Affective Computer-Generated Stimulus Exposure: Psychophysiological Support for Increased Elicitation of Negative Emotions in High and Low Fear Subjects

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Abstract. The present study examined physiological measures of affect when viewing images from the International Affective Picture System (IAPS), computer-generated still images, and computer-generated videos of feared and non-feared stimuli. Twenty low fear (LF) and twelve high fear (HF) individuals viewed static and moving images of spiders and snakes. In both LF and HF subjects, computer-generated video images elicited more intense affective responses than the IAPS images and the computer-generated stills. Computer-generated still images were as effective in eliciting fear responses as the IAPS. These results suggest that computer-generated images can be as or more effective as the IAPS in eliciting fear. Regardless of modality, HF subjects showed stronger physiological responses to their specifically feared stimulus (snake or spider) than to a non-feared stimulus.

Keywords: Psychophysiology, Fear, EMG, skin conductance, VR, startle.

1 Introduction

Fear is essential to the survival of organisms. From an evolutionary perspective, fear was developed in order to facilitate an organism's response to threat. It motivates escape from, and avoidance of, dangerous stimuli in the natural world. Accordingly, much empirical attention has been focused on deconstructing the mechanisms through which humans process and react to fear-producing stimuli.

1.1 Elicitation of Fear in the Laboratory

The study of fear responses in the laboratory has often used emotion laden pictures, such as the International Affective Picture System (IAPS, [1]). The IAPS consists of pictures meant to evoke negative, positive, or neutral affect. This collection of pictures has become the standard in psychological studies of emotion. The IAPS offers many advantages, including extensive normative data and evidence of stability across laboratories in different countries [2].

D.D. Schmorrow et al. (Eds.): Augmented Cognition, HCII 2009, LNAI 5638, pp. 459–468, 2009.

Although the IAPS has been instrumental in the study of affect, preliminary evidence suggests that virtual reality (VR) stimuli may be more effective at eliciting emotional responses. VR technology allows subjects to be immersed in a three-dimensional (3D) virtual environment (VE) in which they are free to look around and explore. This may create a greater sense of presence, or feeling of "being there" [3].

Indeed, VEs may elicit arousal responses comparable to those evoked by in vivo exposure to real world stimuli. For example, Emmelkamp et al. [4] compared the responses of acrophobics randomly assigned to exposure treatment with VR and real stimuli. Subjects in the two conditions evidenced similar subjective ratings of anxiety. This suggests that VR technology can be used to create realistic environments that are as effective in eliciting fear responses as real-world stimuli. Indeed, a recent meta-analysis of VR exposure therapy outcomes concluded that it is effective in reducing phobia and anxiety symptoms [5].

However, the development of VR systems is still quite costly. Before investing the resources necessary for the development of VR stimuli, it is important to assess whether computer-generated (CG) images and videos are as effective in eliciting fear responses as images of real stimuli. Jang et al. [6] measured psychophysiological responses including skin resistance and heart rate variability to assess arousal levels in normal subjects exposed to fear of driving and fear of flying VEs. Subjects showed lowered levels of skin resistance compared to baseline, indicating higher levels of arousal. This suggests that VEs can be physiologically arousing, but direct comparisons of VR stimuli to standard pictures in a controlled within-subjects paradigm is still lacking.

In the current study, we assessed whether VR still images and 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. A within-subjects design was used to control for individual variability in responding. We hypothesize that CG stimuli will be as or more effective than IAPS images in eliciting fear responses.

VR systems are typically equipped with head tracking capabilities to allow the subject to explore his/her environment. However, IAPS slides do not lend themselves well to this type of presentation. Thus, immersive VEs were not used in this study. Instead, CG stimuli that could be used in a VE were projected onto a screen in front of the subjects to achieve greater control of what the subject was viewing, and to prevent the VR stimuli from having an advantage in creating an arousing situation due to the novelty of the head tracking capabilities. In addition to investigating the differences between CG and real stimuli, the current study sought to compare fear responses elicited by static versus moving images. The breadth of literature that has examined differences in psychophysiological responses to moving and static emotional stimuli is quite limited; however, Detenber, Simons, and Bennett [7] showed that participants exhibited stronger skin conductance and heart rate responses to moving, rather than static, images.

Moving images may be more physiologically arousing because humans may have an innate tendency to attend to moving over stationary objects. Franconeri and Simons [8] postulated that humans may have an innate tendency to attend to moving stimuli because they signal an event that could require urgent action. Thus, we hypothesize that CG videos will be more effective in eliciting fear responses than either the CG stills or IAPS images.

The current study also aimed to understand how these stimuli affect subjects who are high in fear of a specific stimulus, and to assess which stimulus modalities work best for differentiating a specifically feared stimulus and a generally fear-relevant stimulus. Responses of a high-fear (HF) group consisting of subjects who scored high on scales of fear of spiders or snakes, but not both, was compared to responses of a low-fear (LF) control group. Previous research has shown that specific phobics tend to be most responsive to their specifically feared stimuli [9]. The inclusion of the HF group allows assessment of which stimulus modality is best for targeting emotional responses to a specifically feared stimulus. This information may have immediate clinical relevance, as there is growing interest in VR exposure as a treatment for phobias.

1.2 Physiological Components of Fear

In measuring fear responses, it is important to consider physiological indices in order to gain a more complete understanding of the response. Self-report data are highly susceptible to influences outside the subject's own targeted attitudes [10]. Emotional responses are commonly thought of as varying across two dimensions: valence and arousal. In this study, we use skin conductance responses as an index of arousal, whereas startle eyeblink responses were used as an index of valence.

Skin conductance responses provide an atypical and useful index of autonomic functioning in that they are mediated exclusively by the sympathetic nervous system. While skin conductance provides a reliable measure of arousal, or motivational intensity [11], it is not an optimal method for differentiating between appetitive and avoidance motivation. Therefore, we also employed electromyographic (EMG) recordings of the startle eyeblink reflex, a widely used psychophysiological index of valence. Vrana et al. [12] found that startle responses are facilitated when presented in conjunction with a negative stimulus, and inhibited when presented with a positive stimulus relative to presentations with neutral stimuli, an effect found to be highly reliable [13].

1.3 Hypotheses

Our primary objective was to examine the effectiveness of IAPS slides, CG stills, and CG videos in eliciting fear responses in HF and LF subjects. We expected that, across groups, CG videos would elicit the highest levels of arousal, as indexed by skin conductance responses. Moreover, CG videos were hypothesized to produce the strongest potentiation of startle eyeblink. We further hypothesized that CG still images would be as effective as IAPS slides in eliciting skin conductance responses and eyeblink potentiation. A second set of goals of the current project consisted of investigation of the physiological responses to feared versus non-feared stimuli among HF subjects. We expected that HF subjects would show stronger responses to their feared stimulus (e.g., snake) than to a non-feared stimulus (e.g., spider).

2 Methods

2.1 Participants

Thirty-two participants (22 females, mean age = 20.59) were selected based on a questionnaire screening of 407 college students. Participants were selected based on their scores on the Spider Questionnaire (SPQ) and Snake Questionnaire (SNAQ; see [14]). Participants were selected for the HF group if their scores were above the 90^{th} percentile on either the SPQ or the SNAQ and below the mean on the other questionniare. The HF group consisted of 12 participants (8 spider fearing and 4 snake fearing). The LF group was selected to match the range of the HF group's scores regarding the non-feared object.

2.2 Stimuli and Design

Participants viewed snakes and spiders using three different media types, including pictures taken from the International Affective Picture System [1], computer-generated (CG) videos, and CG still pictures. Each stimulus was projected onto a screen (33 inches high, 41 inches wide) for five seconds with a 15 to 20 second inter-trial interval.

Four IAPS pictures of both snakes and spiders were selected. Valence and arousal ratings were similar across animal types [1].

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. Spiders and snakes varied in shape, form, and size. Clips also differed in background environment.

Four CG still-framed pictures of both spiders and snakes were taken from the CG videos. Still images were selected in an attempt to match the way each animal was presented in the IAPS pictures, and were considered representative of the video from which each was derived .

The experimental test session consisted of eight blocks of six trials each. A five-minute break followed the first four blocks. During this break, subjects filled out a demographics questionnaire. Block presentation order was counterbalanced across subjects. Each block consisted of one snake and one spider from each of the three media types. The six types of stimuli (snake IAPS, snake CG still, snake CG video, spider IAPS, spider CG still, and spider CG video) were counterbalanced to appear in each ordinal position within the blocks the same average number of times, and each stimulus type was presented before and after each other stimulus type the same average number of times. Each stimulus was presented exactly once during the first four blocks and once during the second four blocks. The deleted information was provided above.

An acoustic startle-eliciting stimulus was presented during three of the six trials of each block. The startling stimulus was not presented during the same type of stimulus on consecutive blocks and no more than three consecutive trials included a startling stimulus. A total of 24 startling stimuli were presented in the experiment. 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.

2.3 Dependent Variables

Electromyographic (EMG) and skin conductance responses (SCRs) were recorded simultaneously throughout the experiment using Contact Precision Instruments equipment and a computer running SAM1 software.

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. 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. 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. Subjects who failed to reach 1 μV amplitudes on more than 50% of startling trials were considered non-responders and were dropped from further EMG analyses. Two subjects from the LF group reached this criterion. If the subject was blinking during the onset of the startle stimulus, the blink was removed from scoring due to artifact. These blinks were replaced with the average of that subject's blinks to the other three startled trials of that stimulus type (i.e., the same animal and modality). Outliers were defined as being 3 standard deviations above the mean for each subject as well as being 2 standard deviations above the next largest response from that subject. Only one response from one subject 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 subjects in EMG responses, and because of a relatively small sample size in the HF group, all blink amplitude values were standardized using a within subject z-transformation. This helped to ensure that all subjects contributed to group means equally.

Skin conductance response. SCR 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 a peak amplitude greater than 0.01 μS.

3 Results

For each dependent variable a mixed analysis of variance (ANOVA) was run with a 3 (media) by 2 (animal type) within subjects design and a group (HF vs. LF) between subjects factor. Another set of ANOVAs was run for both the HF group and the LF control group separately. In the ANOVA for the HF group, spiders and snakes were categorized as being either a "feared" stimulus, meaning those stimuli that the subject was specifically afraid of (i.e. snakes for snake-fearing subjects), or a "non-feared" stimulus, that is a stimulus that the subject was not specifically afraid of, but which may be biologically prepared to be fear inducing (i.e. spiders for snake-fearing subjects). A 3 (media) by 2 (stimulus fear level) repeated measures ANOVA was run to examine the effects of these variables on the HF group. A separate 3 (media) by 2 (animal type) repeated measures ANOVA was run for the LF group in order to check for possible differences in responding to the different animal types (snakes versus spiders) and media. All significant media main effects were followed up with paired samples t-tests in order to identify the precise nature of these effects. A Bonferroni correction for multiple comparisons procedure was used to prevent inflation of type 1 error rates [15]. All significant t-test results reported here are Bonferroni corrected.

3.1 EMG Results

In the ANOVA involving all subjects, an overall media main effect was found, F (2, 30) = 27.85, $p < 0.001$. This effect was the result of larger eyeblink responses during CG video stimuli. Responses to CG video presentations were significantly larger than response to IAPS , t (29) = 5.578, $p < 0.01$, and CG stills, t (29) = 7.946, $p < 0.01$. Responses to IAPS and CG stills did not differ significantly ($p = 0.23$).

The analysis of the LF group alone revealed the same main effect of media, F (2, 18) = 23.648, $p < 0.001$. Responses during CG video presentations were larger than those recorded during IAPS presentations, t (17) = 4.838, $p < 0.01$, or CG still presentations, t (17) = 6.892, $p < 0.01$. Startle eyeblink respnses elicited during IAPS and CG still presentations did not differ significantly (p = 0.29). An unexpected animal type main effect was also found, F (1, 18) = 5.492, $p < 0.05$. Larger responses occurred when viewing snakes than when viewing spiders (snake viewing mean standard score = 0.0987; spider viewing mean = -0.1124).

The analysis of the HF group alone revealed that HF subjects also showed a main effect of media, F (2, 12) = 8.385, $p < 0.01$ (see Figure 1). Once again, CG videos elicited larger responses than IAPS, t (11) = 2.863, $p < 0.05$, or CG stills, t (11) = 4.137, $p < 0.05$. Responses during the IAPS and CG still stimuli did not differ significantly (p = 0.51). A main effect of stimulus fear relevance was also found in HF subjects, F (1, 12) = 6.019, $p < 0.05$. Subjects had larger eyeblink responses during presentations of their specific feared stimuli (M = 0.1553) than during their non-feared stimuli (M= -0.1835), and this effect was consistent across the three media.

3.2 SCR Results

In the ANOVA of all subjects, there was a significant overall media main effect, F (2, 30) = 27.851, $p < 0.001$. SCRs elicited during CG video presentations were significantly

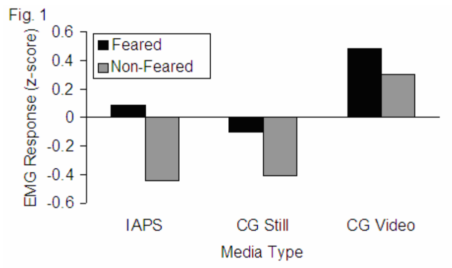

Fig. 1. High fear group's mean startle eye-blink responses to feared and non-feared stimuli across media type

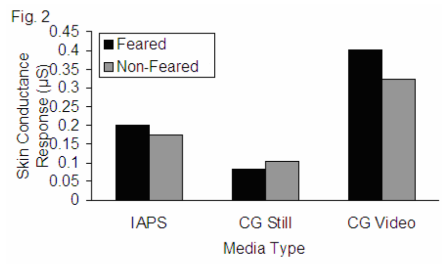

Fig. 2. High fear group's mean skin conductance responses to feared and non-feared stimuli across media type

greater than those elicited during IAPS presentations, t (31) = 3.511, $p < 0.01$, and those elicited during CG still presentations, t (31) = 3.165, $p < 0.01$. SCRs elicited during IAPS and CG still presentations did not differ significantly ($p = 0.328$).

The LF group showed a main effect of media, F (2, 20) = 5.095, $p < 0.05$. However, the pattern of responding was slightly different than that obtained when all subjects were combined. SCRs elicited during CG video presentations were again larger than those recorded during IAPS presentations, though not significantly so after Bonferroni correction, t (19) = 2.374, $p < 0.1$. SCRs elicited during CG still presentations were also greater than those elicited during IAPS presentations, t (19) = 2.641, $p < 0.05$. Videos also had a tendency to elicit greater SCRs than CG stills, though not significantly so ($p = 0.074$). Similar to the EMG results, an unexpected main effect for animal type was also found in SCRs, though this was only a trend, F (1, 20) = 3.406, $p = 0.081$. Subjects again tended to have larger responses when viewing snake stimuli ($M = 0.1378$) than spider stimuli ($M = 0.0885$).

In the HF group, only a trend toward a media main effect was found, F (2, 12) = 3.27, $p = 0.081$ (see Figure 2). Subjects tended to have larger SCRs when viewing videos ($M = 0.3623$) than IAPS ($M = 0.1876$) or CG stills ($M = 0.0936$), although these differences in responding were not significant after Bonferroni correction. A paired t-test also revealed a trend of increased responses in feared versus non-feared during the CG videos, t (11) = 1.809, $p = 0.098$.

4 Discussion

4.1 Effects of Media Type on Fear Responses

Previous studies of fear responses have typically relied on static pictorial stimuli such as the IAPS. In the current study, we sought to examine the effectiveness of moving images in eliciting physiological measures of affect. Consistent with our hypotheses, CG video moving stimuli were more arousing than the CG and IAPS still images, as measured by the skin conductance responses. When compared to still images, video stimuli also exhibited more negative valence, as indicated by greater startle eyeblink responses. These findings suggest that, compared to still images of real objects, VR-style stimuli can be more effective in instigating arousal in both low fear and high fear subjects.

Across LF and HF groups, subjects displayed increased SCRs to CG video stimuli compared to CG still and IAPS pictures. The motion component of video stimuli may elicit greater arousal by creating a stronger sense of presence, or "being there," in participants. Although presence is typically discussed in relation to virtual environments, it has also been used in the context of other media forms, such as television and film [16]. In the current study, we found a strong effect of media on physiological arousal.

Startle eyeblink responses, which are thought to be a sensitive psychophysiological measure of valence [12], were affected by the media manipulation in the same way as the SCRs, which are primarily sensitive to arousal [17]. One explanation for these seemingly contradictory findings is that startle eyeblinks are potentiated when viewing negatively valenced images, but these effects are augmented by arousal [11]. It follows that if all stimuli are negatively valenced, as in the current study, it will be arousal that contributes to differential responding to different stimuli.

Psychophysiological responses to IAPS and CG still images were also consistent with our hypotheses. Startle eyeblink responses and SCRs did not differ when subjects viewed IAPS and CG still images, suggesting that motion was the key factor in eliciting increased responding. These findings also indicate that VR style stimuli can be as or more effective than still images of real stimuli, such as the pictures of the IAPS, in instigating fear responses.

4.2 Effects of Animal Type on Fear Responses in LF Subjects

While the media main effect followed the expected pattern in LF subjects, an unexpected main effect of animal type was also present. Snakes elicited larger SCRs than spiders. Snakes also elicited larger eyeblink amplitudes overall, though this was mainly due to highly differential responses elicited during the CG videos, which in turn led to a media by animal type interaction. These results were unexpected because part of the selection criteria for LF subjects included having very similar scores on the SNAQ and SPQ assessments of snake and spider fear, respectively. Differences in unexplored features of the videos may account for this discrepancy. For example, two of the snake videos involved significant camera movement in addition to movement of the snake, whereas the background was relatively stationary in the spider videos. The present findings call for further investigation of the effects of different feature aspects of video presentations of affective stimuli.

4.3 Effects of Stimulus Fear Level in HF Subjects

Results for the HF group confirm hypotheses that startle eyeblink responses were more pronounced for feared than for non-feared stimuli. HF subjects responded with increased startle eyeblink responses when viewing their feared stimuli, as compared to non-feared stimuli. Surprisingly, skin conductance was not as sensitive to different levels of stimulus fear in HF subjects. HF subjects only displayed a trend toward larger SCRs in responses to the feared stimuli in the CG videos. This pattern of skin conductance responding may be a result of the possible confound of snakes eliciting higher arousal responses in general in this study, and the presence of more spider fearful than snake fearful subjects in the HF group meant that snakes were usually the non-feared stimulus. The LF group also had increased SCRs to snakes compared to spiders. While these findings will need to be replicated, the trend toward differential responding between stimulus fear levels in CG videos does suggest that the CG videos are more effective in fear instigating for specifically feared objects.

4.4 Conclusion

To our knowledge, this is the first study to examine fear responses to CG videos, stills, and IAPS images. One of the main goals of the present research was to provide validity for the effectiveness of VR stimuli in eliciting fear responses in HF subjects. Results suggest that VR stimuli can be as effective, or more effective, than pictures of “real” stimuli, even when viewed on a two-dimensional screen. These findings suggest that VR may be useful in the clinical assessment and treatment of phobias. Future research examining fear responses to CG images and videos in an immersive VE may further validate the effectiveness of VR stimuli in the study of human defensive systems.

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