiating between orienting and defensive responses. While a skin conductance response can be the result of either an orienting response or a defensive response, heart rate will accelerate only during a defensive response and will decelerate when orienting occurs (Graham and Clifton, 1966; Öhman and Mineka, 2001).

7.3. Interactions between stimulus and media

Support for our hypothesis that the CG videos, compared to IAPS and CG stills, would be more effective in differentiating between feared stimuli and negative stimuli was found in electrodermal and heart rate responding. Significant differential skin conductance responding was only present when participants viewed CG videos. Heart rate accelerated most when participants viewed feared CG videos. This acceleration was significantly different from the heart rate deceleration exhibited when the participants viewed the negative CG videos. Neither of the still image media types was successful in creating a significant difference in responding to feared and negative stimuli with electrodermal, eyeblink, and heart rate responses. Though these results are not consistent with some previous studies (e.g., Öhman and Soares, 1994), they may have been the result of a contrast effect, in that the CG videos were so effectively fear-inducing as to render the other media types less differentially effective. Grice and Hunter (1964) reported similar results noting that participants who were given a strong and a weak unconditioned stimulus failed to develop a conditioned response to the conditioned stimulus that was paired with the weak unconditioned stimulus, whereas participants who received only the weak unconditioned stimulus did show conditioning with that stimulus. Thus, the contrast between the strong and the weak unconditioned stimuli in the within-subjects design rendered the weak unconditioned stimulus ineffective.

The results of this study also support the notion that moving stimuli, even when computer-generated, are more effective in eliciting emotional responses to feared stimuli in high fear individuals than static images. VR systems have an added advantage over emotion elicitation using IAPS slides due to movement of the stimuli presented, which is why the current study sought to compare fear responses elicited by static versus moving images. Detenber et al. (1998) showed that participants exhibited stronger skin conductance and heart rate responses to moving than to static images extracted from films and television programs. To our knowledge no studies have used CG videos in emotion elicitation that provide the possibility of using three-dimensional presentations as is the case in fully immersive virtual environments.

7.4. Strengths, limitations, and future directions

To our knowledge, this is the first study to examine fear responses to CG videos, stills, and IAPS images. The current investigation benefited from a number of methodological strengths. We measured both psychophysiological and subjective ratings of valence and arousal, both necessary for a more complete understanding of affect, especially given the shortcomings of self-report data. Additionally, the within-participants design allows for the control of individual differences in physiological response.

Nonetheless, a number of limitations of the current project should be considered. A direct comparison of the CG videos and standardized film clips of real objects has not been made. Gross and Levenson (1995) developed and validated video scenes for eliciting discrete emotions for use in emotion elicitation studies (e.g., Fredrickson and Levenson, 1998). It would be interesting for future studies to incorporate standardized movie scenes to directly compare moving CG stimuli and moving films. However, it should be noted that CG stimuli are more easily manipulated to match a participant's specific fear than a movie scene.

An additional limitation of the current study resulted from the difficulties associated with recruiting participants who are highly fearful of a given stimulus that will be used in the study in which they are asked to participate. This study required that HF subjects be fearful of either snakes or spiders, but not both. Of the 407 students who were screened for fear of snakes and spiders, only 11 snake-fearing participants and 18 spider-fearing participants were even eligible for the study based on the strict criteria employed for inclusion in the HF group. These strict criteria resulted in a relatively small sample size for snake (7 participants) and spider (11 participants) fearing participants. We attempted to counteract this limitation by combining the snake and spider-fearing participants into one HF group in order to better generalize across individuals who may be highly fearful of a given stimulus. Future research may benefit from a larger pool of participants from which to recruit, or reducing the strictness of the inclusion criteria in order to increase sample sizes.

In addition, an increased understanding of the effects of an immersive virtual environment would further validate the use of VR as an exposure therapy. While it is promising to know that CG stimuli that are VR compatible can be effective in emotion elicitation, it would of interest to know whether emotional responses are further potentiated when viewed in an immersive environment compared to being viewed on a screen. Virtual environments can be rendered in a three-dimensional landscape and the use of a head mounted display with tracking capabilities allows the participant to freely explore his or her environment. Greater levels of interactivity afforded by a virtual environment add to an increased feeling of presence or “being there” (Witmer and Singer, 1998) and lead to more pronounced physiological responses to virtual stimuli (Calvert and Tan, 1994; Macedonio et al., 2007; Parsons et al., 2009).

7.5. Conclusion

One of the main goals of the present research was to assess the effectiveness of the types of stimuli used in VR in eliciting fear responses. Results suggest that computer-generated stimuli can be as or more effective in producing fear responses than pictures of “real” stimuli, even when viewed on a two-dimensional screen. Moving CG stimuli were indeed more effective in differentiating between psychophysiological responding to feared versus negative stimuli among high fear participants. Findings of the current study suggest that VR manner stimuli can provide an important new tool for the laboratory study of human emotions.

References

Anderson, P.L., Zimand, E., Hodges, L.F., Rothbaum, B.O., 2005. Cognitive behavioral therapy for public-speaking anxiety using virtual reality for exposure. Depression and Anxiety 22, 156–158.

Bradley, M.M., Cuthbert, B.N., Lang, P.J., 1999. Affect and the startle reflex. In: Dawson, M.E., Schell, A.M., Bohmelt, A.H. (Eds.), Startle Modification: Implications for

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Neuroscience, Cognitive Science, and Clinical Science. Cambridge University Press, New York, NY, pp. 157–183.
Calvert, S.L., Tan, S.L., 1994. Impact of virtual reality on young adults' physiological arousal and aggressive thoughts: interaction versus observation. Journal of Applied Developmental Psychology 15, 125–139.
Carlin, A.S., Hoffman, H.G., Weghorst, S., 1997. Virtual reality and tactile augmentation in the treatment of spider phobia: a case report. Behaviour Research and Therapy 35, 153–158.
Cook, E.W., Melamed, B.G., Cuthbert, B.N., McNeil, D.W., Lang, P.J., 1988. Emotional imagery and the differential diagnosis of anxiety. Journal of Consulting and Clinical Psychology 56, 734–740.
Cuthbert, B.N., Lang, P.J., Strauss, C., Drobes, D., Patrick, C.J., Bradley, M.M., 2003. The psychophysiology of anxiety disorder: fear memory imagery. Psychophysiology 40, 407–422.
Dawson, M.E., Schell, A.M., Filion, D.L., 2007. The electrodermal system. In: Cacioppo, J.T., Tassinary, L.G., Berston, G. (Eds.), Handbook of Psychophysiology. Cambridge University Press, New York, NY, pp. 159–181.
Detenber, B.H., Simons, R.F., Bennett, G.G., 1998. Roll 'em! The effects of picture motion on emotional responses. Journal of Broadcasting and Electronic Media 42, 113–127.
Dillon, C., Keogh, E., Freeman, J., 2002. "It's been emotional": affect, physiology, and presence. Proceedings of the Fifth Annual International Workshop on Presence. Porto, Portugal.
Emmelkamp, P.M.G., Krijn, M., Hulbosch, A.M., de Vries, S., Schuemie, M.J., van der Mast, C.A.P.G., 2002. Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia. Behaviour Research and Therapy 40, 509–516.
Foa, E.B., Kozak, M.J., 1986. Emotional processing of fear: Exposure to corrective information. Psychological Bulletin 99, 20–35.
Franconeri, S.L., Simons, D.J., 2003. Moving and looming stimuli capture attention. Perception and Psychophysics 7, 999–1010.
Fredrickson, B.L., Levenson, R.W., 1998. Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. Cognition and Emotion 12, 191–220.
Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness, T.A., Botella, C., 2002. Virtual reality in the treatment of spider phobia: a controlled study. Behaviour Research and Therapy 40, 983–993.
Geer, J.H., 1966. Fear and autonomic arousal. Journal of Abnormal Psychology 71, 253–255.
Globisch, J., Hamm, A.O., Esteves, F., Öhman, A., 1999. Fear appears fast: temporal course of startle reflex potentiation in animal fearful subjects. Psychophysiology 36, 66–75.
Graham, F.K., Clifton, R.K., 1966. Heart-rate change as a component of the orienting response. Pyschological Bulletin 65, 305–320.
Grice, G.R., Hunter, J.J., 1964. Stimulus intensity effects depend upon the type of experimental design. Psychological Review 71, 247–256.
Gross, J.J., Levenson, R.W., 1995. Emotion elicitation using films. Cognition & Emotion 9, 87–108.
Hamm, A.O., Cuthbert, B.N., Globisch, J., Vaitl, D., 1997. Fear and startle reflex: blink modulation and autonomic response patterns in animal and mutilation fearful subjects. Psychophysiology 34, 97–107.
Hamm, A.O., Schupp, H.T., Weike, A.I., 2003. Motivational organization of emotions: autonomic changes, cortical responses, and reflex modulation. In: Davidson, R.J., Scherer, K.R., Goldsmith, H.H. (Eds.), Handbook of Affective Science. Oxford University Press, New York, NY, pp. 596–618.
Hodges, L.F., Watson, B.A., Kessler, G.D., Rothbaum, B.O., Opdyke, D., 1996. Virtually conquering fear of flying. Computer Graphics and Applications 16, 42–49.
Klinger, E., Bouchard, S., Legeron, P., Roy, S., Lauer, F., Chemin, I., Nughes, P., 2005. Virtual reality therapy versus cognitive behavior therapy for social phobia: a preliminary controlled study. CyberPsychology & Behavior 8, 76–88.
Klorman, R., Weerts, T.C., Hastings, J.E., Melamed, B.G., Lange, P.J., 1974. Psychometric descriptions of som specific-fear questionnaires. Behavior Therapy 5, 401–409.
Lang, P.J., Bradley, M.M., Cuthbert, B.N., 1997. Motivated attention: affect, activation, and action. In: Lang, P.J., Simons, R.F., Balaban, M. (Eds.), Attention and Orienting. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 97–135.
Lang, P.J., Bradley, M.M., Cuthbert, B.N., 2005. International Affective Picture System (IAPS): Instruction Manual and Affective Ratings: Technical report A-6, The Center for Research in Psychophysiology, University of Florida.
Macedonio, M.F., Parsons, T.D., Diguiseppe, R.A., Wiederhold, B.A., Rizzo, A.A., 2007. Immersiveness and physiological arousal within panoramic video-based virtual reality. CyberPsychology and Behavior 10, 508–515.
McKenzie, B.E., Day, R.H., 1976. Infants' attention to stationary and moving objects at different distances. Australian Journal of Psychology 28, 45–51.
Öhman, A., Mineka, S., 2001. Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. Psychological Review 108, 483–522.
Öhman, A., Soares, J.J.F., 1994. "Unconscious anxiety": phobic responses to masked stimuli. Journal of Abnormal Psychology 103, 231–240.
Parsons, T.D., Rizzo, A.A., 2008. Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: a meta-analysis. Journal of Behavior Therapy and Experimental Psychiatry 39, 250–261.
Parsons, T.D., Iyer, A., Cosand, L., Courtney, C., Rizzo, A.A., 2009. Neurocognitive and psychophysiological analysis of human performance within virtual reality environments. Studies in Health Technology and Informatics 142, 247–252.
Renaud, P., Bouchard, S., Proulx, R., 2002. Behavioral avoidance dynamics in the presence of a virtual spider. IEEE Transactions on Information Technology in Biomedicine 6, 235–243.
Rom, D.M., 1990. A sequentially rejective test procedure based on a modified Bonferroni inequality. Biometrika 77, 663–665.
Rothbaum, B.O., Hodges, L.F., Ready, D., Graap, K., Alarcon, R.D., 2001. Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder. Journal of Clinical Psychiatry 62, 617–622.
Schwarz, N., 1999. Self-reports: how the questions shape the answers. American Psychologist 54, 93–105.
Simons, R.F., Detenber, B.H., Roedema, T.M., Reiss, J.E., 1999. Emotion processing in three systems: the medium and the message. Psychophysiology 36, 619–627.
Simons, R.F., Detenber, B.H., Cuthbert, B.N., Schwartz, D.D., Reiss, J.E., 2003. Attention to television: alpha power and its relationship to image motion and emotional content. Media Psychology 5, 283–301.
Thomas, S.J., and Luck, S.J., 2000. Multiple pathways to the autonomic capture of attention. Unpublished manuscript.
Trautmann, S.A., Fehr, T., Herrmann, M., 2009. Emotions in motion: dynamic compared to static facial expressions of disgust and happiness reveal more widespread emotion-specific activations. Brain Research 1284, 100–115.
Vrana, S.R., Spence, E.L., Lang, P.J., 1988. The startle probe response: a new measure of emotion? Journal of Abnormal Psychology 97, 487–491.
Witmer, B.G., Singer, M.J., 1998. Measuring presence in virtual environments: a presence questionnaire. Presence 7, 225–240.

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