The Psychophysiology of Video Gaming: Phasic Emotional Responses to Game Events

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ABSTRACT

The authors examined phasic psychophysiological responses indexing emotional valence and arousal to different game events during the video game Monkey Bowling 2. Event-related changes in skin conductance, cardiac interbeat intervals, and facial EMG activity over corrugator supercilii, zygomaticus major, and orbicularis oculi were recorded. Game events elicited reliable valence- and arousal-related phasic physiological responses. Not only putatively positive game events, but also putatively negative events that involved active participation by the player elicited positive emotional responses in terms of facial EMG activity. In contrast, passive reception of negative feedback elicited low-arousal negative affect. Information on emotion-related phasic physiological responses to game events or event patterns can be used to guide choices in game design in several ways.

Keywords

video games, emotions, psychophysiology, facial electromyography

The popularity of digital (computer and video) games has reached phenomenal proportions. In 2003, over 239 million video and computer games were sold in the United States alone [6], and their worldwide markets are expected to grow strongly also in the future. In addition to entertainment, digital games are more and more used for therapeutic, educational, and work-related purposes [e.g., 9, 24]. Surprisingly enough, there is little evidence to suggest that the developers of digital games have used psychological research, for example, to make games better

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and more appealing [30]. Nevertheless, there is no doubt that being able to measure people's emotional responses, or game enjoyment, during game play with high temporal resolution would be very important from the perspective of game designers, media psychologists, and those who are concerned on the potential adverse effects of games.

Emotions and Games

Most important theories of media enjoyment concentrate on affective responses to mass media [31], and emotional responses have also been highlighted in the literature on computer game enjoyment [e.g., 10]. Entertainment experiences are multidimensional and highly dynamic during computer game play, with games potentially eliciting a multitude of different emotions (e.g., joy, pride, anger, fear, suspense, relief) and cognitions (e.g., "I am a superhero") varying across time (13). By definition, emotions are biologically based action dispositions that have an important role in the determination of behavior [14], and there is no reason why this would not hold in the case of game playing. Most theorists endorse the view that emotions comprise three components: subjective experience (e.g., feeling joyous), expressive behavior (e.g., smiling), and the physiological component (e.g., sympathetic arousal); others add motivational state or action tendency and/or cognitive processing [see 25].

Theorists differ over a discrete versus a dimensional emotion model. Some theorists emphasize basic discrete emotions, such as anger, fear, sadness, happiness, disgust, and surprise [e.g., 5]. According to them, these emotions are unique experiential states that stem from distinct causes, are present from birth, and have distinct adaptive value. In contrast, a dimensional theory of emotion holds that emotions are fundamentally similar in most respects, and all emotions can be located in a two-dimensional space, as coordinates of valence and arousal (or bodily activation) [e.g., 14]. The valence dimension refers to the hedonic quality or pleasantness of an affective experience, and ranges from unpleasant to pleasant. The arousal dimension indicates the level of activation associated with the emotional experience, and ranges from very excited or energized at one extreme to very calm or sleepy at the other.

Emotions and Physiology

Several studies have shown that tasks requiring cognitive effort or active coping elicit emotional arousal and sympathetic nervous system (SNS) activation as indicated by an increase in heart rate (HR; i.e., a decrease in cardiac interbeat intervals, IBIs) [18]. For example, studies on psychophysiological reactivity to stress have shown that different video games (i.e, an active coping task) prompt notable increases in HR and blood pressure [e.g., 12, 17, 16]. It has also been found that violent video game play elicits greater arousal as indexed by HR and systolic blood pressure compared to a nonviolent game [3, 7], although this effect has not been present in all studies [e.g., 11, 28]. When interpreting HR responses, it should be recognized, however, that the heart is dually innervated by both the SNS and parasympathetic nervous system (PNS) [18]. Therefore, HR carries information on both sympathetic and parasympathetic activity, which may entail interpretative difficulties. Increased cardiac sympathetic activity is related to emotional arousal and causes the heart to speed up, whereas increased cardiac parasympathetic activity is related to information intake and attentional engagement and causes the heart to slow down [26]. Given that video game play may elicit both emotional arousal and attentional engagement, HR may not be an optimal measure of arousal in this connection.

Electrodermal activity (EDA; or skin conductance) has also frequently been used as a measure of arousal. The advantage of EDA is that it is interpretatively unambiguous, given that it is innervated entirely by the SNS [4]. When emotional arousal increases, the accompanying activation of the SNS results in increased sweat gland activity and skin conductance. The validity of EDA as a measure of emotional arousal has been established in studies showing that EDA varies linearly with self-reported arousal when viewing emotional pictures, for example [e.g., 15]. Bersak et al. have also recently developed a therapeutic game called Relax-to-Win where the player's level of arousal as indexed by EDA controls the speed of a racing dragon, an increase in arousal resulting in a decrease in the dragon's pace (the player who relaxes more quickly wins the race) [1].

Facial electromyography (EMG) provides a direct measure of the electrical activity associated with the facial muscle contractions related to emotional expression [18]. The facial EMG is an established index of hedonic valence; that is, increased activity over corrugator supercilii, which draws the brow down and together into a frown, is associated with negative emotions, whereas increased activity over zygomaticus major, which pulls the corners of the mouth back and up into a smile, is associated with positive emotions during affective imagery and when viewing pictures (for 6 s) or other media stimuli [e.g., 15, 19, 29]. In addition, increased activity at the orbicularis oculi (periocular) muscle area has been associated with both positive and high-arousal emotions during affective imagery and media viewing [18, 21]. Unfortunately, prior game studies have not used psychophysiological measures of emotional valence, such as facial EMG.

The Present Study

In video games, there is a dynamic flow of events and action, with games potentially eliciting a large number of different emotions varying across time. A serious limitation of prior game studies is that they have used tonic, rather than phasic, psychophysiological measures. Tonic measures (e.g., the mean physiological value during the game minus pre-game baseline) do not enable the examination of the varying emotions elicited by different instantaneous game events. Given that psychophysiological measurements can be performed continuously with high temporal resolution, it is possible to quantify phasic responses to instantaneous game events (e.g., by comparing the local pre-event baseline to physiological activity immediately following event onset). Therefore, in the present study, we examined phasic emotional valence- and arousal-related psychophysiological responses (facial EMG, skin conductance, and cardiac IBI) to game events in the video game Monkey Bowling 2. If reliable emotion-related physiological responses can be identified, they may turn out to be very useful criterion variables in game design. This is because emotions would be expected to play an important role in gaming behavior, as suggested above.

METHODS

Participants

Participants were 36 (25 male and 11 female) Finnish undergraduates with varying majors (1 participant was about to apply to the University), who ranged from 20 to 30 years of age. All participants played video or computer games at least once a month. They participated in return for three movie tickets.

Video Game

In the present study, we used a video game called Monkey Bowling 2 (Sega Corporation, Tokyo, Japan). The game was played with the Nintendo GameCube (Nintendo Co., Ltd., Kyoto, Japan) and presented on a screen using the Panasonic PT-LC75E Multimedia Projector (Matsushita Electric Industrial Co., Ltd., Osaka, Japan). The image size was 114 cm (width) × 85 cm (height), and the distance between the player's eyes and the screen was about 200 cm.

This game takes place in a surrealistic world with bright colors, a bowling lane situated in outer space, and a cute little monkey inside a transparent (bowling) ball. The game view is mainly from behind the monkey. Before each throw, a number of selections have to be made: (a) throwing position, (b) direction, (c) strength, and (d) spin. As a result of a poor throw, the monkey may fall off the edge of the lane to the depth of outer space. There is little the player can do after the throw when the monkey is rolling on the lane.

The practice session and the easier one of the actual play sessions were played using the Normal mode and Strike rule. The game was almost like normal bowling. On each turn, the player faced ten pins, had one throw to try knocking the pins, and was awarded one point for each fallen pin. The more difficult one of the actual play sessions was played with Challenge mode. The player faced different formations of three pins. The player had to start from formation 7 and was allowed to proceed to formations 8, 9, etc. only when he or she had cleared the previous formation. Here also the player was awarded one point for each fallen pin. Monkey Bowling 2 is a nonviolent game with happy background music and atmosphere, and requires motor coordination and evaluation ability.

Procedure

When arriving to the laboratory, the participant returned a number of questionnaires that had been sent to him or her beforehand. After a brief description of the experiment, the participant filled out an informed consent form. Electrodes were then attached and the participant was seated in a comfortable armchair, followed by a rest period of 7 min. The participants played four different video games in a random order. There were three 5-min game sessions for each of the four games; that is, a practice session and two actual play session (i.e., easy and difficult). In the present study, we used only data from Monkey Bowling 2 played with the Normal mode. The participant was told that the three best male and female gamers would be awarded one movie ticket as a bonus. The room was dimly illuminated during the rest period and when playing the games. After playing all games, the electrodes were removed, the participant was debriefed, and thanked for his or her participation.

Physiological Data Collection

Electrocardiogram (ECG) was recorded using the Psylab Model BIO2 isolated AC amplifier (Contact Precision Instruments, London, UK), together with three EKG leads in a modified Lead 2 placement. IBIs (ms) were measured with the Psylab Interval Timer.

Facial EMG activity was recorded from the left corrugator supercilii, zygomaticus major, and orbicularis oculi muscle regions as recommended by Fridlund and Cacioppo [8], using surface Ag/AgCl electrodes with a contact area of 4 mm diameter (Med Assoc. Inc., St. Albans, VT). Electrodes were filled with TD-240 electrode gel (Med Assoc. Inc). The raw EMG signal was amplified, and frequencies below 30 Hz and above 400 Hz were filtered out, using the Psylab Model EEG8 amplifier. The raw signal was rectified and integrated using the Psylab INT8 contour following integrator (time constant = 50 ms).

Skin conductance level (SCL) was recorded with the Psylab Model SC5 24 bit digital skin conductance amplifier that applied a constant 0.5 V across Ag/AgCl electrodes with a contact area of 8 mm diameter (Med Assoc. Inc.). Electrodes were filled with TD-246 skin conductance electrode paste (Med Assoc. Inc.) and attached to the middle phalanges of the ring and little fingers of the subject's nondominant hand after hands were washed with soap and water (the ring and little fingers were applied to reduce the interference between gaming and EDA recording).

The digital data collection was controlled by Psylab7 software, and all physiological signals were sampled at a rate of 500 Hz.

Video Recording of the Game

During the game, the output signal (video and audio) from the GameCube was stored as digital video (25 frames per second) with the V1d Random Access Video Recorder/Player (Doremi Labs, Inc., Burbank, CA). Psylab7 software was used to trigger the V1d Disk Recorder to start recording the game screen at the same time when the physiological data collection started. After taking the (constant 280-ms) delay in the initiation of recording into account, the recorded video image of the game screen was in time synchrony with the physiological data with a one-frame (40 ms) accuracy.

Event Scoring

The exact onset times of predefined game events were determined by examining the played games, frame by frame, using V-ToolsPro 2.20 software. The event codes and onset times of the game events were saved as CSV files that were then converted with special software (V1 Clip Converter for Psylab) and imported into Psylab7 software. We scored the following game events: (a) the monkey (inside the ball) falls off the edge of the lane to the depth of outer space (Event 1), (b) the ball knocks down at least one pin (Event 2), (c) the player misses the pins completely

(Event 3), and (d) negative feedback after a poor throw (Event 4). None of the events was systematically followed by another event within a 6-s period following event onset.

Data Reduction and Analysis

Mean values for the psychophysiological measures were derived for one 1-s epoch before each event (second 1) and for six 1-s epochs after event onset (seconds 2 to 7). Logarithmic transformations were conducted for SCL and EMG data to normalize the distributions. The data were analyzed by the Linear Mixed Models procedure in SPSS with restricted maximum likelihood estimation and a first-order autoregressive covariance structure for the residuals. Participant ID was specified as the subject variable, and the sequence number of an event and second (seconds 1 to 7) were specified as the repeated variables. This sequence number and second were selected as factors, and a fixed-effects model that included the main effects of these variables was specified. Event-related changes in physiological activity were tested using the following orthogonal contrasts: (a) linear trend across seconds 1 through 7 (Contrast 1) and (b) quadratic trend across seconds 1 through 7 (Contrast 2). These contrasts were used because, during the time period examined, a game event may elicit the following types of changes in physiological activity: (a) a progressive increase (or decrease) after event onset or (b) an increase (or decrease) after event onset followed by a decrease (or increase; a return to baseline).

RESULTS

Event 1 (Falling off the Edge of the Lane)

Contrast 2 indicated that Event 1 prompted an increase in both zygomatic and orbicularis oculi EMG activity that peaked 2 s after event onset, *t*s(*df*s = 79.57 and 104.11) = 3.81 and 7.16, *p*s < .001, respectively (see Figure 1, left panel and middle panel, respectively). In addition, Contrast 2 showed that Event 1 elicited a decrease in corrugator EMG activity that peaked 2 s after event onset, *t*(*df* = 100.93) = 4.64, *p* < .001 (Figure 1, right panel).

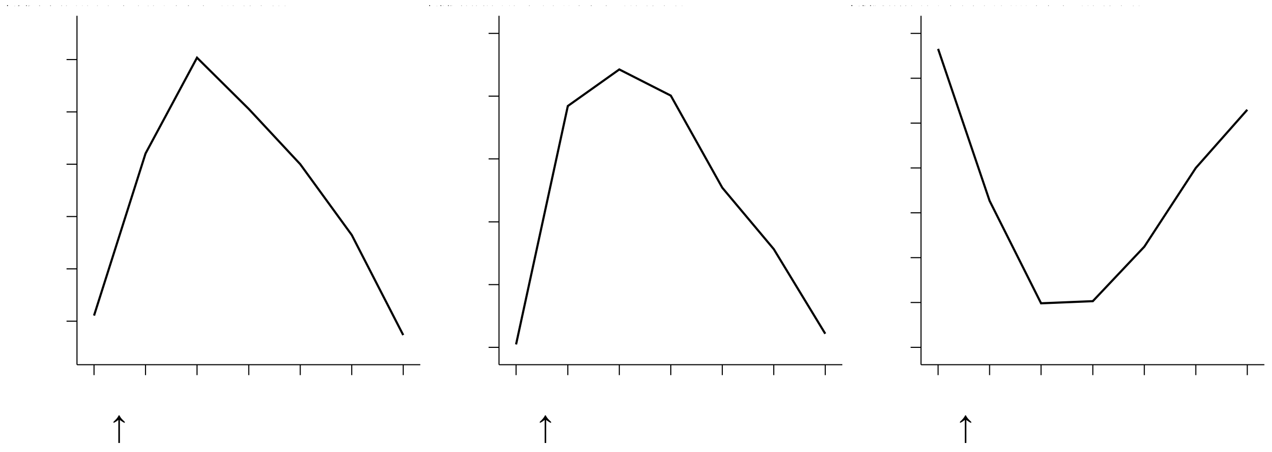

Figure 1: Zygomaticus major (left panel), orbicularis oculi (middle panel), and corrugator supercilii (right panel) electromyographic (EMG) responses elicited by falling off the edge of the lane (Event 1). ↑= event onset time.

Contrast 1 was significant when predicting cardiac IBI, thereby suggesting that IBI decreased (i.e., HR increased) linearly in response to Event 1, $t(df = 251.83) = 3.07$, $p = .002$; however, visual inspection of Figure 2 (left panel) suggested that there was, in fact, an initial increase in IBI followed by a decrease. Contrast 2 also indicated that Event 1 prompted an increase in SCL peaking 3 s after event onset, $t(df = 32.69) = 7.59$, $p < .001$.

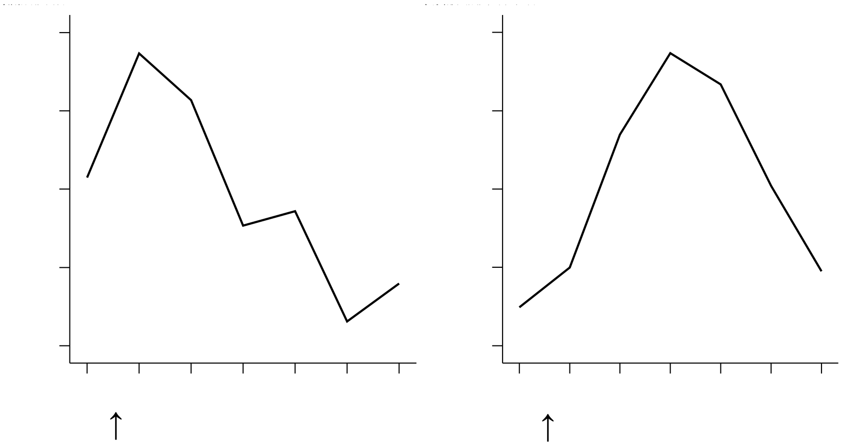

Figure 2: Cardiac interbeat intervals (IBIs; left panel) and skin conductance level (SCL; right panel) responses elicited by falling off the edge of the lane (Event 1). ↑= event onset time.

Event 2 (Knocking down at Least One Pin)

Contrast 2 showed that Event 2 elicited an increase in both zygomaticus major and orbicularis oculi EMG activity that peaked 2 s after event onset, $ts(dfs = 149.76 \text{ and } 150.21) = 3.00$ and 5.37, $ps = .003$ and $< .001$ (see Figure 3, left and right panel), respectively. No significant effects were found for corrugator supercilii activity.

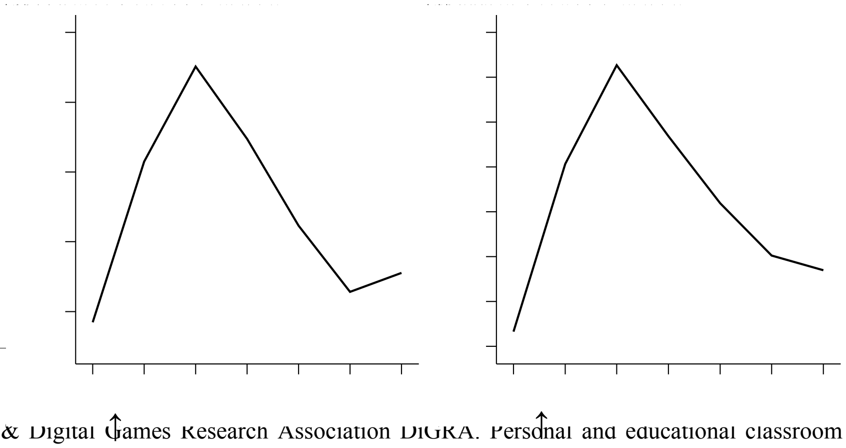

Figure 3: Zygomaticus major (left panel) and orbicularis oculi (right panel) electromyographic (EMG) responses elicited by knocking down at least one pin (Event 2). ↑= event onset time.

Event 2 also elicited a decrease in cardiac IBI (i.e., an increase in HR) that peaked 3 s after event onset as was shown by Contrast 2 (Figure 4, left panel), $t(df = 171.76) = 5.44$, $p < .001$. In addition, Contrast 1 indicated that Event 2 prompted a linear decrease in SCL after event onset (Figure 4, right panel), $t(df = 36.88) = 7.40$, $p < .001$.

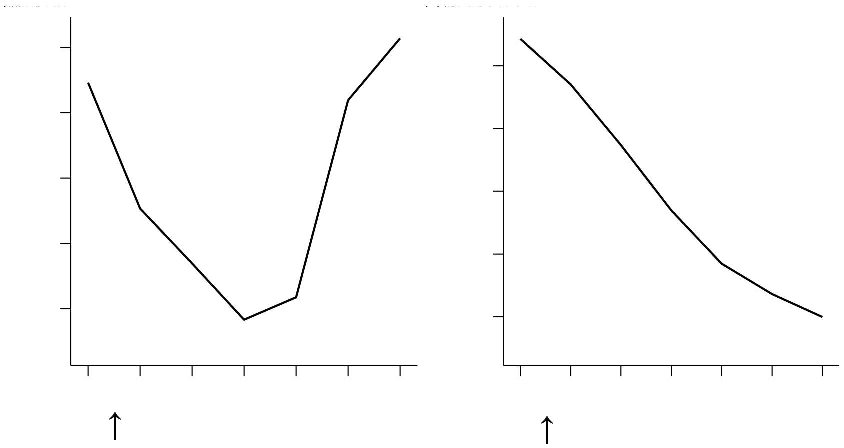

Figure 4: Cardiac interbeat intervals (IBIs; left panel) and skin conductance level (SCL; right panel) responses elicited by knocking down at least one pin (Event 2). ↑= event onset time.

Event 3 (Missing the Pins Completely)

Event 3 did not elicit any significant changes in zygomatic, corrugator, or orbicularis oculi EMG activity. However, Contrast 2 showed that Event 3 elicited a significant decrease in IBI (i.e., an increase in HR) that peaked 4 s after event onset (Figure 5, left panel), $t(df = 25.92) = 4.13$, $p < .001$. In addition, Contrast 1 showed that Event 3 elicited a progressive decrease in SCL (Figure 5, right panel), $t(df = 17.04) = 2.43$, $p = .027$.

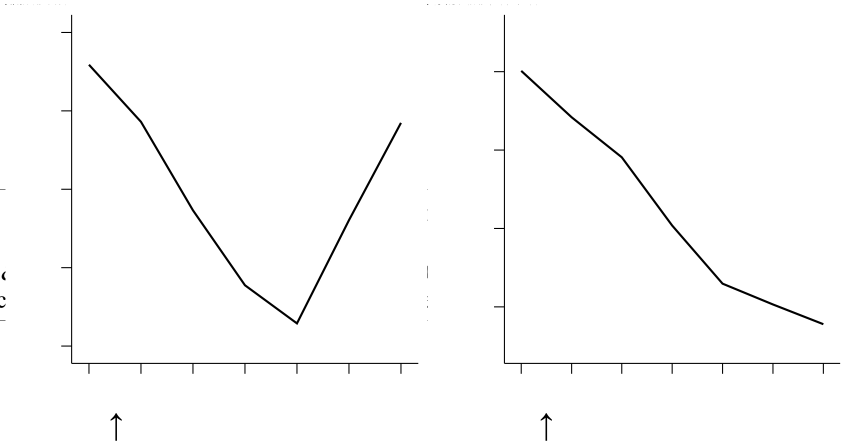

Figure 5: Cardiac interbeat intervals (IBIs; left panel) and skin conductance level (SCL; right panel) responses elicited by missing pins completely (Event 3). ↑= event onset time.

Event 4 (Negative Feedback)

Event 4 tended to elicit a decrease in zygomatic EMG activity (not shown), although Contrast 2 narrowly failed to reach statistical significance, *t*(*df* = 51.35) = 1.81, *p* = .076. Contrast 1 indicated, in turn, that Event 4 elicited a linear decrease in orbicularis oculi EMG activity (not shown), *t*(*df* = 53.04) = 2.17, *p* = .035. There were no significant changes in corrugator activity. Contrast 2 showed that Event 4 prompted an increase in IBI (i.e., a decrease in HR) that peaked 4 s after event onset (not shown), *t*(*df* = 61.89) = 3.05, *p* = .003. Likewise, Event 4 tended to elicit a linear decrease in SCL (not shown), although Contrast 1 narrowly failed to reach statistical significance, *t*(*df* = 31.51) = 2.03, *p* = .051.

DISCUSSION

In the present study, we examined phasic psychophysiological responses indexing emotional valence (i.e., facial EMG) and arousal (i.e., IBI and SCL) to different game events in a video game called Monkey Bowling 2. The results showed that the game events studied (i.e., the monkey [inside the ball] falls off the edge of the lane to the depth of outer space, the ball knocks down at least one pin, the player misses the pins completely, and negative feedback after a poor throw) elicited reliable emotional valence- and arousal-related physiological responses. The emotional valence of the responses was not always what one might intuitively expect, however. Given the importance of emotional experiences in (sustaining) gaming behavior, the present results suggest that information on the emotional responses elicited by game events and event patterns may be applied in game design.

Unexpectedly, we found that Event 1 (the monkey falls off the edge of the lane to the depth of outer space) elicited an increase in positive affect as indexed by an increase in zygomatic and orbicularis oculi EMG activity, and a decrease in negative affect as indexed by a reduction in corrugator EMG activity. In addition, the event elicited arousal as indexed by an increase in SCL (IBI data were somewhat equivocal). Thus, although the event in question represents a clear failure, several physiological indices showed that it elicited positively valenced high-arousal emotion (i.e., joy), rather than disappointment. This is an important finding suggesting that event characteristics such as visual impressiveness and excitingness may be more potent determinants of the emotional response of the player compared to the meaning of the event in terms of failure or success. In regard to the temporal characteristics of the physiological responses, it is interesting to note that all facial EMG responses peaked 2 s after the event, whereas SCL response peaked 3 s after event onset. It is well established, however, that SCL response develops slower compared to facial EMG responses [4].

We also found that Event 2 (the ball knocks down at least one pin) elicited increased positive affect as indexed by an increase in both zygomatic and orbicularis oculi EMG activity. Again, these responses peaked 2 s after event onset. However, this positive event did not decrease negative affect, given that corrugator EMG activity did not change. Although one might expect that success in a game would also elicit increased arousal, SCL data showed that arousal decreased in response to Event 2. An apparent reason for this is that there is likely to be high anticipatory arousal before the ball hits the pins, after which arousal diminishes. This is also in agreement with our previous study showing that arousal (as indexed by SCL) decreased after attaining the goal in the video game Super Monkey Ball 2 [20]. It is of note, however, that cardiac IBI decreased (i.e., HR increased) in response to Event 2. Given the aforementioned sympathetically-mediated decrease in SCL, it is likely that this HR increase does not reflect changes in cardiac sympathetic arousal, but is a parasympathetically mediated phenomenon. That is, in addition to anticipatory arousal, attentional engagement is likely to be high before the ball hits the pin(s), after which it decreases. Recall that high attentional engagement is associated with heightened cardiac parasympathetic activity that causes the heart to slow down [18]. That being so, when attentional engagement decreases after the ball hits the pin(s), cardiac parasympathetic activity (i.e., a decelerative effect) also decreases, resulting in increased HR. These data clearly demonstrate the interpretative difficulties associated with HR also in game research. SCL is clearly a better index of arousal in game studies, given that physiologically it is influenced only by the SNS [18], and therefore there are no difficulties when interpreting the data.

The results also showed that Event 3 (the player misses the pins completely) that was supposed to be a negative event did not elicited any emotional valence-related EMG responses. This raises the question whether facial EMG is insensitive as a measure of negative emotional responses to video game events (but see below). Of course, an alternative interpretation would be that this particular (putatively negative) game event simply did not elicit negative affect. However, Event 3 elicited cardiac IBI and SCL responses that were identical to those elicited by Event 2. Given that also Event 3 is likely to be preceded by high anticipatory arousal and attentional engagement and followed by a decrease in these variables, this finding increases our confidence in the interpretation presented above.

We also found that Event 4 (negative feedback after a poor throw) elicited negative emotions as indexed by a decrease in both zygomaticus major and orbicularis oculi EMG activity. In addition, it elicited an increase in IBI (i.e., a decrease in HR) and a decrease in SCL, suggesting that arousal diminished. Thus, Event 4 appeared to elicit depressed affect characterized by a combination of negative valence and low arousal. The data of the present study suggest that the valence of the emotional response to game events may vary as a function of the active participation of the player. Recall that a putatively negative event the player actively participated in (falling off the edge of the lane) elicited a positive emotional response. In contrast, Event 4 characterized by passive reception of negative feedback elicited a negative emotional response. This finding is in line with our prior research showing that, when playing Super Monkey Ball 2, the valence of the emotional response was positive when the player actively participated in a putatively negative game event, but it was negative when the player passively perceived a replay of the same event [23].

Given the reliable emotional valence- and arousal-related psychophysiological responses to game events, there are several ways how phasic physiological responses can be used to guide choices in game design. First, these physiological responses can be used to examine whether a given game event elicits the targeted emotional response. This implies that the game designer should intuitively know what kind of emotional response (e.g., positive vs. negative, fear vs. joy) a given game event should preferably elicit. However, this may also be an empirical question, given that it is possible to empirically examine what kind of emotional response to a given type of game event is associated with greatest self-reported overall enjoyment. However, the predictive validity of the emotional responses to games and game events can also be established by examining how the emotional responses predict game play in the long run. This can be accomplished in the following way, for example: (a) emotional responses to a set of different games or game versions are recorded, (b) people are let to choose how much to play each game during a longer time period (e.g., 3 months), and (c) the relationship of the previously measured emotional responses with people's long-term game selections is assessed. Of course, from the perspective of emotion theory, one might predict that game events eliciting positive emotional responses are particularly effective in sustaining game playing, given that positive emotions serve as affective rewards for goal-directed behaviors (e.g., game playing) [27]. On the other hand, it is well known that people may enjoy seeing horror films that elicit fear, for example. Thus, also negatively valenced emotional responses may be desirable in some connections [18].

Emotion-related physiological responses to game events vary also in terms of their amplitudes, with a high-amplitude zygomatic EMG response indicating a more positive emotional experience compared to a low-amplitude response, for example. That being so, the amplitudes of responses to different game events or event patterns can be compared to select events or event patterns that best elicit the targeted emotional response. Information on the temporal characteristics (e.g., rise time and recovery time) of emotional responses to game events may also be useful. The present study showed, for example, that EMG responses peaked 2 s after event onset, after which they recovered to (local) baseline relatively fast. To avoid player boredom, the recovery time of the responses should be allowed for. It may be advisable that different game events follow each other in close enough temporal succession so that the previous emotional response does not recover completely before the onset of the next response, for example. In psychology, it is well established that repeated exposure to an emotional stimulus may lead to sensitization or desensitization (or habituation) of emotional responses [2]. Thus, information on sensitization or habituation of emotional responses with repeated exposure to game events can be applied when making design choices concerning the temporal distribution of events. This issue relates to the reinforcement schedule of the game.

It is of note that there may be large individual differences in people's emotional responses to games and game events. In our previous study, we found that James Bond 007: NightFire (i.e., a first-person shooter game) elicited higher self-reported engagement among high Impulsive Sensation Seeking scorers compared to low Impulsive Sensation Seeking scorers, while the reverse was true for three non-violent games [22]. This finding was expected, given the preference of high sensation seekers for thrills and danger. Obviously, future studies should allow for the potential individual differences in psychophysiological responses to game events.

In sum, the present study indicated that different video game events elicit reliable psychophysiological responses indexing emotional valence and arousal. In addition to putatively positive game events, also putatively negative game events that involved active participation by the player elicited positive emotional responses as indexed by facial EMG. However, passive reception of negative feedback elicited low-arousal negative affect. The present results suggest that it may be possible to use emotion-related phasic psychophysiological responses as criterion variables in game design in several ways, although the predictive validity of these responses to games remains to be established.

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