Dynamic Lighting for Tension in Games

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Introduction

Video and computer games are among the most complex forms of interactive media. Games simulate many elements of traditional media, such as plot, characters, sound and music, lighting and mise-én-scene. However, games are digital artifacts played through graphic interfaces and controllers. As interactive experiences, games are a host of player challenges ranging from more deliberate decision-making and problem solving strategies, to the immediate charge of reflex action. Games, thus, draw upon a unique mix of player resources, contributing to what Lindley refers to as the “game-play gestalt,” “a particular way of thinking about the game state from the perspective of a player, together with a pattern of repetitive perceptual, cognitive, and motor operations” (Lindley, 2003).

Game Aesthetics

Comprehending such a complex interactive experience is difficult, but can be approached using the discourse of game aesthetics. A survey of contemporary writings and resources from video and computer games research and design resources reveals at least two significant clusters of meaning and assumption around the term “game aesthetics.” One defines “game aesthetics” as a sensory phenomena that the player encounters in the game: the visual, aural and haptic (and embodied) experience of gameplay (cf. www.gameinnovation.org), while the other defines it as an expression of the game experienced as pleasure or emotion, with focus on the “aesthetic experience” (Lautern, 2002). However, both of these contemporary understandings mirror the larger history of aesthetics discourse (Kelly, 1998).

Besides helping us better understand games, analyzing the aesthetic experience of gameplay has the potential to inform higher-level game design concerns. According to psychology theory, the prototypical aesthetic experience is one in which attention is firmly fixed upon the components of a visual pattern, excludes the awareness of other objects or events, is dominated by intense feelings or emotions and is integrated and coherent (Kubovy, 2000). This emphasis upon attentiveness, emotion and pleasure resonates well with the desired outcomes of game design, in which the goal is to design an enjoyable play experience, one that has the potential to help further grasp important game studies concepts, such as “flow” defined as a mental state of total involvement in a task (Csikzentmihalyi, 1997).

Grounded on the emerging study of game aesthetics, our strategy for understanding the player’s sensory and emotional experience is to cut a thin slice through this complex system by focusing on one component of the aesthetic experience of games: simulated illumination. In particular, we aim to focus on the impact of simulated illumination on emotions and tension, thus making an argument for the role of lighting on gameplay and “flow.”

Simulated Illumination in Games

Simulated illumination is defined as the method by which virtual 3D game environments are rendered taking into account all lighting information in the scene. Due to the flexibility of game rendering engines, and the variety of game styles, we organize simulated illumination exhibited in games into a dimension ranging from more abstract forms of light and colour representation, e.g. “Rez” (United Game Artists, 2002), through cel-shaded games, to those that approach photorealism (which incorporate a range of lighting that approximates the visual experience of real space) [1]. It should be noted that even more abstract cel-shaded games display a limited set of light and spatial effects, such as drop shadows beneath the player’s avatar, e.g. “Okami” (Clover Studios, 2006) and stylized light beams, e.g. “Jet Set Radio Future” (Smilebit, 2002).

In a game design context, simulated illumination is embedded in the vocabulary of the 3D modelling software (Maya, 3D Studio Max, etc) used in game production (Manovich, 2001). Art directors and level designers often struggle with various software products, including image editing software, e.g. Adobe Photoshop, level editors, and 3D modelling Software, such as Maya or Max, to produce the desired illumination effect in the game environment. Each software product contains algorithms that establish simulated illumination. These algorithms have their own set of assumptions concerning how lighting is established or simulated, including shadow appearance and colour.

Although these algorithms are used to render images that do not fully reproduce a realistic illumination model, it is fair to argue that the experience of simulated illumination is analogous (though not identical) to our experience of light in real space. The terms of the analogy remain to be discovered through further game aesthetics research, but initial findings suggest that, just like light in real space, simulated illumination in virtual space has a direct effect upon participants’ emotional experiences. Knez and Niedenthal (forthcoming) have demonstrated that warm and cool simulated illumination conditions have differing emotional and performance effects upon players navigating a virtual maze created in the “Half Life 2.0” game engine.

This link between visual sense phenomena and emotional response suggests that game designers have yet another powerful design material to manipulate along with sound, character, narrative, game challenge, genre, etc., when creating satisfying and whole gameplay experiences. There are many lighting design techniques exhibited in theatre, film, architecture and dance that address the role of lighting on emotions and arousal. Currently, game developers and designers adopt cinematic and animation lighting techniques to enrich the aesthetic sense of the virtual space and the gaming experience. For example, game lighting designers manually manipulate material properties and scene lighting to set a mood and style for each level in the game.

While many lighting principles can be borrowed from film and theatre lighting design theories, the interactive nature of games distinguishes them substantially from film and theatre. Game environments are dynamic and unpredictable due to the interactive freedom afforded to users within the world, thus narrative context, users’ positions and perspectives within the gameworld-crucial parameters to the calculation of lighting-cannot be assumed. Therefore, in this article, we argue for the use of dynamic lighting. Dynamic lighting is a type of simulated lighting where lighting calculations are computed in real time. Therefore, using dynamic lighting enables on-the-fly lighting calculations accounting for real-time variations, such as change in game state, narrative, player’s and characters’ positions and camera movement. This practice privileges interaction, emotion and dramatic content, as opposed to the current methods that tend to rely on static lighting to emphasis virtual space.

In this article, we investigate the use of dynamic lighting in game environments and its effect on game aesthetics. To enable such investigation we have developed a dynamic lighting prototype within a first person shooter game developed as an “Unreal Tournament 2004” (Epic 2004) mod. This prototype is built based on two bodies of work which will be discussed in this article: (1) a set of film lighting patterns identified for their effect on tension projection and modulation; these patterns were identified based on a qualitative study involving several films and (2) TDELE (Temporal Dynamic Expressive Lighting Engine) developed by one of the authors (Seif El-Nasr et al., 2005), a system that adapts the lighting in real-time based on variations in the game state and narrative, while balancing artistic constraints and accounting for the temporal dimension. We conclude this article by presenting results investigating the effect of dynamic lighting in projecting and modulating tension and its impact on the play experience, and, hence, we return to the main objective of the article, to investigate the role of simulated illumination on game aesthetics.

Lighting and Tension

In this section, we discuss lighting in terms of theory and practice, setting the stage to understanding the lighting design process and its impact on game aesthetics and its influence on the gaming experience.

Light is understood, manipulated, and simulated through its most basic characteristics:

- brightness or luminance (which in real space can be measured in lux, lumens, footcandles, etc.)
- colour (as expressed through it spectrum, measured through degrees Kelvin, or manipulated through filtration)
- hard or soft shadow quality
- direction
- variation over time

Moreover, the interrelation of lights in a scene with surfaces and other lights introduces effects of brightness and colour contrast, shadowing, etc. These provide a basic vocabulary for a lighting researcher and a palette of possibilities for a lighting designer.

We define a lighting pattern as a specific configuration of these basic elements of light and interrelation, occurring over time, and having an effect upon the viewer or player. An example pattern can be identified as follows: a lighting designer sets all lights in the environment to bright saturated red light that slowly changes from 100 percent brightness to 50 percent brightness over a specific number of seconds. Lighting patterns can be observed and articulated in filmic media and interactive artefacts, as well as experienced in performance. They can also be expressed as a means of specifying illumination within design contexts, and encoded within game rendering technologies.

Lighting Patterns for Manipulating Tension

In this section, we address the question of what lighting patterns can be used to release, manipulate or parallel narrative tension. We will do so through discussing cinematic lighting techniques involving contrast and affinity used by film and theatre lighting designers to parallel narrative tension (Cheshire and Knopf, 1979; Crowther, 1989; Calahan, 1996; Gillette, 1998; Birn, 2000; Block, 2001). We have performed a qualitative study and analysis of over thirty movies within several genres, including Horror, Science Fiction and Drama. These movies include *The Cook, The Thief, His Wife and Her Lover, Equilibrium, Shakespeare in Love, Citizen Kane and The Matrix*. In addition, this study was performed by two researchers, one of whom has spent two years of training as a theatre lighting designer, and thus has gained tacit knowledge of theatre lighting design. Based on this study and experience, we have identified several patterns used to evoke or parallel tension. Before we discuss these patterns, it is important to differentiate between two types of lighting patterns used in film [2]. The first is a colour composition sustained over time, where the composition and its lack of change over time causes an escalation of projected tension. The other is a group of specific variations across colour patterns in time, where the variation in a specific order or pattern causes rise or fall of projected tension.

Figure 1: Chiaroscuro Technique used in Sacred love versus profane love Painting

An example of the former type is the use of high brightness contrast in one shot. Brightness contrast is a term we use to denote the difference between brightness of different areas in the scene. High brightness contrast denotes high difference between brightness in one or two areas in a shot and the rest of the shot. This effect is not new; it was used in paintings during the Baroque era and was termed “chiaroscuro” which is an Italian word meaning light and dark. An example composition can be seen in Giovanni Baglione’s painting “Sacred Love versus Profane Love” shown in Figure 1. This kind of composition is used in many movies to increase arousal. Perhaps the most well known examples of movies that use this kind of effect are film noir movies (shown in Figure 2), for example, *Citizen Kane,* ***The Shanghai Gesture*** **and** ***This Gun For Hire.***

Another form of contrast used in movies is the contrast between warm and cool colours (Block, 2001). This composition appeared in several movies, including The Shining which used a high warm/ cool colour contrast composition, where contrast is defined as the difference between warm-coloured lights lighting the character and cool-coloured lights lighting the background. These kinds of patterns are usually used in peak moments in a movie, such as turning points (Block, 2001).
Lower contrast compositions often precede these heightened shots, thus developing another form of contrast, contrast between shots.

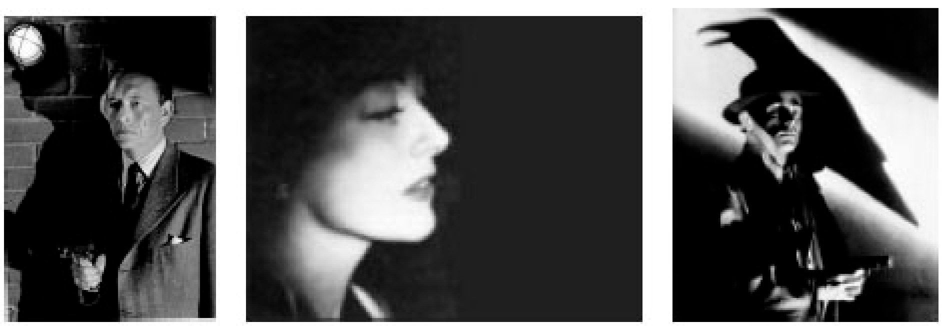

Figure 2: Film Noir uses contrasts and shadows

In addition to colour and brightness contrast, lighting designers also use affinity of colour, e.g., affinity of high saturated warm colours or unsaturated cold colours for a period of time (Cheshire and Knopf, 1979; Crowther, 1989; Calahan, 1996; Gillette, 1998; Birn, 2000; Block, 2001). Movies such as *The Cook, the Thief, his Wife, and her Lover* sustain affinity of highly saturated warm colours for a period of time. We believe that the temporal factor is key to the effect of this approach; this is due to the nature of the eye. The eye tries to balance the projected colour to achieve white colour. Hence, when projected with red colour, the eye will try to compensate the red with cyan to achieve white colour. This causes eye fatigue, which in turn affects the participant’s stress level, thus affecting arousal.

In contrast to the use of affinity, several movies used contrast between shots to evoke arousal (Alton, 1995; Block, 2001). For instance, lighting designers used warm saturated colours in one shot then cool saturated colours in the other, thus forming a warm/ cool colour contrast between shots to reflect a decrease in dramatic intensity. Some designers use saturated coloured shots then de-saturated coloured shots creating a contrast in terms of saturation; example films that used this technique include *Equilibrium and The English Patient.*

Based on these observations, we have identified twelve patterns. We categorize these patterns into the following:

1. patterns that subject an audience to low contrast images followed by high contrast images (in terms of brightness contrast or warm/ cool colour contrast) increase projected tension
2. patterns that subject an audience to low affinity of colour (in terms of saturation/ brightness/ warmth, followed by high affinity of colour, in terms of saturation/ brightness/ warmth) increase projected tension
3. patterns that subject an audience to high contrast images followed by low contrast images (where contrast is defined in terms of brightness or warm/ cool colours) releases projected tension
4. patterns that subject an audience to high affinity of colour (in terms of saturation/ brightness/ warmth, followed by low affinity of colour, in terms of saturation/ brightness/ warmth) releases projected tension
5. patterns that subject an audience to a long duration of high contrast or high affinity of colour (in terms of saturation/ brightness/ warmth) causes an increase in projected tension.

The impact of some of these patterns on tension projection has been confirmed experimentally in the psychophysics literature. For example, the effect of prolonged exposure of saturated warm colours can cause increased arousal as discussed in MacEvoy (2001).

The Use of Such Lighting Patterns in Games

The lighting patterns discussed above have been embedded in games through static design, i.e. manual definition of materials and lighting in game levels. An example of lighting patterns in games can be seen in the way lighting contributes to gameplay in survival horror games such as those in the "Silent Hill" and "Resident Evil" series. One key way in which survival horror games create their emotional effect is by maintaining a state of player vulnerability, often by suspending the player in a state of incomplete knowledge. The perceptual conditions for this state of vulnerability are enhanced through visual obscurity. Obscurity supports a sense of vulnerability (uncertainty) and is thrilling because it is makes the object of terror indistinct. It should be noted that the opposite of obscurity is not light, but clarity; thus, obscurity can be produced by anything that thwarts clear perception: darkness, atmospheric phenomena (such as fog) or occlusion (blocking by architectural objects).

Lighting patterns in these games rely on contrast, as identified in the study. The sorts of illumination contrasts that one experiences in *Resident Evil 4* (Capcom, 2005) and *Silent Hill 2* (Konami, 2001) are day/ night, light/ dark, and warm/ cool. Both *Resident Evil 4* and *Silent Hill 2* exhibit a similar day/ night cycle over the game as a whole, beginning in the daytime, followed by dusk and night and completing at dawn or sunrise. The bulk of the action in these games takes place at night, or under moonlight, though much of the action occurs in interior spaces where players are kept away from natural light. Interior spaces in *Resident Evil 4* tend to be warm, and in contrast with the cool moonlight of the outdoor spaces. Bright and dark sequences do exhibit a sort of logic in Resident Evil 4, the darkest spaces occur when one is playing Ashley: the character with the fewest resources and greatest vulnerability (Niedenthal, submitted).

Even though games use the lighting patterns identified by the study above, these patterns are often experienced in time through virtual space; their variation is often dependant upon player movement from one environment to another. While game state and tension points vary depending on gameplay, most game environments are currently built with static lighting allowing very little variation to account for tension or state change.

A System for Dynamic Lighting for Games

To investigate the question of embedding the lighting patterns identified above as a design vocabulary attached to specific game states and triggered dynamically, an intelligent system that understands the psychological effect of lighting manipulation on tension escalation and release is required. In this section, we discuss such a system. This system is composed of two subsystems: Expressive Lighting Engine (ELE), a system that allows variation of lighting parameters in real-time based on game state while balancing the lighting aesthetic properties (Seif El-Nasr and Horswill, 2004) and Temporal Dynamic Expressive Lighting Engine (TDELE), a system that was developed as an extension of ELE to allow for temporal modulation of lighting based on temporal patterns. We first discuss ELE.

ELE (Expressive Lighting Engine)

Lighting is a complex process that involves balancing many parameters, including colours, positions, angles of lighting in relation to objects, materials and colours and angles of lights used on other surfaces within the frame. Moving or changing one colour of light may change the perceptual effect of the entire image, or may make no difference at all perceptually, depending on the context and current colours used in the image. Therefore, introducing dynamic lighting requires a dynamic system that accounts for the perceptual impact given a desired effect. In order to account for such variations, we borrow from one of the authors' earlier work on an intelligent lighting, specifically the work on ELE (Expressive Lighting Engine).

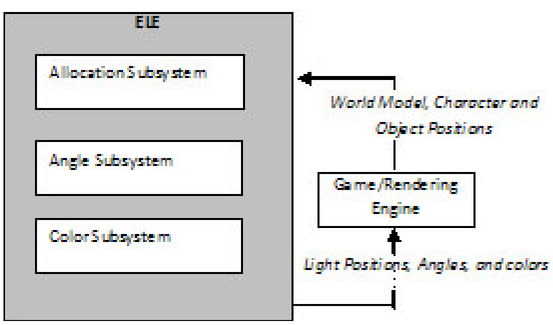

Figure 3: ELE's Architecture

Expressive Lighting Engine is an automatic intelligent lighting system developed based on cinematic and theatrical lighting design theories; it is designed to automatically select the number of lights, their positions, colours and angles given desired artistic constraints. To accomplish this task, ELE uses lighting design rules formulated based on a study of film and theatre lighting design techniques. These rules are represented mathematically in an optimization function. The use of optimization is important to balance conflicting lighting design goals. While adjusting the lighting, ELE also maintains stylistic and artistic constraints.

Expressive Lighting Engine as a black box is illustrated in Figure 3. As shown, ELE takes in several parameters, including stage layout or scene graph, character locations, local props that emit light, e.g. windows, torches, lamps, stylistic parameters including: low-key/high-key, desired depth value and importance or depth, desired direction, overall contrast level, overall palette, specific ideal saturation, warmth, intensity or hue values for particular areas in the level or scene, and dramatic intensity of the scene. Expressive Lighting Engine then emits the number of lights used, and properties for each light, including colour, angle, position, attenuation, etc. These parameters are given to a rendering engine to render the frame.

Using theatrical and cinematic lighting design theories, ELE uses stage layout or scene graph information as well as artistic stylistic constraints to device a light layout. It divides the scene into n different cylindrical areas. It then categorizes these areas as: focus (describes the focus of the scene), non-focus (areas surrounding the focus area) and background areas. This is important because a lighting designer often uses light to bring out the focus, increase depth by varying brightness or colour of lights in different areas or increase contrast (determined by colours of lights lighting focus and non-focus areas). Expressive Lighting Engine determines where to direct viewers' attention (or the focus) given the number of characters in the frame and the dramatic importance of their actions. Artists can manipulate the style of lighting by adjusting several constraints, which include desired values for depth, motivation, contrast, etc., and their importance. Using these constraints, ELE determines the number of lights to use, their locations and angles.

The interaction between colours assigned for each area in a scene composes the contrast and feeling of the entire image. Thus, ELE differentiates between the three types of areas: background, focus and non-focus. Expressive Lighting Engine calculates contrast and depth according to the difference between colours assigned to each area. Using the supplied lighting constraints, ELE uses constrained nonlinear optimization to select an appropriate colour for each individual light in the scene to balance these constraints.

TDELE (Temporal Dynamic Expressive Lighting Engine)

In order to account for the temporal dimension of lighting, we expanded ELE developing another system called Temporal Dynamic Expressive Lighting Engine (TDELE). This system includes a state that keeps track of ticks (simulation time) as well as the history of lighting colour compositions used in the past, in terms of the contrast value, contrast type, hues used, etc. Based on this state information, the desired pattern and the desired tension level, the system calculates current tension value using history of lighting values. It also calculates values of constraints, including desired saturation level, desired warmth value and desired contrast level within an environment. These values are then fed to ELE to manipulate the current frame.

We have integrated this system with the Unreal 2.5 Engine (Seif El-Nasr et al., 2005). We added an interface within the Unreal Tournament Level Editor, "Unreal Edit," to enable developers to trigger a desired lighting pattern given a specific game state. In addition, designers are also able to integrate their own tension formula and link it to these patterns.

A Brief Study: Lighting Movement in Games

When developing this system, we posed the question: “If environment lights can be manipulated dynamically in a game, what aesthetic utility can that achieve?” One possibility is to adapt the environment, lights and music/ sounds to the gameplay in a way similar to what is established in *Rez* but in a complex 3D environment. *Rez* is a great example of a game that dynamically manipulated the visuals and the sounds to suit the gameplay. While *Rez* was the first to create a dynamic environment that changes and adapts to gameplay, the visuals were simple and non-realistic.

We explored yet another possibility, which is to use the modulation of environment lighting as a method of paralleling tension and portraying criticality of the situation to the player. Using the system described above and its implementation within Unreal, we developed a first person shooter mod where we specifically made use of the patterns identified and discussed above. In particular, we increased and decreased affinity warmth and saturation of lights’ colours within the environment as a function of how dangerous the situation is to the user. Therefore, if the player is confronted with many monsters and his health is dropping over time, the warmth and saturation of colour will increase over time showing an increase in tension. While if the player is killing monsters, and danger level is diminishing, the warmth and saturation will decrease through time, releasing tension. Screenshots from several parts of the game are shown in Figure 4 [3]. It should be noted that we removed the original HUD of the *Unreal Tournament 2004* game because the lighting itself gave the player the information he/she needed through the patterns used.

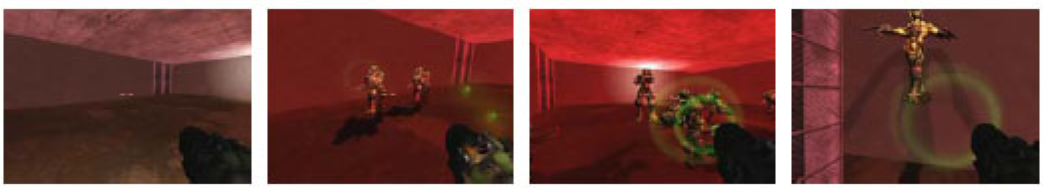

Figure 4. Change in Saturation as a function of danger

We presented an interactive demo of this system within the “Interactivity venue” in the “Computer Human Interaction CHI Conference 2005.” We set up two laptops. The two laptops ran the same game: one with the TDELE and the other with static lighting. This study was run as a voluntary study: participants were given flyers explaining the game, and then asked to play the two games and share their experience with us, if they so desired. We explained to all participants that the two laptops ran the same game, our own mod of Unreal Tournament 2004 (Epic Games, 2004). Participants were notified that one used enhanced temporal light and the other used static lighting. Each participant was encouraged to play both games. Since we ran this as an informal study, we did not ask participants to fill out surveys. However, we noted their responses.

Through observation and interaction with over 100 participants who played the game (judging by the number of flyers we handed out), we collected several interesting responses. Many participants expressed an interest in the system and voluntarily discussed their experiences with us after their play sessions. An interesting outcome was that many non-first-person shooter (FPS) players loved the game with the dynamic lighting and liked the effect of the lighting. Some noted that it was beautiful and more aesthetically pleasing to play with the dynamic lighting than with the static lighting. In addition, some commented that they saw the lighting as a method of portraying game state information, which was unique in their experience.

We also had several experienced FPS gamers play the two versions of the game. We got very different responses from gamers than non-gamers. Some gamers commented that the dynamic lighting gave them too much information and that made the game too easy. Many others were disturbed by the lighting. One observation made was that many FPS players seem to try to get themselves emotionally detached from the game. Using the lighting patterns described in this article tends to escalate arousal subconsciously, and thus might have attached players emotionally to the game. Some commented that this effect made them feel as if they were not in control of the game.

Conclusion

This article has explored the use of dynamic lighting, its potential in expanding the design palette and its impact on game aesthetics through the use of a testable prototype. The prototype consists of a temporal dynamic lighting that adapts the game lighting in real-time to modulate projected tension. This prototype was based on two research developments discussed in this article. The first is a study of cinematic lighting patterns and their effect on tension modulation, increase and release. The second is a design study that resulted in the design and development of a temporal dynamic lighting system allowing lighting to dynamically adapt to the game state while keeping the essence of the lighting design as well as accounting for its temporal dimension.

In conclusion, we would like to discuss the implication of this prototype on game aesthetics by reflecting on the responses collected in the informal study. These responses revealed many interesting insights on the use of lighting in projecting tension, as well as its impact on gameplay and game aesthetics. The range of player responses-some found the lighting to be disturbing, fearing loss of control, while others found it beautiful-is a validation of the impact of dynamic simulated illumination on audiences' affect. Clearly, strong emotions can be evoked by dynamic lighting. However, the nature of the affective responses is dependent on individual difference, preferences and previous gaming experiences, as is evident by the range of comments collected. We believe that a dynamic and responsive illumination system for games will support current game genres, as well as encourage the development of new game forms and game aesthetics. In our view, providing such dynamic manipulation of lighting can increase the designer's palette and positively affect game aesthetics. An understanding of the ways in which illumination supports play and adapts to participants' needs as they engage in virtual space, narrative, and play activities will open the door to new game experiences. Just as "Rez" explored the potential of sound in virtual space, so we hope that dynamic lighting can contribute to the sort of experience proposed by Antonin Artuad in his sketch of a theatre of the senses from 1932:

"The lighting equipment currently in use in the theatre is no longer adequate. The particular action of light on the mind comes into play, we must discover oscillating light effects, new ways of diffusing light in waves, sheet lighting like a flight of fire arrows . . . Fineness, density and opacity factors must be reintroduced into lighting, so as to produce special tonal properties, sensations of heat, cold, anger, fear and so on" (Artaud, 1977, p. 74).

In future studies, we aim to further explore these open questions. In particular, we aim to expand our investigation of lighting beyond tension manipulation looking at the roles of lighting in different aspects of game aesthetics. We also aim to explore the use of dynamic lighting in enhancing current gaming experiences as well as creating new game experiences.

Notes

1 Cel-shaded or toon-shaded rendering is a term used to denote a type of non-photorealistic rendering used to mimic the style of a comic book or cartoon.

2 While these patterns are identified as film patterns, they have been used in theatre lighting as well, and thus are not limited to film. However, since the study is based on film examples, we will use the words cinematic patterns and film patterns.

3 A video of the demo can be found at URL: [faculty.ist.psu.edu/SeifEl-Nasr/ELEUnreal.html.](faculty.ist.psu.edu/SeifEl-Nasr/ELEUnreal.html)

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