The Influence of Subliminal Visual Primes on Player Affect in a Horror Computer Game

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***Abstract*—Subliminal priming is an extensively researched technique in cognitive psychology. Research often focuses on highly controlled lab-environments, with only a few studies attempting to translate it to applications outside the laboratory. In this study, visual affect priming was deployed in the complex environment of a horror computer game, while maintaining strict standards in regard to subliminal thresholds. Fear-inducing images of one prime-type were shown repeatedly to players (N=60) during 5-minute playing sessions, using sandwich masking and a prime-duration of 33.3 ms. Three types of images were compared to an empty control-image: text, faces and spiders. Players were monitored with heart-rate and galvanic skin response (GSR) sensors to determine effects on a physiological level and were interviewed directly after playing. Results show no significant differences in affective self-report. GSR measures show an increase of relaxation between the start and finish of the game for players who were primed with face images, which we attribute to a result of our relative small player sample. We conclude that in a perceptually complex environment such as a video-game, subliminal visual priming does not noticeably influence player affect. However, measures directly around prime-windows coinciding with in-game sounds showed a significantly effect on GSR. This suggests that GSR is a suitable tool to gauge the affective impact of game elements.**

Keywords*—*Affective gaming, priming, fear, player affect

I. Introduction

Subliminal visual priming refers to the presentation of visual stimuli to test-subjects in such a way that they are not consciously aware of them. This kind of priming is a research staple in cognitive psychology, revealing unconscious effects of certain stimuli and the associated processes in the brain [1]. In subliminal priming, a stimulus is presented to a test-subject for a short amount of time, typically 10 to 50 milliseconds (ms), allowing subconscious cognitive processing but no consciously accessible awareness of the stimulus. To allow for longer exposure times, generally an additional masking technique is used. With masking, the prime is 'hidden' through displaying an information-rich stimulus preceding and/or following it. The processing of the extra stimulus overrides the processing of the prime, effectively hiding it from consciousness [2].

It is theorized that, in our complex visual world and due to saccades, people are frequently exposed to subliminal stimuli in daily life [1]. However, subliminal priming is most often studied in a laboratory setting, where primes, masks and target stimuli are presented to test-subjects in an isolated fashion and without other distractions. The way isolated primes are processed by a test-subject might very well differ from the way unconscious cues are used in the real world, as the environment has been shown to play a large role in stimulus-evaluation [3]. Research into non-isolated prime presentation could therefore further illuminate the general influence of unconscious processing on evaluation, decision making and other conscious cognitive functions.

In this study, we are interested in the potential of using subliminal visual priming in a complex environment. We focus specifically on affect-priming, and more specifically priming of fear. Horror computer games offer players the ability to engage with fearful emotions for entertainment purposes. While players are aware that they will be subjected to situations designed to heighten their fear-response, the specific methods are unknown to them. If subliminal priming could be used to intentionally direct player affect, it would enable game designers to shape the emotional experience of games in addition to consciously perceivable influences such as visual- or sound design. Furthermore, it would enable research into subliminal affect priming in a more complex environment than generally used.

A. Related Work

When subliminal priming is studied outside of tightly controlled laboratory settings, it is often within the context of advertising. The best known example is a claim, made in the 1950's, that showing movie-goers subliminal visual primes of the words 'Drink Coca-Cola' made sales of the soft-drink go up during breaks [4]. Further studies have either failed to replicate this result, or found effects to be much weaker than originally claimed [5] - for instance only when subjects were already predisposed towards the stimulus due to being thirsty [6]. The original study is now a confirmed hoax [4].

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These events have contributed to a largely negative perception of subliminal priming among the public [7], making practical applications difficult or at least controversial.

A classic example of subliminal priming is the effect emotionally charged depictions of a person have on subsequent analysis of a neutral picture of that person. By preceding a neutral drawing of a person by a subliminally presented picture of the same person either stabbing someone with a knife, or offering them a cake, the evaluation of the persons character by test-subjects was significantly altered [8].

Affective priming is an important research area in the field of perceptual priming [9]. Emotionally charged stimuli have been shown to influence the affective evaluation of subsequent stimuli by test-subjects. With only subliminal exposure, this effect often remains or even increases. It is theorized that conscious defenses against manipulation are activated when stimuli are consciously perceived [10], making them more effective when presented subliminally. A recent study asked test-subjects to label neutral faces with emotions. Unbeknownst to the test-subjects, a positively or negatively valenced face was shortly displayed before the depiction of the neutral face, acting as a subliminal prime. The study showed a significant correlation between affect labeling and type of prime [11]. There are also indications of cross-over between perceptual systems; affective visual primes influencing the response to auditory target stimuli [12].

Aside from the influence on affect labeling, priming has also been shown to be able to induce affect in test-subjects, with some research focusing on the induction of fear. One approach is to use words with fearful connotations, which seems to influence mood potency but not valence [13]. Another approach is the use of fear-inducing pictures such as depictions of snakes or spiders [14]. Both snakes and spiders have the advantage of eliciting a natural fearful reaction in humans, attracting attention away from other stimuli [15], [16].

Subliminal affective priming addresses questions about the conscious and unconscious aspects of affect and their neural correlates. Happy and fearful faces have been shown to elicit a neural response even when presented below the threshold of conscious perception, in the amygdala [17] as well as in the occipital cortex [18] and amygdala-prefrontal circuits [19].

In terms of making use of subliminal priming within virtual environments, recent studies [20]–[22] have shown indications that the behavior and memory of test-subjects can be influenced by presenting subliminal primes. For example, the subliminal presentation of happy faces lead players to evaluate a computer game more positively than when subjected to angry faces [22].

II. Research Question

Our aim is to compare three different categories of visual primes, chosen in accordance with previous research, to determine which kind of subliminal imagery has the largest impact on the affective state of a test-subject interacting with a complex environment. Hence, the research question raised is whether certain types of subliminal primes elicit a greater fear response when compared to a control.

A. Hypothesis

We expect that subliminal affect priming in a game setting will enhance the players conscious experience by influencing affect, specifically fearfulness. Based on the conclusions of previous research, we hypothesize that such an influence will be reported by players themselves as well as be evident in the physiological measures of heart-rate and galvanic skin response (GSR).

III. Method

A. Horror Game

The computer game (see Fig. 2a) used in our experiment was designed to be very close to that of a similar study [22]. The game is a simple exploration game in a 3-dimensional environment, played from a first-person perspective. The player is locked in a museum, with only a few accessible rooms. The game is set in night-time with heavy rain and lightning, suggested through continuous sound effects and lightning flashes. At predetermined times, additional unnerving sound effects play out to keep the game interesting but avoid random influences on player affect. In the beginning, players are instructed to collect six hidden keys to escape the museum. However, only five keys can be found and used to partly unlock the main door. Players can therefore never escape before the scheduled active play duration of five minutes.

B. Subliminal Threshold

For subliminal imagery, certainty that primes have not been consciously perceived is paramount. Two pilot studies were conducted to determine the appropriate prime duration and image-contrast. The first pilot (N=5) used a prime duration of one frame at 60fps (16.6 ms). The second pilot (N=7) tested exposure to two frames at 60fps (33.3 ms). These pilot studies indicated that two frames was an appropriate duration for subconscious priming under the subjective threshold.

The threshold was determined by a forced choice recognition task between the primes shown and other images. The subjective threshold is reached when participants evaluate their own performance on the forced choice task to be at chance level. The objective threshold is reached when their performance in the forced choice task is indeed at chance level [23].

As there is some debate on whether primes still have any unconscious effect when presented at the objective threshold [24], the pilot studies focused on determining the subjective threshold, on which we based our final experimental prime-duration. In our final experiment, we excluded cases in which the primes were reported to be perceived and players rated their performance on the forced choice task as above chance. It should be noted that the game-environment necessitates a non-individualistic approach to prime-duration. The duration is therefore expected to be sub-optimal for some players. Implications of this are discussed in section IV-D.

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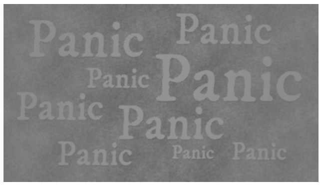
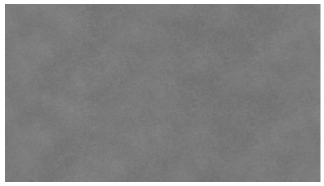
(a) Face prime

(b) Spider prime



(c) Text prime



(d) Empty prime

Fig. 1. Example images of each prime category. Each category consisted of three images to reduce the chance of conscious recognition due to repeated use.

C. Conditions

Prime-types were chosen for expected effectiveness based on prior research. Participants were randomly sorted into one of four conditions: pictures of spiders [25] [26], pictures of faces [27] [28], a blank background with words [29] [13] and a control group, using just a blank background. Each participant was presented with several different pictures of this same prime-type during game-play.

D. Visual Primes

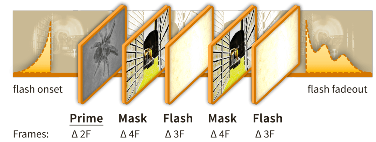
Spiders were selected for highest induced arousal level and visual clearness from the Geneva Affective Picture Database (GAPED) [30]. Faces were selected from the The Karolinska Directed Emotional Faces Database (KDEF) [31] on fearful expressions and mixed gender. Words were selected with a preference for more abstract fear-associated words based on prior research [32].

The pictures were altered to be in black-and-white and to have similar contrast (Fig. 1), a procedure common in priming research [33]. For each prime-type, six different pictures were obtained. Pictures were paired, and one from each pairing was chosen randomly to appear in the game. The other picture was subsequently used in the forced choice task next to the actual prime. This resulted in three different in-game primes of the same type per condition, reducing possible repeated-exposure effects on conscious perception.

E. Masking

Although there are many different masking methods available [34], an advantage of immersing the primes in a game is that the game environment itself (Fig. 2a) can function as a visually complex sandwich mask while being unobtrusive to the game-experience [35]. Nonetheless, it should be noted that we had no influence on where the player was looking (and thus on the actual mask-image) during the presentation of the primes. This however also reflects the application scenario if subliminal priming were to be used in computer games.

(a) Example screenshot of the horror game used in our study.



(b) Illustration depicting the chronological frame composition (from left to right) of each lightning flash event in the game.

Fig. 2. Game image and prime composition.

Complex textures were used throughout the game environment to reduce the chance of a player looking at a non-suitable background before and after the prime-window.

The prime was presented as a full-screen image over the game environment, hidden within a lightning flash (see Fig. 2b). After the prime, the game environment was shown again for 66.6 ms (4 frames at 60fps), acting as the second half of the sandwich mask. Then a white image was shown full-screen for 50 ms (3 frames at 60fps), acting as the conscious illustration of the lightning flash. The mask-flash sequence was then repeated a second time.

F. Sampling

A total of 60 participants took part, mostly composed of students from three separate universities. Ages ranged from 17 to 47 (M=22.7, SD=4.64). The gender distribution was 35% female (N=21) and 65% male (N=39). Snowball and convenience sampling was used to find participants. Selection involved a screening process for epilepsy and specific phobias. None of the participants had to be excluded on these grounds.

G. Measurements

The primary measurements taken in this study were a post-game survey for self-reported affect, and physiological measures (heart-rate and GSR). The post-game survey used the Self Assessment Manikin (SAM) [36] as method for quantifying affective self-report. Following the game, participants chose a point on three dimensions (valence, dominance and arousal) using an illustrative nine-point scale. We also made use of the E3 drawing method [37] as qualitative affective self-report. Participants were asked to complete the drawing to reflect how they felt during the game-play. In addition to SAM and E3, we asked participants to rate their experience (game scariness, fear experienced, and game enjoyment) on a ten-point scale.

Physiological measures were taken to check for expected fear-related arousal [38] [39] [40]. An earclip sensor was used to measure heart-rate, while GSR was measured on the index and middle finger of the hand that operated the mouse (more sudden impact movements on the keyboard were expected). Sensor data were recorded, logged and time-stamped on the same computer on which the game was running. For our evaluation we looked at raw, non-normalized physiological measures, and used these measures to create deltas that were then compared.

H. Procedure

The experiments were conducted at three universities: Leiden University, Erasmus University Rotterdam, and Delft University of Technology. Two laptops were prepared for concurrent testing. For both, we ensured that the game would run at the intended 60 fps. A camera, filming the screen at 240 fps, was used to verify the intended prime duration before starting the experiments.

During the experiments, players used the laptop keyboard for character movements and a corded optical mouse for camera movements. All sessions were conducted with headphones and with roughly similar lighting conditions (indoor, passive light during daytime).

Participants were told that they were evaluating a horror computer game. Each playing session began with a short survey regarding demographics and game-playing experience. Then, sensors and headphones were applied, followed by sensor checks by the experimenter. After that, participant watched a short movie clip (around one minute in length) to stabilize the sensors.

After the movie, the game was started and one of the four condition groups was randomly selected. The participant then had five minutes of active playing time after which the game ended automatically. At this point, the experimenter asked participants to answer general subjective affect questions, SAM, E3 and the forced choice questions regarding the subjective threshold for subliminal presentation. Finally, the test-subject was debriefed. On average, each subject took approximately 20 minutes to complete the experiment.

IV. Results

We used an alpha-level of 0.05 for all statistical tests. All data was checked for normality and homogeneity before performing ANOVA.

A. Sample Sizes

Out of all participants (including the control-group), 16 claimed to have seen something unusual when prompted with an open question before the forced-choice task. Six of these mentioned images corresponding with the prime-type presented to them. Two of those mentioned text, two 'a female face' and two others 'a startled face'. They rated their confidence in the forced choice test between 70 - 100%. The remaining 10 participants did not mention anything 'unusual' that was actually related to the primes, and did not express high confidence or perform better than chance in the forced-choice selection. Hence, only the first six cases were deemed to have exceeded the subjective threshold and were excluded from further analysis.

This means that, out of a total of N=60, six participants were dropped and self-assessment results were limited to N=54 (separated in N=15 for the control-group, N=15 for the spider-group, N=13 for the text-group, and N=11 for the faces-group). Moreover, some physiological data of 14 participants had to be discarded due to sensor problems. The N for tests involving physiological measures therefore varies slightly: N=51 for heart-rate (missing one extra data-point out of the control-, the faces- and the text-group), and N=42 for GSR (N=12 control, N=12 spider, N=10 text, and N=8 faces).

B. Self Report

ANOVA results showed that there were no significant differences between groups in SAM self-report measures (nine-point scale) on valence (M=5.57, SD=1.19), arousal (M=4.81, SD=1.74) and dominance (M=5.56, SD=1.77). Chi Square tests yielded similar results indicating no differences between the groups. Furthermore, there were no significant differences between the groups when questioned on their game experience (ten-point scale), split up in game scariness (M=3.8, SD=1.7), fear experienced during playing (M=3.61, SD=1.8) or game enjoyment (M=5.11, SD=1.95).

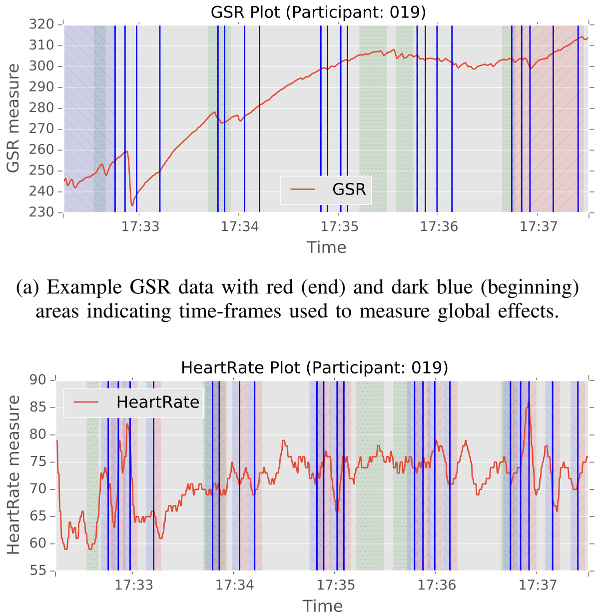
The E3 assessments revealed that the majority of participants were focused on the task of finding the keys in the game, with only a minority responding with fear-related comments. Participants also added comments for possible game improvements. Overall, the occurrence of emotion- or fear-related content was too low to be used effectively in analysis.

C. Physiological Measures

Heart-rate and GSR data were used for analysis of the physiological response both over the entire game-play and around the prime-windows. For the global effect, the delta between the average signal of the time between game start and the first prime, and the average signal of the last 30-second block of primes was used for statistical analysis (see fig. 3a). For the short-term effect, the delta between the average signal of the four seconds before a prime-window and the four seconds after a prime-window was used (see fig. 3b).

1) Global effects: Global effects - the delta over the first and last 30 seconds of the game - were analyzed using an ANOVA, showing non-significant effects of prime-type on heart-rate ($F(3,47) = 1.09$, $p > 0.5$). Prime-type did have a significant effect on GSR values, however, with the faces-group showing a significantly higher increase in skin resistance over the gaming-period ($F(3,38) = 2.89$, $p=0.48$). An increase in skin resistance indicates a higher degree of relaxation.

2) Short term effects: A split-plot ANOVA was used to analyze the delta over the short period of time around each prime-window, with a total of 21 prime-windows during the entire game (with Greenhouse-Geisser correction for degrees of freedom of the within subject factor prime-window). For the heart-rate data, the main effect of within subject factor prime-window was non-significant ($F(7,322) = 0.94$, $p > 0.05$), as was the main effect of between subject factor prime-type ($F(3,47) = 1.58$, $p > 0.05$). The interaction of these two was non-significant as well ($F(21,322) = 0.89$, $p > 0.05$). For the GSR data, the main effect of prime-type was also non-significant ($F(3,38) = 1.45$, $p > 0.05$), as was the interaction-effect between prime-type and prime-window ($F(26,324) = 0.90$, $p > 0.05$). The main effect of prime-window was significant ($F(9,324) = 2.65$, $p = 0.007$). Further analysis showed that



(a) Example GSR data with red (end) and dark blue (beginning) areas indicating time-frames used to measure global effects.

(b) Example heart-rate data with red and blue areas around primes (blue spikes) indicating time-frames used to measure short term effects.

Fig. 3. Physiological measurement plots from a single participant. Blue horizontal lines indicate lighting flashes including subliminal primes. Green dotted areas show at which times frightening audio effects were audible. Blue and red hashed areas indicate time-frames of measured averages. Delta over the blue and red average was used in analysis

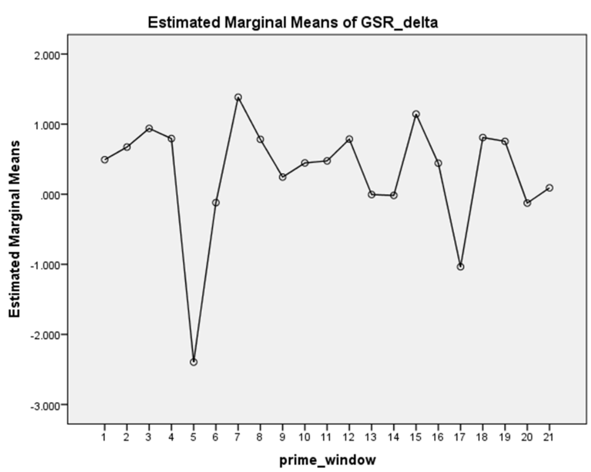


Fig. 4. Averages (n=42) of the change in GSR over each of the 21 prime windows.

a steep decrease of skin resistance around prime-windows 5 (Fig. 4) was that significantly lower than the skin resistance drop around prime-window 4, 7, 8, 9 and 15 (Bonferroni corrected, p=0.049, 0.012, 0.032, 0.027, 0.009 respectively).

D. Discussion

The most noteworthy result to discuss is arguably the impact of face primes on the difference in GSR measures between the start and end of the gaming-period, which is the only significant result between prime-types. This result suggests that the subliminal presentation of face primes caused a *decrease* in physiological fear response. With no other significant differences found in measures between prime groups, and after carefully checking the data, we believe that this effect is the result of chance in a relatively small sample size. Considering the current state of knowledge based on previous affect research, there is no reason to believe that the presentation of face primes are, for one, causing a relaxation effect, and secondly are the only type of prime that cause a significant physiological impact compared to a control. If we had to speculate on a reason for why this result could in fact be repeatable, it could be due to the fact that the game environment is devoid of any human presence. It might be the case that face primes offer familiarity, despite their fearful expressions. However, there is no conclusive evidence that this is in fact the case and such a hypothesis would have to be tested in a separate, more focused study.

Our results suggest that subliminal priming with fear-inducing imagery does not lead to an increase of fear or arousal in players of a horror computer game. In none of our measurements we found a significant effect of prime types (or indeed the use of priming in general) and an increase in fear. As such we have to reject our hypothesis that subliminal visual priming can be used to influence player affect in a computer game environment.

It is important to note that the platform of a computer game does not offer an ideal environment to facilitate subliminal priming. Where studies in cognitive psychology would use individual prime durations through subject thresholding, our study explicitly tested a practical application which foregoes adjusting the parameters for each individual separately. If subliminal priming were to be used in games, we argue that a general prime duration would have to be chosen. This has also been the case in previous studies regarding the use of subliminal primes in computer games [21], [22].

These former studies have demonstrated subliminal priming impacts on self-reported game experience and brand awareness respectively, which seems to contradict the results of the present study. One could argue that the implementation of subliminal primes under the subjective threshold was too subtle to cause an impact. At the same time, 6 out of 60 participants were able to identify what prime image was displayed. Increasing the duration of the prime display would likely have increased the amount of players who would have consciously perceived the priming image.

It is possible that longer game sessions would have resulted in subliminal primes causing a more discernible impact on player affect. On the other hand we did not come across any evidence in support of this possibility. We also recognize that our sample size is relatively small, which we had to accept as limitation of our research. It is, however, an indication that the effect magnitude, if present, might not justify the effort required in terms of design and performance stability (required to maintain a frame-rate of 60 fps).

At this point we would like to discuss two of the methods that we used to measure affect in terms of their suitability: physiological GSR measures and the self-report survey E3. During the analysis of the data we gathered, we found a significant impact of sound effects used in the computer game on GSR measures of players, and this is supported by the reported main effect of prime-window (e.g., the drop in GSR at window 5 is just around such a sound effect) on the GSR-delta. This supports the notion that physiological measures, in this case GSR, are suitable to detect the impact of game elements on player affect.

In contrast to this, we found the E3 survey method for self-reported affect unsuitable for this study. This method of measuring affect was added in an effort to provide the researchers with the possibility to consider potential semi-conscious thought processes in response to subliminal priming. However, we argue that the use of E3 is more effective in studies where participants can connect their thoughts to specific questions or situations.

Finally, it is worth noting that a large number of participants expressed enthusiasm and interest in the potential implementation of subliminal priming in computer games for entertainment purposes. We believe that there is a general interest in the subconscious processes that occur in the human mind. While the public may have largely negative associations with subliminal priming as related to advertising, its use seems to be viewed as less controversial in a situation where affect manipulation is not only expected, but even desired by the participant.

V. Conclusion

Overall the conclusion of our study is that we did not find evidence that subliminal priming in a computer game influences player affect significantly. A larger subject sample size might show small effects, but the need for large samples to show small effects casts doubt upon the usefulness of subliminal priming as an interesting method of affect direction for game designers. While an effect for one prime type (images of scared faces) was found, it did not correlate with affective self-report and in fact suggested relaxation instead of increase in fear (even though the fear faces used for priming were from a standard data set (GAPED) [30]).

While this study is the first to look at the possibility of influencing affect through subliminal priming in computer games, previous studies have indicated that subliminal priming in computer games can influence game experience and recollection of primed imagery. Although it is possible that player affect is more difficult to influence, we would have expected to find a measurable impact, especially when it comes to physiological measures. However, computer game environments are highly varied and any effort to study them must accept that there may be a large number of variables that cannot be fully controlled. As such we do not believe that the results of our study should be considered as evidence that subliminal priming does not cause any impact to players in computer games. We rather argue that if subliminal priming should be considered as potential method for directing player affect in computer games, its functional implementation cannot require very narrow parameters.

Consequently, we attempted to create a controlled environment that is reflective of how games are created as well as consumed. Future studies interested in the use of subliminal priming in computer games should investigate the parameters that are required for successful implementation, as well as the range in which parameters can be varied without compromising the intended effect. Otherwise we believe that the use of subliminal priming would be restricted to tightly controlled environments that are not reflective of the way in which computer games are made and played.

Considering the negative public perception of subliminal priming, some might argue that any difficulty in its successful implementation is a positive result. At the same time, participants in this study were intrigued by the notion of adding subliminal priming into horror computer games. Whether there is going to be a role for subliminal priming in computer games remains to be seen. For now, players will need to rely on the more conscious influences to get properly scared.

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