COMPLICATED SHADOWS:

THE AESTHETIC SIGNIFICANCE OF SIMULATED ILLUMINATION IN DIGITAL GAMES

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The main title of my thesis, "Complicated Shadows," has been borrowed from a 1996 song by Elvis Costello.

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I dedicate this thesis to the memory of my father Morris Niedenthal, who died while I was writing the extended introduction. He didn't really like anything having to do with the computer, but he would have been awfully proud anyway.

1. INTRODUCTION

Although I had played a number of groundbreaking computer games—*Zork* (Infocom 1980) in my college's computing center in 1981, *Myst* (Cyan 1993) in my design school's multimedia lab 13 years later—it wasn't until I slipped *Silent Hill 2* (Konami 2001) into a rented Playstation 2 in 2002 that I realized what digital games could be. My first response to repeated play sessions was nausea. Not physical sickness, not "simulator sickness" related to perceptual lag in the virtual game space (though there was a bit of that). Rather, I felt a visceral dread produced by the deep hold that the dark world of the town of Silent Hill had on me. I couldn't get those images out of my head. I realized that I was, in a profound way, responding to the simulated illumination of Silent Hill, a place where full visual understanding of a scene is almost always frustrated by atmospherics, darkness or claustrophobic, labyrinthine design. And though obscurity was the main aesthetic strategy, and terror the main effect upon me, there were amazing moments of contrasting delicacy, as when, in one room, a gentle perturbation of light and sound slowly resolved itself into a room full of moths. Moving towards the climax of the game, it struck me that here at last was the advent of the *gesamtkunstverk*, just as predicted.[1]

1 *By my former advisor, Peter Lunenfeld*

As I played through the game for the second time, I began wondering what it would be like to conceive of and execute lighting that could have such a profound effect on people. Since I had a background in lighting for filmic media and 3D computer graphics, I sought to identify with those Japanese digital artists who had kept me up so late. How had they proceeded? Had they known what do from the start? Was there a single, brilliant vision behind the game world? Or had they built their world slowly and iteratively, carefully refining their results? What was the influence of genre? Something was done at design time that had a profound effect on me and many other players.

In 2002 I had already been working with computer graphics and studying virtual worlds and digital illumination simulations for several years. It had seemed to me that the discourse related to the luminous qualities of new synthetic game environments was thin and fragmented. Although there were a few scholars in the humanities doing interesting work with virtual light (Vasseleu 2002), the "anti-visual" stance of many of their peers (see Manovich's (2001) discussion of Virilio and Jay, p. 175) made it difficult for their insights to contribute meaningfully to discourses outside of their discipline, in the area of design for example. Psychology researchers had been looking for several years at the effects of light in real space upon non-visual processes and emotion (Knez 1997, Knez 2001), but nobody outside of the field seemed be interested in exploring the ramifications for simulated illumination in virtual spaces. Digital animation had gotten to the point of developing a self-conscious design practice related to light (Calahan 2000), but the differences between interactive and non-interactive media stood in the way. At the same time, the technological development of new lighting algorithms and rendering engines moved along, programmatically exploring progressively more complex light effects and materials. This creative and interesting design process was met by skepticism from game reviewers and player communities, who responded that "good graphics doesn't equal good gameplay."

So what is the relationship between the visual qualities of a game world—specifically game lighting—and "good gameplay?" I believed then, and still do, that the answer to the question requires a multi-disciplinary effort and a lot of communication. It also requires a willingness to explore disciplinary boundaries and to take the chance that new alignments of knowledge production might provide something special that can help us move forward. What I hope will emerge from this thesis (and note: this is a spoiler) is the appreciation that simulated illumination has its own share of influence in the complex experience that is a digital game. More than just a technical means of rendering the synthetic worlds of games, simulated illumination is an aesthetic phenomenon that has a unique power to elicit the emotions that underlie gameplay, and is rooted in its own emerging design discourse.

1.1 RESEARCH PROBLEM DOMAIN AND CONTRIBUTION

My research problem in this thesis is to construct a transdisciplinary theoretical framework for understanding the contribution of simulated illumination in game worlds to the experience of gameplay. Within this larger aim, there are a few sub-goals. Since I hope to contribute to the discipline of game studies, I have sought to situate my work within the understanding of aesthetics as currently practiced in that field. Finally, since this thesis supports the application for a Ph.D. in the area of interaction design, I offer a model for articulating use qualities within the area of game aesthetics, and outline some of the concerns to be faced by game designers. The reader will note that I have given equal time to the discussions of these topics as they appear in various game design fora.

Moving the consideration of simulated illumination forward as an aesthetic discourse requires the construction of a stable foundation. The design of illumination in games has traditionally been approached as a "seat of the pants," intuitive process in an industry that is just beginning to achieve design self –consciousness (Lindley, Sennersten 2007). The fact that attitudes about illumination in digital games are so unformed requires the researcher to confront two challenges: first, to begin to extract the "tacit knowledge" concerning simulated illumination that exists within the game design community, and, second, to subject some basic theories about the effects of simulated illumination to empirical evaluation, as a means of testing assumptions, and offering back to the design community a more complex understanding of the potential effect of illumination design choices. Contextualizing this effort as an aesthetic investigation (rather than an exercise in the social sciences, or design theory) requires as well a broader set of historical and artistic references, and offers the opportunity to study the way in which the experience of simulated illumination in digital games contributes to a more widely conceived aesthetic pleasure.

The two-year *Shadowplay* research project (2005-'06) gave me the opportunity to instantiate this sort of platform for aesthetics research. We set up a small lab, where were ran a study on player responses to the effects of warm (reddish) and cool (bluish) simulated illumination in a virtual game space. We conducted a design workshop on game lighting with warm and cool light with creative practitioners (virtual architects and game design students), as well as interviews and talk-aloud sessions with game level designers. We also analyzed qualities of illumination in existing games, and speculated about the contribution of those qualities to the player's experience of gameplay.

What I hope to demonstrate in the course of this thesis is that simulated illumination matters to gameplay. More specifically, we learned that—beyond its role in the visual description of synthetic environments, and enhancing the player' sense of presence in the game world and game state—simulated illumination has an effect upon player affect and performance that can be interpreted as providing "eliciting conditions" for more complex game emotions. Moreover, our work with creative practitioners suggested an interesting correspondence between the attitudes of designers and the effects we observed in the lab. The effect of simulated illumination is manifest not just in what empirical results tell us, but also in the way in which people manipulate and speak about light. Besides specific results related to the effects of simulated illumination, this thesis offers a transdisciplinary model of conducting "middle level" aesthetics research that combines methodological rigor with breadth of artistic and historical reference, analysis of existing games, and a grasp of the interactive qualities of new digital media.

1.2 READER'S GUIDE

1.2.1 The Compendium Texts

The Ph.D. thesis you are holding is a compendium rather than a monograph. As such, it consists of a number of my previously published or submitted writings, tied together by an extended introduction (*kappa*, or jacket, in Swedish), which contextualizes the individual works and provides conceptual linkage, a sort of narrative of the intellectual development behind the writings. I have provided notes in the extended introduction directing the reader to the original articles where appropriate.

The pleasure of this type of thesis is that it represents an intellectual journey; the first article in the compendium was written almost 10 years ago. The concomitant danger is that this thesis may appear fragmented, or to lack coherence. There is always the possibility that one may shift positions over 10 years, or contradict oneself, since the articles were not originally written in relation to one another. I had no inkling when I started that I would ever complete a Ph.D. thesis. On the other hand, if I had set out to do a Ph.D. from the start, I might have followed a very different route, or may never have finished the journey.

I began the work collected in this thesis at a design institution that, at the time, was just beginning to establish its own research traditions. The fact that I wrote articles for publication and presentation in scholarly venues made me something of a curiosity. I received a little support for my work, but on the other hand was never subjected to any pressure to produce academic writings. Under these conditions, I wrote my earlier articles solely for my own pleasure, and to satisfy my own curiosity. As an amateur scholar, I assumed that every published article might be my last, so I tried to pack as much as possible into the texts. Sometimes I overreached myself; other times I was perhaps rash; occasionally the style is a bit florid. If any traces of this remain in the articles in this compendium, please understand. Where possible I have sought to clarify things in the extended introduction.

These articles also bear the marks of a convoluted educational background. Graduate studies in English literature (lots of obscure Middle English and Scots dialects) were followed by photography, computer graphics and media design. These studies allowed me to indulge my interests in darkness (Jacobean theatre, Brassai's night shots of Paris, Whistler's nocturnes, the Gothic, and survival-horror games), translucence, and radiance in many different contexts. The rise of digital games has afforded me the ideal medium in which to tie it all together.

The seven writings that comprise this compendium, listed in chronological order of composition (not necessarily publication), are:

1. Six St. Jeromes: notes on the technology and uses of computer lighting simulations (initially presented at the University of Copenhagen in 1999 and published in *History and Images: Towards a New Iconology* in 2003). This article grew out of my participation in the Digital Media Design Research project at Art Center College of Design in 1998, and was originally presented to a group of medieval art historians. In it, I sought to communicate the roots of digital light simulation, and to speculate about the potential uses of such simulations for art scholars (Niedenthal 2003).

2. Learning from the Cornell Box (presented at the *Digital Arts and Culture* conference in Bergen, Norway in 2000, and published in *Leonardo* in 2002). This article grew out of a class in new media theory at Art Center in 1999, taught by Peter Lunenfeld, and also reflected my duties as Associate director of the Office of Design Transfer (1999-2001), working to find opportunities for cross-disciplinary, project-based collaboration between Art

Center and the California Institute of Technology (Caltech). In the article, I was particularly interested in exploring creative art and design processes as embedded in two artifacts that shared the same name: the shadow boxes of Joseph Cornell, and the box in which radiosity algorithms were verified at Cornell University. This rhetorical device served to spark a meditation on digital and real-space illumination and its significance for our perceptual life (Niedenthal 2002).

3. Documents of Light: Three Case Studies and a Preliminary Model for Organizing Light Knowledge (presented at Tromsö University, Norway in 2002, and published in *A Document (Re)turn: Contributions from a Research Field in Transition* in 2007). This article was written specifically for presentation to researchers in the very interesting and radical program in library and information sciences run by Niels Windfeld Lund. In Documetation Studies, as conceived by Niels, an artwork or performance can be considered a document. My goal was to attempt to list the sorts of documentary evidence that light can provide as witnessed in the work of illumination researchers and creative practitioners in lighting design (Niedenthal 2007b).

4. Shadowplay: Simulated Illumination in Game Worlds (presented at the Digital Games Research Association 2005 conference in Vancouver, Canada, and published in *Worlds in Play: International Perspectives on Digital Games Research* in 2007). This article marked my transition to game studies, and allowed me to bring together everything I had explored to that point regarding simulated illumination, illumination in media, and digital games (Shadowplay was selected "Best Paper" at the DiGRA 2005 conference) (Niedenthal 2007c).

5. Patterns of Obscurity: Gothic Setting and Light in *Silent Hill 2* and *Resident Evil 4* (presented at the *Gothic and horror in literature, film and computer games* conference at Lund University, Sweden, 2006, and submitted to *Gaming after Dark: Welcome to the World of Horror Video Games*, an anthology of game studies writings on horror games). This article, the first of three that present material generated during the *Shadowplay* project, examines the luminous environments of two horror games in relation to the player's experience of vulnerability, and draws upon historical sources in literary theory, as well as current psychology research and eye tracking data (Niedenthal 2006).

6. Lighting in Digital Game Worlds: Effects on Affect and Play Performance (co-written with Igor Knez, forthcoming from *Cyberpsychology and Behavior*). This article presents the results of our empirical tests on warm and cool light in computer games and digital environments (Knez, Niedenthal 2008).

7. Dynamic Lighting for Tension in Games (co-written with Magy Seif El-Nasr and Igor Knez, published in *Game Studies* 2008). This article speculates on the potential of dynamically calculated (as opposed to static) lighting in games, through a new type of rendering engine (Seif El-Nasr et al. 2007).

Each article is presented with citations in the original format. Since I had to prepare the articles for reproduction here, I have taken an author's prerogative to make changes to the texts, which in some cases will depart slightly from the published versions.

1.2.2 The argument of the extended introduction

The extended introduction is composed of 6 chapters. In the chapter that follows, I seek to establish the relevance of my thesis topic in the context of the current understanding of aesthetics as it relates to digital games. I conduct a survey of representative literature from game studies, and draw as well from game design fora. Noting that discussions of "game aesthetics" tend to cluster around three main cores of meaning, I argue that the most productive path for further development of aesthetic practice is to examine the "aesthetic experience" of gameplay, and draw upon a basic description from psychology: a prototypical aesthetic experience is deeply absorbing, is experienced as whole and coherent, evokes intense feelings or emotions, and engages a sense of "make believe" (Kubovy 2000). Given the concurrent relevance of the topics of emotion, embodiment and design in game studies, I argue that a strategy for advancing game aesthetics is to look closely at the contribution of one particularly fitting aesthetic material of games—simulated illumination—to the experience of gameplay.

In chapter 3 I attempt to create a well-rounded description of simulated illumination, beginning with its procedural nature and the development of lighting algorithms, then looking at the way in which designers have begun to manipulate it as a digital material, and finally discussing the effects of simulated illumination on people. Media practice of lighting (from film) is relevant to simulated illumination in games, but I also argue that our real-space experience of light informs what we feel in simulated environments. Finally, I consider the interactive and visualization potentials of game lighting, those aspects that are unique to games. Based upon the rich set of lighting references and possibilities that are present in digital games, I offer a taxonomy of influence of simulated illumination. This taxonomy is organized such that it moves from progressively simple patterns and mechanisms that work without much player awareness, towards progressively greater complexity and consciousness of light qualities. I conclude that the effects of simulated illumination are complicated, with possible effects that are both subtle and powerful, and involving complex and often simultaneous processes.

Chapter 4, on methodology, begins with an acknowledgement of the challenges facing the light researcher studying digital games: simulated illumination has subtle workings, and digital games are rich and complex artifacts. Approaching the aesthetic experience of simulated illumination is best done, method-wise, from a transdisciplinary stance that welcomes the consideration of the cultural significance of illumination, as well as the possible contributions from more empirical experiments coming from emotion psychology. Accordingly, I propose a research method of "triangulation," in which empirical methods are complemented with design workshops aimed at accessing the "tacit knowledge" (Polanyi 1983) of creative practitioners working with simulated illumination. This effort is informed and guided by the third part of the methodological tripod—critical analysis of the effects of simulated illumination in existing games, based upon articulation of the use qualities of digital games.

Chapter 5 presents a concrete example of how such a triangulation study can be conducted, in the context of the *Shadowplay* project (2005-'06). We explored the influence of warm (reddish) and cool (bluish) simulated illumination in game environments upon the emotions and behavior of the player. Noting that variations in warm and cool simulated illumination make up an important visual dimension in the fabric of digital games in general, and *Resident Evil 4* (Capcom 2005) in particular, we constructed a prototype game environment in the form of a labyrinth and conducted a lab experiment in which we sought to evaluate the emotional influence of warm and cool light. We learned that exposure to warm light created more positive affect and led to better performance. Subsequently, we organized a design workshop in which we asked creative practitioners (virtual architects and game design students) to design the lighting of various game scenarios, working with the same hues of warm and cool light. We learned that warm and cool light have particular genre associations, and have a perceived power to attract and repel within virtual space. Follow-up interviews with game level designers confirmed these lighting attitudes, suggesting that we tend to bring certain expectations about warm and cool light to our play experiences.

Finally, in chapter 6, I discuss the results of the *Shadowplay* research activities in a more complex context with reference to the understanding of pleasure as it is developed in phenomonological philosophy and hedonic psychology (Kubovy 2003). This construct allows us a richer interpretive framework, and can account for some of the ways in which game lighting functions contextually. Within a game, I would suggest, we respond emotionally to exposure to qualities of simulated illumination, based upon what we bring with us into the game (whether based upon tastes, attitudes related to genre, memories or more "hard-wired" responses to light). At the same time, we implicitly learn the significance of the illumination that we encounter through our activity in the game. This means that there is no simple mapping of illumination quality to emotional outcome. Rather, designers need to learn to manipulate the unique potentials of simulated illumination in relation to the other elements of the gameplay experience. On the higher, more conscious levels of the taxonomy of influence of simulated illumination, light functions as metaphor, standing for something other than itself—for divinity, to take an example. The transcendent potential of simulated illumination can best be grasped by moving beyond psychology concepts, and immersing oneself instead in the power of light that is manifest in art, culture, cosmologies and magic.

2. WHAT WE TALK ABOUT WHEN WE TALK ABOUT GAME AESTHETICS[1]

Digital games exist in the realm of art and aesthetic experience. This assertion is not just a pitch for greater social credibility, it also reflects the current understanding in the new academic discipline of game studies, and is a regular topic of discussion in the game design industry. One notable formulation for describing games in their fullness and complexity (taken, in this case, from the program of a major game studies conference) is that they are an "aesthetic, social and technological phenomenon" (DiGRA 2007). But, though it could be argued that this statement now constitutes common knowledge about games, it is still not completely clear what we mean when we talk about game aesthetics, nor what aesthetics can contribute to our understanding of games and play.

Rather, questions about the aesthetic nature of digital games tend to divide both scholars and designers. The suggestion that digital games might share some of the characteristics of art, and involve players in experiences that draw upon some of our most profound sources of pleasure, is not received with unqualified enthusiasm in the games industry. "Here we go again" was the resigned response of one interviewee in a recent *Gamasutra.com* article on the question "Are games art?" (Ochalla 2007). Despite this response, it is clear that many have high hopes for game aesthetics and the sort of discussions that can emerge from the practice. In the words of another respondent to the article, "It's an extremely simplistic question, but the spirit of it is worthwhile. In essence, we're asking, 'what are video games capable of as a medium?'" This sort of question is not unusual (nor unhealthy) for the practitioners of new media to grapple with, as the histories of photography and film demonstrate.

1 *Apologies to Paul Dourish, from whom I cribbed the idea for the title of this chapter.*

The mixed feelings evident in the *Gamasutra* article represent in many ways the current attitudes towards the broader practice of aesthetics. The term "aesthetics" brings its own baggage, and admits sources of resistance that have to do with the traditional topics of aesthetics discourse, as well as the near impossibility of defining what constitutes an art object. "What (people) typically object to (in their assumptions about aesthetics) is the idea that art can be understood according to a set of universal principals about its immutable properties . . . " (Kelly 1998, p. xi). Others believe that the problem with aesthetics is not that it proposes to explain too much, but that it aims too low. Casual assumptions about aesthetics that are present in writings not specifically on the topic reveal shared meanings of the term: early in the game design textbook *Rules of Play*, for example, Salen and Zimmerman (2004) refer offhandedly to "aesthetic trappings" (p. 11) which they consider apart from the more crucial fundamental rules and core mechanics of a game prototype under development. The word "trappings" carries with it associations of décor, a thin veneer of "eye candy" that may attract attention and provide fleeting motivation, but otherwise serves as a less important part of the experience of playing (or designing) a game.

As a means of mapping current attitudes and orienting ourselves towards a productive understanding of game aesthetics, lets first take stock of the stances towards the topic that are emerging within game studies and design. Keyword searches in scholarly databases, as well as popular search engines turn up recent game studies and design articles (and other resources) that manifest 3 main clusters of meaning around the term "game aesthetics:"

1. Game aesthetics refers to the sensory phenomena that the player encounters in the game (visual, aural, haptic).
2. Game aesthetics refers to those aspects of digital games that are shared with other art forms (and thus provides a means of generalizing about art).
3. Game aesthetics is an expression of the game experienced as pleasure, emotion, sociability, etc (with reference to "the aesthetic experience").

Moving from simpler to more complex concepts, we can expand each cluster of association with reference to current writings (these understandings are not exclusive categories; many writers engage several of these meanings).

1. Game aesthetics refers to the sensory phenomena that the player encounters in the game. An example of this can be found in the gameinnovation.org tax-

onomy supported by the Carnegie Mellon Entertainment Technology Center (Schell 2006), which considers digital games according to the following categories: game mechanic, computation, interface, aesthetic, story, genre, and business. According to this taxonomy, ”Aesthetics relate to the way a game looks, sounds, and presents itself to the player.” This includes visual aesthetics: “A graphical innovation is any innovation that affects the way a game is visually perceived,” as well as character aesthetics, music and sound effects. Writers coming from this perspective sometimes use game aesthetics as a platform for discussing game graphics or visual styles. Hayward (2005), for example, takes aim at photo-realism, which he sees as the dominant aesthetic of videogames. He uses a modified version of Scott McCloud’s “picture plane” triangle to sketch alternatives that allow for less common, more abstract formal vocabularies (McCloud 1994). The focus upon sense and perception in this understanding of game aesthetics echoes the etymological roots of the word in the Greek *aisthesis*, which means sensation or perception. Further, aesthetics as it developed in the classical period was a means of doing justice to “sensory knowledge” (p. ix) as an alternative to logical or rational ways of knowing (Kelly 1998).

2. Game aesthetics refers to those aspects of digital games that are shared with other art forms. Digital games share certain forms, aims, content, themes and design practices with other media and types of art, which allows for comparison and generalization. These speculations can go both ways—Hayward (2005) considers ways in which an awareness of the history of contemporary sculpture could support new, non-photoreal formal vocabularies in games. On the other hand Quaranta (2006) traces influence in the opposite direction: the impact of computer games and modding culture on the current gallery scene. Once again, there is an historical echo here: as aesthetics discourse developed in the 18th century, it was deployed in opposition to the practice of writing treatises on specific art forms. However, there continues to be debate within aesthetics on the wisdom of generalizing about art (Kelly 1998).
3. Game aesthetics is an expression of the game experienced as pleasure, emotion, or sociability. According to this understanding, games are approached as artifacts that have the potential to give rise to an aesthetic experience. The somewhat open-ended nature of this kind of experience has drawn a number of writers, who, in some cases, characterize the aesthetic experience of a game as ”fun” (further subdivided by Hunicke et al (2005) into a

taxonomy of 8 different player goals and emotional states), in other cases, as ”pleasure” (further elaborated by Lauteren (2002) through constructs drawn from psychoanalysis, social identity and Barthian *jouissance*). Drawing upon Kant, Kirkpatrick (2007) identifies the aesthetic experience with ”the play of imaginative and cognitive faculties” (p. 75).

Though this brief survey casts a wide net, the intention is to sketch the emerging attitudes towards game aesthetics in game studies and design communities. We can draw a few conclusions. First, the popular understandings of ”game aesthetics” mirror the larger development the aesthetics discourse itself; the clusters of meaning that have emerged in current literature can be traced back to different conceptions within aesthetics as it has historically been practiced. There is, however, no widely shared, comprehensive meaning of game aesthetics that is any more specific than the very inclusive definition of general aesthetics offered by Kelly (1998): the practice of aesthetics consists of ”critical reflection on art, culture and nature” (p. ix).

Secondly, game aesthetics is not linked to any one critical framework. There are no analytical tools that are inextricably bound to game aesthetics at present. Several writers have drawn upon semiotics as a theoretical foundation (Lauteren 2002, Myers 2005), while others refer to psychoanalysis and feminist film theory (Lauteren 2002), media studies (Hayward 2005), cultural theory and philosophy (Kirkpatrick 2007), or contemporary art theory and practice (Quaranta 2006). This can be read as a strength: aesthetics is a capacious practice, “uniquely situated to serve as a meeting place for numerous academic disciplines and cultural traditions” (Kelly 1998, p. ix). In its theoretical indeterminacy, pursuing game aesthetics has come to resemble the research practice sketched by Aarseth (2003), in which aesthetics constitutes one of the possible ”modes” of the ”playing analyst” (p. 6) who is free to apply whatever theoretical foundation she chooses. Aarseth locates the proper focus of game aesthetics in exploration and analysis of game worlds (rather than gameplay or rules). But, in the end, researcher integrity and methods of inquiry are clearly of greater interest to Aarseth than offering a comprehensive definition of what constitutes game aesthetics.

As it is currently pursued, then, writing from a game aesthetics perspective is a somewhat amorphous practice. Given the tendency of some to link aesthetics to the sensory presentation of games, with generally negative associations of game graphics and ”eye candy,” the outlook for an aesthetic approach to games would appear not particularly vibrant. And, in fact, if one merely sums up the number of times the word "aesthetic" appears in keywords, abstracts and paper titles from the bellweather Digital Games Research Association (DiGRA 2008) conferences from 2003-2005, there seems to be a drop-off in scholarly interest (In 2003, 7 papers contained references to "aesthetics;" in 2005 (a larger conference) only 4 papers did so. At the 2007 conference (on the theme "Situated Play"), the term "aesthetics" was conspicuous in its almost total absence).

It is worth the effort to seek an expanded and revitalized role for game aesthetics. The sorts of discussions that an aesthetic approach has spawned are too rich to abandon just because the term has become troublesome. Moving game aesthetics forward, however, requires taking a more nuanced look at the core meanings of the term that have emerged in game studies thus far. The first core of game aesthetic associations—linking aesthetics to the sensory qualities of games—has the benefit of supporting discussion of the way in which gameplay is rooted in our physical being. A perspective on games as a play of the senses, sensory play, has not been adequately developed in game studies. Our terms of reference for understanding sensory experience are currently somewhat impoverished, making it difficult for us to approach aesthetic experience as something more than a superficial sensation (think "aesthetic trappings"). This lack of a deeper vocabulary tends to mire the design discourse rooted in this understanding of game aesthetics in graphics style analysis (Hayward 2005). Still, there are grounds for hope with this approach, coming from geography (Rodaway 1994) and cultural studies (Howes 2005). Both approaches are interested in exploring ways in which our sense knowledge functions as a cultural construction. In addition, Howes' approach has the higher-level goal of questioning, and posing alternatives to linguistically-derived forms of critical analysis such as semiotics. Perhaps through this approach we can reclaim some of the classical understanding of sense knowledge as an equal alternative to rational ways of knowing.

The second core of associations of the term game aesthetics—that which supports broader comparisons between games and other art forms—is a bit more problematic. The further development of game aesthetics will take place in a scholarly landscape in which a great deal of energy has gone into establishing the primacy of play as the locus of game meaning. Game studies as a discipline has arisen over the past decade or so, and has been shaped by scholars coming from a number of different fields, including film and media studies, literature, cultural studies, sociology, psychology, computer science and human-computer interaction (or HCI). Each has brought their own perspective and methodology. While this has created an exciting ferment, it has also been somewhat difficult to move the emerging discipline forward. One means of doing so has been through the practice of ludology, a particular orientation within game studies that focuses on the primacy of play and player activity. As developed by Juul (2003), Frasca (2008) and others, ludology attempts to locate a core understanding of digital games by considering their inherently playful nature and comparing them to other types of non-digital games. This has led to the renewed appreciation of earlier play and game researchers such as Sutton-Smith, as well as to the favoring of specific research strategies. Juul, for example, who has a design background, regularly isolates particular qualities of play by studying earlier or simpler games, or self-developed game prototypes (Juul 2003). At the same time, a debate has emerged between ludologists and ”narratologists,” those scholars who apply concepts derived from literary studies to the new medium of digital games, approaching them as forms of interactive text (Ryan 2001) (see also the discussion of this debate in Kirkpatrick).

Despite the cautions of ludology, it is clear that comparing and contrasting digital games to other art and media forms can help us gain a better understanding of the newer medium. Mitchell (1998), for example, engages the new medium of digital imaging in the traditional discussion between photography and painting, and reframes the debate in a way that re-establishes a new relationship to old forms. From a ludological perspective, problems arise when we deal with games *as if* they were merely new manifestations of older forms. However, within a design context, this particular meaning of game aesthetics—comparing games to other art forms—returns us repeatedly to the ultimately unproductive question “are games art?” As has been demonstrated numerous times recently (Arey 2008, Preston 2008), this question tends to founder upon individual interpretations of the current, very open definition of what constitutes an artwork (see Kelly, above), rather than upon failure to appreciate the artistic qualities specific to digital games.

Focusing our energies instead upon the third understanding of game aesthetics allows us to finesse this problem. Both art and games ultimately aim at the aesthetic experience. Whether or not we believe games to be works of art, it is undeniable that games can give rise to an aesthetic experience, as currently understood. A prototypical (visual) aesthetic experience:

1. Is one in which attention is firmly fixed upon . . . components of a visual pattern
2. Excludes the awareness of other objects or events
3. Is dominated by intense feelings or emotions
4. Hangs together, is coherent
5. Involves “make-believe” (Kubovy 2000, p. 188)

Even this very basic definition of the aesthetic experience maps quite nicely to a number of important terms within game studies, moving us immediately deeper than the question ”are games art?” allows us. The emphasis upon attentiveness, absorption and wholeness in the play experience can be identified with the immersive (Ermi, Mäyrä 2007) and ”flow” qualities of digital games (Csikszentmihalyi 1990). An aesthetic approach to games as sites for ”make believe” allows us to focus on the qualities of fictional worlds in games, the roles we can take on, as well as the mechanisms through which games involve our participation, such as Huizinga's (1955) notion of games as existing in a ”magic circle” in which the normal rules of our lives no longer apply. These terms also resonate well with the desired outcomes of successful game design. Game designers themselves, for example, frequently speak about creating games that are "tight" (cohesive) as essential to fashioning a good play experience (Bergholz 2007).

The coupling of aesthetic experience to intensity of ”feelings or emotions” perhaps offers the most compelling reason for seeking a revitalized game aesthetics. Why is it that we experience pleasurable anticipation before launching into our favorite game? What are the qualities of that pleasure? What compels us forward as we play? What particular sequences and experiences do we remember and reflect back upon after we play? What are our favorite genres, games, or play memories? There are questions that have historically been addressed within the study of other art and media forms, and can be further fleshed out in relationship to our experience of play. Aesthetics discourse affords a means of doing justice to our most profound experiences of gameplay, as well as helping us gain a better understanding of what makes playing (and designing) games worthwhile.

If we want to fully understand the sort of emotion and pleasure we experience in games, we must acknowledge the body. Current thought on emotion emphasizes the importance of embodiment and embodied cognition, the fact that our feelings arise within, and are shaped by our corporeal being (Niedenthal 2007a). According to this view, feelings and emotions do not take place exclusively in the brain; rather, they emerge and are re-experienced through a complex loop between brain processes, physiological processes, and musculature. According to P. Niedenthal,

> "In theories of embodied cognition, using knowledge—as in recalling memories, drawing inferences, and making plans—is thus called "embodied" because an admittedly incomplete but cognitively useful reexperience is produced in the originally implicated sensory-motor systems, as if the individual were there in the very situation, the very emotional state, or with the very object of thought. .. . The embodiment of anger might involve tension

> in muscles used to strike, the enervation of certain facial muscles to form a scowl, and even the rise in diastolic blood pressure and in peripheral resistance, for example" (p. 1003).

Thus, the aesthetic experience of intense "feelings or emotions" is implicitly an embodied experience.

Play, embodied emotion, and design are three major topics of concern within the discipline of game studies today. A revitalized game aesthetics ought to take on these concerns: first, aesthetics must acknowledge the ascension of the ludological trend in game studies: thus, what is the relationship to play? Second, given the general interest in embodiment within interaction design (Dourish 2004), what can game aesthetics tell us about embodied interaction in digital games? And third, in an era of modding and player-created content, what is the relationship between game aesthetics and creative design activity?

2.1 PLAY AND AESTHETICS

It is clear that game aesthetics has been hobbled by its association with visual styling and static elements in game worlds. But a revitalized game aesthetics must prioritize the interactive nature of digital games, in which the player can rearrange the digital materials of the game artifact over time through their own agency and activity. Game studies researchers rightly prioritize the activity of the player: as interactive artifacts, games give rise to aesthetic experience *through* play. A revitalized game aesthetics claims the primacy of the aesthetic in the play experience. This is exactly the bold argument made by Kirkpatrick (2007), who situates the central concept of the ludological study of games—play—within aesthetics discourse. According to his argument, play inheres in aesthetic experience, and is only incidentally present in games (which are the focus of ludology, as sites of structured play): "most importantly, play features prominently in the inner life of art and in the reflective discourse of philosophical aesthetics . . . What Kant means by play in this context refers primarily to imagination and its relationship to cognition" (p. 80).

Further, the traditional associations with the purely visual presentation of games represents an inadequate understanding of what constitutes game aesthetics:

> ”It is not because they are visually pleasing or stimulating to the senses that computer games are aesthetic. It is because they facilitate play and have the kind of form that corresponds to long-standing ideas about aesthetic experience as an autonomous sphere of value. The value in question here can be understood in Kantian terms, as a hint at the divine, or, in Adornian terms, as sparking a sense of the magical” (p. 81).

Drawing further upon Kant’s aesthetics, Kirkpatrick refines the relationship between a ludological and an aesthetic understanding of the status of digital games: ”positioning the computer game in this way, it becomes clear that it stands somewhere between the traditional ’game,’ which structures play, and the aesthetic object or ’artwork,’ which works by stimulating the play of imaginative and cognitive faculties in the subject of the aesthetic experience” (p. 75). Kirkpatrick quotes Kant to demonstrate that the sort of play of faculties that Kant has in mind is not purely an intellectual exercise, it felt in the body as well:

> ”Music . . . and what provokes laughter are two kinds of play with aesthetic ideas . . . the quickening effect of both is physical, despite its being excited by ideas of the mind, and . . . the feeling of health . . . makes up that entire gratification of an animated gathering upon the spirit . . .” (p. 81).

2.2 EMBODIMENT AND THE AESTHETIC EXPERIENCE

It may seem paradoxical to speak of embodied interaction in games. After all, digital games are often pilloried for contributing to a sedentary lifestyles and thumb mutations. With the launch of game platforms such as the Wii, however, which have physical interfaces through which a player can actually work up a sweat, the question of embodiment in games no longer seems so farfetched.

Torben Grodal, whose work is rooted in the study of the psychology of film viewing, further expands the way in which ”cognitive faculties” are engaged in the aesthetic experience of games, by emphasizing the links between perception, emotion, cognition and motor activities of the player. Grodal (2003) argues that instead of considering digital games as representations (and thus analyzing them via media theory or semiotics), they are best approached as interactive artifacts that achieve their power by placing the player in situations that engage mechanisms drawn from real-life experiences.

Grodal is interested in the way in which digital games differ from non-interactive media, particularly the way in which player can affect the game state through motor control: ”by providing an ”interactive” motor dimension to story experience the computer adds a powerful new dimension to the possibility of simulating first-person experiences” (p. 138). This dimension of digital games makes them more likely to support specific emotions and experiences. The centrality of the motor dimension ”makes emotions supported by sympathetic (fight or flight-related) reactions based on coping more probable than emotions supported by parasympathetic reactions based on acceptance and relaxation, and first-person emotions more probable than third-person (empathetic) emotions” (p. 151).

Although this contention has a certain predictive value (with regards to the popularity and appeal of first-person shooter games, for example), Grodal's somewhat limited analysis does not account for more nuanced game experiences, nor for the entire range of game types. How, for example, would Grodal accommodate the sort of struggle that occurs in *Shadow of the Colossus* (Sony Computer Entertainment 2005), in which defeat of the colossi is accompanied, not by feelings of ”triumphant aggression,” but by melancholy? Near the end of his analysis, however, he points out that some games do a good job of evoking ”lyrical-associative experiences:”

> ”the pleasure of such *Myst*-type adventure and mystery games is partly a series of associative and contemplative situations and feelings, in which the associative processing of perceptual input is just as important as the motor output. Such static associations cue feelings, that is, general emotional states without specific objects or specific action tendencies . . . Such ”passive” feelings of a mismatch between grandiose input and blocked output were called ”sublime feelings” by the preromantic and romantic poets, and the quest for sublime feelings is one of the main parasympathetic reactions cued by video games, as an alternative to the dominant aesthetic of sympathetic control” (p. 151).

Grodal correctly notes that our experience of games varies over time as we progressively master them, and he asserts that the aesthetic experience of playing is an ”aesthetic of repetition.” His perspective focuses upon learning, and he begins by pointing out that, historically, games have served as sites for ”repetitive training of coping skills.” In contrast to non-interactive stories, such as tragedy, the repetitive and, more importantly, reversible nature of games makes them feel less serious, and also serve as a venue for learning.

> ”. . . video games provide an *aesthetic of repetition*, similar to that of everyday life. A film is mostly experienced as a unique sequence of events, and we do not learn the physical outlay of a given simulated world very well, we are carried from space to space. In everyday life, however, we repeat the same actions over and over in order to gain mastery . . . the video game experience is very much similar to such an everyday experience of learning and controlling by repetitive rehearsal” (p. 148).

The limitation of Grodal’s argument here is that it doesn’t tell us much about the motivation to play games. Although we may practice skills in games in a way that is present in our interaction with the world, we clearly enter game worlds for an emotional payoff that is different from that of our quotidian existence, just as we do when we engage other non-interactive media such as books and films. Though Grodal’s argument illustrates the social utility of gameplay, focus on learning and coping skills helps us understand just a part of the aesthetic experience of games. Anticipation and desire are also, as we shall see, important elements of game aesthetics.

2.3 AESTHETICS AND GAME WORLDS

Embodiment in games is not just a function of engaging motor control, it can also be traced in the player’s relationship to game worlds and the play context. As we have seen, Aarseth (2003) locates the focus of game aesthetics in the analysis of game worlds (as opposed to the rule sets that underlie games and player activity). The relationship between player and context is an important site to explore for a deeper understanding of how embodiment works through digital games. In this task, we can draw upon recent interaction design theory of Paul Dourish, who mines phenomenology, as well as the ecological psychology of J.J. Gibson and Polyani’s concept of ”tacit knowledge,” to develop his own conception of embodied interaction (Dourish 2004).

The lesson that Dourish draws from phenomenology is that it is impossible for us to understand and design interactive systems in isolation; embodied interaction means that we must take the physical context of interaction—in its greatest extension, the world—into account. It is our activity in and through the world that is the source of meaning: "we find the world meaningful primarily with respect to the ways in which we act within it" (p. 125). Dourish is skeptical about whether 3D simulations constitute a significant world (he refers to the world of a computer game as a "metaphor" rather than a "medium" for action), but, as we have seen in the work of Grodal, it is fruitful to consider engagement with the game world as an analogy of real-world activity. Game worlds in this sense shape player exploration and action, and enable particular kinds of play. They are much more complex than simple containers, or placeholders for visual styles. Of importance to Dourish, and of particular relevance to this thesis, is the work of J. J. Gibson, whose ecological psychology emphasizes the activity of movement and exploration in the process of perception. The structuring of visual information through illumination is one of the important concepts in his work; our luminous environment is a crucial component of our actions (Gibson 1986).

Dourish's skepticism can also be addressed by placing the 3D world in its wider play context: the space around the console or monitor. It has become a commonplace that digital games are a "lean forward" medium, TV a "lean back" medium (Bogost 2007). This is perhaps the first degree of game embodiment. Scholars who have studied the couch and spaces of media use (Klastrup 2003) point out that space surrounding 3D game worlds makes them social, even in the case of single-player games. From a perspective of aesthetics and embodiment, we could say that the 3D game world is experienced in relation to our own bodily experience of surrounding space, through musculature, our senses, and our sense of equilibrium. The embodied and aesthetic experience of digital games could be compared to looking at a Baroque ceiling, to which we might respond with both wonder and vertigo.

2.4 GAME AESTHETICS AND CREATIVE PRACTICE

If our experience of luminous environments is one aspect of our aesthetic response to a game, we could say that the design of such environments is another. That design activity is increasingly performed as much by players as by people working in game companies. The world of digital games incorporates a substantial amount of overlap between players and designers, and, in an era of modding and player-created content, it is increasingly difficult to separate understanding games from understanding the process of creating them. To extend Aarseth's (2003) argument, games researchers need to be more than "playing analysts," they also need to have insight into game design and design process. Game aesthetics offers a useful point of connection between the experience of playing a game, and the goal of the design process. It is the aesthetic experience of play that players seek, and that designers design for.

One point of aesthetic contact between players and designers occurs through the repetitive nature of gameplay. Grodal (2003) points out that insight into the creative choices of the designer is implied in the final stages of game mastery: "our experience of 'art' is based on our insight into the way in which a given creator realizes specific intentions that are only fully understandable as a choice selected among several possible options, and this demands expertise" (p. 144). It is through game mastery that players and designers meet. And, increasingly, the creative roles that designers and players take on have begun to fade into one another.

2.5 MOVING FORWARD WITH GAME AESTHETICS

Based on this overview, it is possible to argue that there are a number of pressing individual topics in game studies that can be explored and perhaps accounted for by an aesthetics perspective. But what direction should we take to further develop it? We have seen that the aesthetic experience of digital games is realized through embodied play, and functions also as a site for understanding and practicing creative decision-making. Grodal offers a foundation in cognitive psychology for understanding game mechanisms, but fails to outline the pleasure of games in a nuanced way. Clearly, we need to return to Kirkpatrick's (2007) formulation: game aesthetics needs to further explore the way in which games stimulate "the play of imaginative and cognitive faculties in the subject of the aesthetic experience" (p. 75).

One way of further developing game aesthetics in this manner is to cut a thin slice through a complex system, by focusing on just one part of the aesthetic material of existing games. Simulated illumination—the lighting we experience in game worlds—is just such a material. Simulated illumination as a phenomenon in games engages all the emerging associations of game aesthetics: it is a sensory phenomenon, it allows reference to illumination and creative practices in other media and art forms, and, as we shall see, it inflects the aesthetic experience of embodied play through its contribution directly to the emotions, as well as indirectly through the visual information that helps the player establish a relationship to game worlds. Further, light in games has broader thematic gameplay significance as a player goal (”bring light to the world” in *Okami* (Clover Studios 2006), or ”knock out the lighthouse lantern” in *Splinter Cell: Chaos Theory* (Ubisoft 2005)), as well as moment-to-moment tactical significance as players negotiate the game (”do I turn on my flashlight, or grab my weapon?” in *Doom 3* (Id Software 2004), or ”do I turn on my flashlight and attract zombies?” in *Silent Hill 2*). Finally, the design of simulated illumination is a recognized subtask within game design, and it has its own developing creative practice and discourse.

Game lighting might seem to be an odd point of entry into a new discourse on game aesthetics. Why not develop a new aesthetic superstructure? Simulated illumination is but one of the aesthetic materials of the game designer, and is ultimately of secondary interest to the player. People don’t play games because they want to experience light qualities, they play for the way the game makes them feel, the roles they can take on, the worlds they can be transported to, the challenges they can surmount. Game lighting may seem to be too quiet a craft to deserve this much focus. But this thesis will argue that studying a background aesthetic phenomenon in games can inform the way we understand the foreground play experience, in a new way.

3. WHAT IS SIMULATED ILLUMINATION?

The jumping-off point for our consideration of the nature of simulated illumination is a quotation from Lev Manovich (2001): "the visual culture of the computer era is cinematographic in appearance, digital in the quality of the material, and mathematical (that is, guided in the program) in its logic" (p.27). This multi-faceted assessment captures the complexity of digital artifacts, which are produced algorithmically, and experienced according to our habits of participating in other media, as well as our manner of acting in the world. A rich understanding of simulated illumination within games thus calls us to explore not only the way in which virtual light is produced, the nature of the digital material and how designers manipulate it, but also—in the fullest sense—its effect upon people.

3.1 SIMULATED ILLUMINATION IS PRODUCED ALGORITHMICALLY

Simulated illumination exists first as part of a digital simulation: "A simulation can be defined as: a representation of the function, operation or features of one process or system through the use of another" (Lindley 2003). A digital illumination simulation is thus a representation of light through computation, and has as a final output a pre-computed image, or, as in the case of games, an environment in which certain effects of light are calculated in real time by the rendering engine, according to light algorithms that take into account the illumination and surface information present in the synthetic scene (Note: in this section, I am drawing from, and at times paraphrasing material from compendium texts 1-3).

Light is a highly complex and multi-faceted phenomenon to simulate. In terms of its scientific nature, light remains a puzzling limit case: its nature as either wave or particle makes light the quintessence of modern uncertainty (Park 1997). But of course we don't attempt to replicate the behavior of light at the quantum level, but rather at the level of our visual experience. The calculation of light effects in an illumination simulation is carried out through the relevant digital equivalents of real-space light characteristics and behavior. Light in real space is specified and manipulated through certain basic characteristics. In an attempt to develop a system of light "notation," lighting designer Louis Clair (2003) draws upon a combination of quantitative and qualitative measures and ideograms to express these characteristics:

1. Brightness or luminance (which in real space can be measured in lux or lumens, depending upon whether the measurement is carried out at the source or an illuminated surface).
2. Color (as expressed through color rendering index, measured through degrees Kelvin, or specified through chromatic diagrams or verbal descriptions).

3. Lighting distribution, direction and movement from the source (which can be indicated with a system of arrows).
4. Shadow quality (shadow density and hard or soft shadow edge quality, which can be indicated with special ideograms).
5. Illumination contrasts (between background, structure and openings, which can be represented through a series of nested squares) (p. 71).

Not all of these measures are relevant or possible for digital simulations, but all of these characteristics are (or can be) taken into account by game rendering engines. The color of light emanating from a source in a lighting simulation is specified by an RGB value. The way in which that light is distributed from the source (as a point source, or constrained to the cone of spotlight) and the spatial contribution of light to the simulated scene can be specified in code, or interactively in the synthetic scene through the interface of 3D software (seek figure 1).

The richness of light as a topic of intellectual and artistic history is present in microcosm in the design of algorithms for lighting simulation. The history of the digital simulation of light incorporates the scientific exploration of light and visual perception, as well as the history of art and visual media, as translated through the need for economy of computation. The narrative of light algorithm development reflects above all the struggle to recreate a complex phenomenon and to humanize digital simulations.

Designing a simulation requires telling choices to be made; attitudes towards the subject of a simulation can be read in the priorities that are set as the simulation is developed. According to emerging attitudes towards simulation, the process of simulation development includes:

1. Acquisition of valid source information about the referent
2. Selection of key characteristics and behaviors
3. The use of simplifying approximations and assumptions within the simulation
4. Fidelity and validity of the simulation outcomes (Wikipedia, accessed 8/01/2007)

Addressing each of these points in turn can help us understand how lighting algorithms have developed.

The source information about light that has been incorporated into common lighting algorithms includes discoveries about light dating back to the 9th century Arab philosopher Al-Hazan (specular reflection), and includes 17th and 18th century contributions by Newton (the inverse square law, used to calculate attenuation of light intensity over distance) and Lambert (diffuse reflection as a function of angle of light incidence) (Park 1997). More complex characteristics of light that have been recently incorporated into digital light simulations include diffuse interreflection and color bleed, which is modeled in radiosity renderers using logic based upon conservation of energy (Goral et al. 1984), and caustics (specular refractions cast on diffuse surfaces), calculated by photon-mapping algorithms.

The complexity of light as a phenomenon has imposed stringent economies and numerous simplifying approximations and assumptions upon computer-based light simulations. Earlier algorithms favored the recreation of direct light effects over more complex shading and indirect effects of light. Raytracing algorithms reduce the complexity of light behavior in a space by considering only rays that are visible from a viewpoint (see figure on p. 137). As Mitchell (1998) points out, this particular design choice recapitulates the practice of perspective construction. Real-time renderers, such as those used in games, have imposed much more extreme economies. Historically, these approximations have reduced the number of light sources calculated, as well as the complexity of light effects rendered, though the current crop of rendering engines can reproduce much greater complexity of illumination effect.

The validation of the results of lighting simulations has taken various forms. Several light algorithms have been framed with the ambition to produce images that are "indistinguishable from live action motion picture photography" (Cook, Carpenter & Catmull 1987, p. 95) and, indeed, the Phong algorithm was validated by comparing digital renderings with photographs of similar subjects (Phong 1975). Other algorithms have been validated by comparing simulated light values from a virtual space with photometric readings taken from a real-space equivalent (Goral et al. 1984).

The history of light algorithm development is exciting in itself when studied as a creative activity. Light algorithms can be considered as meta-documents that contain not just sequences of variables and operations, but also reflect higher-level attitudes towards the history of light exploration, and visual perception, as well as towards art and media. This can be traced even in the design of validation environments, such as the Cornell University box, that evoke the sort of light environments simultaneously explored by artists such as James Turrell (Niedenthal 2002). But the refinement of light simulations towards greater visual verisimilitude should not be read simply as a confirmation of the ascendancy of photo-realistic media aesthetics; the simulation of progressively more subtle light effects also serves the sorts of human perceptual needs that are embedded in our way of engaging our environment (Gibson 1986). Whether light exploration occurs within computer science labs, or artists' ateliers, certain broader urges are shared: to humanize extremes by recreating the intimate, or to participate in the sublime of the limitless.

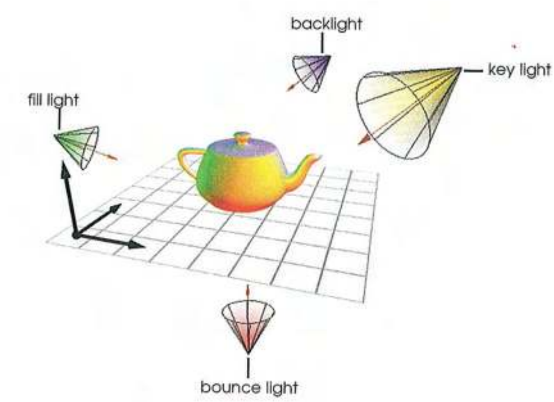
3.2 SIMULATED ILLUMINATION IS MANIPULATED AS A DIGITAL DESIGN MATERIAL

As a design substance, light has long been acknowledged as the basis for our perception of form and space, but there is a new awareness of its deeper effects upon people. Light and its effects can be richly evocative—light can be manipulated as sense phenomenon, as mood or attention regulator, or as the binding element of filmic media and architecture. Adding to its design potential, light has traditionally held a profound cargo of symbolic and metaphorical associations, as witnessed in theologies and cosmologies of light (Note: in this section and the following, I am drawing from, and at times paraphrasing material from compendium text 4).

The synthetic environments of digital game worlds afford the game artist tremendous control over the visual properties of surfaces and materials; indeed, a simulated game world must be created essentially from scratch. The creation of a game world within 3D software is accordingly an activity of specification and synthesis of material and illumination qualities, in contrast to the creation of a real-world fictional space (in film production, for example), in which selection of existing materials, environments, surfaces and objects is a greater part of the balance of artistic activity, and in which illuminating these surfaces is considered a separate competency. Given this difference, one might, in the case of digital games, be tempted to jettison the distinction between illumination and surface qualities, and speak only of perceived color (the conflation of illumination and surface qualities as produced by the rendering engine is popularly summed up in the term "graphics").

There are, however, good reasons for retaining simulated illumination as a focus, and considering its unique contribution to the aesthetic character of digital games. Even in virtual spaces, light, as opposed to color, is a spatialized phenomenon; its propagation through space and interaction with surface are calculated at

Figure 1: How a virtual scene might be lit.



varying degrees of fidelity in the rendering process. This spatialized characteristic of light is very much in keeping with the key characteristics of new media artifacts, which are, as Manovich notes, built upon the experience of navigable virtual space (Manovich 2001). Further, emphasis upon the spatialized nature of light in virtual environments allows us to better access the lighting knowledge of creative practitioners who work in real space and media.

In a game design context, simulated illumination is embedded in the filmic vocabulary of the 3D software (Maya, 3DS Max, etc) used for game production, and is a part of the design workflow influenced and executed by art directors and level designers. Currently lighting design practices for games borrow substantially from traditional media, including animation, film, and theatre. Game lighting designers manually add lights, position them within 3D virtual space, and identify colors for each light depending on the game level and current mood, genre and style of the game.

Sharon Callahan, a lighting designer at Pixar, a company that produces computer-generated animations, proposes the following design goals when lighting the synthetic scene:

1. Directing the viewer's eye
2. Creating depth
3. Conveying time of day and season
4. Enhancing mood, atmosphere and drama
5. Revealing character personality and situation (Calahan 2000, p. 338)

The task of lighting design thus incorporates both descriptive elements directed towards helping a viewer take in visual information and make sense of a scene, as well as higher-level goals that are directed towards emotion and the understanding of more complex narrative structures. All of these goals can be seen as supporting the different components of the aesthetics experience: attentiveness, absorption, coherence, emotion and "make believe."

These aims also reflect the largely cinematic influences upon Pixar's pre-rendered animations; similar goals exist within film lighting as well. Particularly constraining, in the case of pre-rendered animation, is the fact that a film shot is projected for a finite amount of time, often very short, from a single perspective, onto a flat screen. This fact creates proportionately greater emphasis upon the descriptive task for the digital lighting artist in an animation company; they face the need to make sure that a certain quantity of visual information is communicated in a limited time. In the case of interactive media, such as games, the player can theoretically take as much time as they want to view and move through a scene, and can experience it from multiple perspectives, which helps simulate depth. Although scene description is also an important, basic goal in game lighting, there is more of an opportunity to begin to explore the emotional content of lighting in interactive media.

3.3 HOW WE ENGAGE SIMULATED ILLUMINATION

3.3.1 Simulated illumination draws upon our experience of light in other media

Manovich's assertion that "the visual culture of the computer era is cinematographic in appearance" must, in the case of digital games, be qualified. A filmic vocabulary and lighting design practice is embedded in the 3D software that is used to produce game environments, and there are elements of games—such as pre-rendered cut scenes—that by their nature invite comparison to film. Moreover, certain larger lighting strategies that relate to game genres, face lighting conventions, time of day, narrative elements and mood respond to filmic lighting concepts (Niedenthal 2007c).

There are, however, important differences between films and games. Film images are created from a particular, fixed perspective, and lighting decisions are made accordingly. Games, on the other hand, are interactive, allowing for free navigation, and the position of the player in virtual space cannot be assumed (Seif El-Nasr et al. 2007). In this sense, the game lighting task likens that of the architectural lighting designer. Further, as Grodal points out, the sort of motor control afforded in games tends to evoke first-person emotions rather then the third-person emotions of film, and thus tend to simulate real-world patterns of interaction.

3.3.2 Simulated illumination is analogous to our experience of light in real space

It has been said[1] that we take a subset of our senses with us into any virtual environment, and it can be argued that our experience of simulated illumination is thus analogous to our experience of light in real space. The precise terms of this analogy remain to be discovered by further research. Clearly our experience of light in games is not identical to our experience in the real world; light effects in games are mediated by a screen (occupying only a portion of our visual field) that presents a limited range of illumination. Moreover, simulated illumination often does not account for all the characteristics of real world light. Still, according to Gibson, our encounter with illumination even in a representation or simulation qualifies as a direct response to light: "a picture," he writes, "is a surface so treated that (it) contains the same kind of information that is found in the ambient optic arrays of an ordinary environment" (Gibson 1971, p. 27).

If we accept that our experience of simulated illumination is in some way analogous to our experience of light in real space, it opens up a large body of research on light that can be repurposed (with qualifications) in the study of simulated illumination. Much research on light over the past decades has been directed towards establishing lighting standards—understanding just how much light, and which qualities of light, best support visual tasks in work and public spaces. In recent years, however, light researchers have looked at the influence of light upon biological mechanisms and more complex behaviors, as well as the non-visual effects of light upon emotion (see the survey in Knez 2001). It has been proposed that illumination qualities in our environment in and of themselves can directly affect how we make decisions and take risks (Belcher, Kluczny 1987, McCloughan, C. L. B., Aspinall & Webb 1996). Moreover, Knez has proposed a causal link from the luminous environment to cognitive performance via mood, and uncovered gender differences in the emotional response to warm and cool light (Knez 1997). These

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findings not only suggest new methodological approaches to the study of simulated illumination, they also enrich the potential aims of game lighting design. Visual definition of game worlds remains the most basic goal; but the ability to influence mood and more complex behaviors, such as risk-taking, engages the game lighting in higher-level gameplay considerations.

3.3.3 Designing simulated illumination in games

Neither film lighting nor our experience of illumination in real space is fully adequate to do justice to the task of understanding and designing the luminous environments of a digital game. There are examples of current games (*Splinter Cell: Chaos Theory* for one) that give the player the option of visualizing the scene through sources of energy beyond visible light, such as heat and infrared energy. Beyond the task of visual description, some games also allow the player to relight the simulated world, as a means of contributing to player goals and resources. Found most often in stealth and survival horror titles, flashlights (Niedenthal 2007c) contribute strongly to the effect of playing the game. The interactive nature of game lighting—the fact that the player may herself alter the luminous qualities of a game space for the purposes of play—widens the lighting designer's toolset and concerns. The designer must then consider the following for game lighting (and here I am reproducing material at length from compendium text 4):

1. Defining the basic characteristics of the environment's illumination, in both time and space. Given that the player might relight the scene by adding or subtracting light (as in the case of games where the player has a flashlight, or can shoot out lights), the designer's task is to define the base ambient illumination, the essential shadow density, sketching the visual affordances of the world. Here we can speak, in the parlance of film, of broader "high-key" or "low-key" strategies, in reference to the overall distribution of value in the scene. High-key is traditionally associated with comedy and lighter fare, and gives us *Super Monkey Ball* (Sega 2002). Lower-key strategies are of course appropriate for survival horror and stealth.
2. Outlining the capabilities of the player. As we have seen, the energy of a game scene can be represented in different ways. Offering the player a range of visualization choices, as in *Splinter Cell: Chaos Theory* extends player capabilities, and creates the illusion, at least, of a greater degree of mastery

over the environment. Conversely, limiting the player's illumination resources, by, for example, linking flashlight usage to negative consequences (*Doom 3* or *Silent Hill 2*), creates a sense of vulnerability and forces choices to be made. Once again, these decisions need to be made in relation to the game genre.

3. Integrating illumination concerns within the whole game experience. This includes harmonizing visual capabilities of the player with other sense modalities, most importantly sound. It also includes considering the issue how to balance risk and reward, to make the choices available to the player (as actor or designer) meaningful within the game genre, according to the desired emotional complex of the game experience.

3.4 A TAXONOMY OF INFLUENCE OF SIMULATED ILLUMINATION IN GAME WORLDS

At the most basic level, simulated illumination visually describes game environments and brings them out of formlessness. But recent research, and the potentials of interactive media, suggest that there are important higher-level goals for game lighting that allow it to support gameplay and more directly influence the player's experience. Based upon the results of real-space research on light, the consideration of games as an interactive medium, case studies of existing games, as well as existing lighting design practice for virtual environments, we can propose six main dynamics through which simulated illumination influences the aesthetic experience of games. These can be listed in order from lesser to progressively greater engagement of player awareness and agency:

1. Exposure (direct experience of light qualities in virtual environments)
2. Contrast (variations of light qualities within the visual field)
3. Temporal change (as a function of player navigation from environment to environment, as well as external time influences that are embedded in games)
4. Lighting patterns and conventions (recognition of illumination patterns from other games and media types, genres, characters, etc.)
5. Lighting effects (moments at which the player becomes aware of light qualities, either to enhance the immediate game environment or to engage metaphor)

6. Interaction and player agency (strategic or tactical player activity related to lighting, or lighting that serves as a feedback device for player actions)

1. Exposure: one of the lessons of current research on light is that specific illumination qualities have the potential to affect our non-visual experience in and of themselves. When we are exposed over a period of time to light, qualities such as brightness or color have the ability to affect our emotions and behavior. This occurs through activation (how aroused we become), as well as affect, or mood (Knez 2001). When specific illumination qualities predominate in game worlds, we can expect a contribution to player affect.

2. Contrast: Within any given perspective within a game world, it is unlikely that we will encounter single light qualities; most scenes are composed of more complex patterns of illumination: light and shadow, combinations of hue, indoor and outdoor, etc. Our experience of illumination differences, of contrast, is one of the main mechanisms through which we make visual sense of a scene. Contrast is, for example, one of the ways in which the lighting designer directs the eye, to return to Callahan's categories. The way in which visual information is given to the player, or withheld, can also affect our emotional experience of a virtual space.

3. Temporal change: Many of the contrasts we experience in a game world are ones we feel over time, often through the activity of navigating virtual spaces. The sorts of illumination contrasts that one experiences in *Resident Evil 4* and *Silent Hill 2*, for example, are on the day/night, light/dark, and warm/cool dimensions. Further, some of the illumination changes that are designed into games reflect larger temporal patterns that are embedded in the environments. 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.

4. Lighting patterns and conventions: As we move from space to virtual space, we may recognize patterns of illumination contrast from our experiences of other games or media. Qualities of environment that we associate with specific genres (film noir, for example) might awaken expectations and anticipatory moods. The same can be said for specific patterns of illumination that we encounter in character lighting. As Callahan mentions, illumination has the potential to reveal character and personality.

5. Lighting effects: There are moments in games in which we become intensely aware of particular light qualities. This is at times used to make a particular environment strongly felt (such as visible beams of moonlight in *Resident Evil 4*), or to employ light qualities in a metaphorical manner (such as the emanating light out of which the supreme being speaks in *Shadow of the Colossus*). Also, light effects can be associated with objects of importance within the game scene, objects that can be manipulated or acquired by the player. These light effects can include reduced contrast, specularity, twinkle or lens effects, or pulsing.

6. Interaction and player agency: In some games, players don't simply experience the illumination designed into the game, they actively contribute to it. This can be witnessed in strategic as well as tactical player activity. In *Okami*, the overarching goal of the player throughout the game is to "bring light" to a world darkened by evil spirits. This is accomplished through the skills that the player masters during the game. In other games, players re-light the game environment in a tactical way, as they attempt to move forward from one environment, one challenge, to the next. Two examples are *Doom 3* and *Silent Hill 2*. In both games, players have a flashlight that they can use to illuminate dark places, but use of the flashlight in both games has negative consequences. In *Doom 3*, use of the flashlight inhibits defensive activity (one cannot hold both the flashlight and a weapon at the same time), while in *Silent Hill* 2 use of the flashlight attracts enemies. The tactical engagement of player lighting activity engages particular "first person lighting emotions," to paraphrase Grodal, that exploit the player's fears, sense of vulnerability and need for visual information. In other games, light effects are used as a feedback device for magic, to indicate the performance of a particular spell in *Folklore* (Game Republic 2007), for example.

The potential effects of simulated illumination upon the player offer the lighting artist a rich palette of possibility, but they are emphatically not simple in their operation. The dynamics of light influence sketched above occur simultaneously, some working rapidly and overtly, in a fraction of a second, others having a subtle and largely unconscious effect over time. Further, these dynamics engage different perceptual, cognitive, motor and emotional processes that affect the play experience. A fuller understanding of the contribution of simulated illumination to the aesthetic experience of gameplay calls for a research strategy that is flexible enough to tease out the traces of a multifaceted phenomenon, as simulated in a complex interactive medium.

4. TRIANGULATION AS A TRANSDISCIPLINARY RESEARCH METHODOLOGY

How can we know about light? As we have seen, light is a multi-faceted phenomenon, one that is not yet, from a scientific perspective, fully understood. Many communities of practice, ranging from physics, to psychology, to media, performance and the arts, inform the study of light. Few sensory phenomena are so extolled in literature ranging from the scientific to the artistic and theological (Park 1997); yet few are so taken for granted in our everyday experience, in which physiological mechanisms (adaptation, color constancy) work to suppress our awareness of variations in light brightness and hue (Goldstein 2002).

Moreover, the study of light as simulated in interactive media such as digital games presents its own challenges. Digital games are among the most complex of interactive media. Not only do games simulate many of the components of traditional filmic media, such as plot, characters, sound and music, lighting, sets and pre-rendered animations, they are also digital artifacts played through graphic interfaces and controllers. As interactive experiences, furthermore, games are the site for 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 perceptual, cognitive and motor resources, contributing to what Lindley (2002) refers to as a "game-play gestalt."

The systematic study of simulated illumination in games is thus difficult, for two reasons. Games are complex, and the effects of light can be subtle. How can we create an equally subtle research methodology, one that can tease out the influences of light and help inform the way in which it "subconsciously matters" in our experience? (Boone 1997).

Within the current study of digital games, as we have seen, the most promising route is to trace influence of light upon the aesthetic experience of play. To recap: the aesthetic experience itself can be characterized by intensity of emotion, attentiveness, absorption, coherence, and a sense of fantasy or make-believe. Simulated illumination contributes to all of these characteristics. First, qualities of simulated illumination are a means through which coherent games and game worlds can be realized, and they serve as an important modulator of attention through contrast and light effects. Further, studies of light in the real world demonstrate that exposure to light in and of itself has the potential to inflect emotional response (Knez 2001). The sense of participating in a fiction, of being immersed in another realm, is also enhanced through illumination conventions, which engage shared memories and meanings.

4.1 AESTHETIC EXPERIENCE AS EVOLUTIONARY ADAPTATION OR CULTURAL CONVENTION

Though simulated illumination is of obvious relevance to game aesthetics, it is not immediately clear which sort of research methodology is best suited to teasing out its subtle influence. But consideration of the main schools of thought on how people experience the aesthetic moment can give us some suggestions. According to psychology discourse, it has been noted that aesthetic judgments have remained relatively stable over time. That is, there is fairly good agreement on the sort of art works in which the aesthetic experience has been best realized (Kubovy 2000). Two main theses have been advanced to explain this: first, that the aesthetic response is an evolutionary adaptation, something hardwired into our brains. Ramachandran and Hirstein (1999) and others have explored this approach in the area of "neuroaesthetics." The second thesis is that our aesthetic responses are culturally conditioned, which is supported by the observation that aesthetic judgments do in fact change over time.

The study of illumination is uniquely well suited as an area in which to compare these two conceptions of the aesthetic experience. There is a very primal aspect to light—associated as it is with the sun, fire and the hearth—that suggests that indeed our evolutionary development in a particular kind of luminous world may have left strong impressions. At the same time, lighting practices as represented in art, performance, media and architecture—though not always explicated theoretically—have developed a high degree of refinement, and generated a host of lighting conventions, shared agreements on what lighting ”means” in specific contexts, that are not stable over time, but rather comprise a sort of cultural repository of illumination knowledge.

A research methodology for studying simulated illumination could side with one stance in this debate and ignore the other. Indeed, a huge range of possible approaches to light and the aesthetic experience have been applied within different scholarly practices. Mary Boone chooses a semiotics and gender studies approach to explicate lighting ”codes” and power relationships in the career of a theatre lighting designer (Boone 1997). Piotr Winkielman et al. (Reber, Schwarz & Winkielman 2004), working from experimental psychology, locate the aesthetic experience in processing fluency in the interaction between viewer and artwork. The gap between Mary and Piotr would seem to be unbridgeable. However, there is good reason to try.

4.2 DELIMITATIONS

This would seem to be a prudent point at which to introduce a few delimiting boundaries to the research agenda outlined here. So far, we have described a fairly ambitious, transdisciplinary methodological domain, as applied to two challenging subjects: digital games and simulated illumination. Obviously, there are a number of possible variables or foci upon which one could concentrate.

4.2.1 Beyond immersion

The conventional wisdom in the popular game press goes something like this: good graphics equals better ”suspension of disbelief” equals better immersion equals a better gameplay experience. In this limited sense, lighting in games could be seen as supporting the player's absorption and sense of presence in the synthetic game world, by helping that world conform as closely as possible to our visual experience outside of it. This argument unfortunately limits the scope of lighting concerns to a range of descriptive functions. Even the best scholarly treatments of the concept of immersion, such as that of Ermi and Mäyrä (2007), describe sensory immersion as concentrating the player: "Large screens close to the player's face and powerful sounds easily overpower the sensory information coming from the real world, and the player becomes entirely focused on the game world and its stimuli" (p. 45). Obviously, in a study of simulated illumination, we can hope to contribute to a more nuanced picture of how light qualities feed our sensory experience of a game.

As we saw in the previous chapter, simulated illumination serves the aim of directing attention and visually describing spatial relationships, both of which are very important for games, as well as filmic media. And, in chapter 1, we acknowledged that the prototypical aesthetic experience is one that is characterized by a high degree of attention and absorption. Still, even a cursory query of our own experience of light in the real world will quickly demonstrate that illumination can do a lot more than simply fix us in our environment, and give us the visual information we need to feel at home in a space. Light, after all, has associations with divinity, magic, and the sublime. Clearly we should hope for nothing less in our experience of simulated illumination. This study will accordingly focus upon those aspects of the aesthetic experience that help us understand the influence of simulated illumination upon the emotions and behavior of the player, rather than simply the way in which illumination serves the description of game worlds, and the corresponding significance for the concept of immersion.

4.2.2 Middle-level research

Besides delimiting the scope of our research agenda, it also seems wise to sketch some boundaries to the potential significance and application of our results. By now, the reader should suspect that not every game nor game genre will respond to an analysis of simulated illumination. Nor can an understanding of the simulated illumination in a game tell us everything we need to know about that game. Finally, a mastery of simulated illumination is only one of the many competencies required to design a good game.

In 1996, David Bordwell and Noel Carroll wrote a (somewhat polemical) book in which they attempted to shake up the film studies community. In it, they took aim at what they called Grand Theories, bemoaning film studies' tendency to "exude a sweeping confidence that we are on the verge of the next Big Theory of Everything" (as quoted in Plantinga 2001, p. 23). In its place, they proposed what they called "piecemeal" theory, with "an emphasis upon middle-level research that chooses small, manageable questions for investigation." The ambition of this study is to produce middle-level research, and I would argue that—given the problems that aesthetics has traditionally had with universalism and sweeping claims (Kelly 1998)—this is the correct level at which to conduct game aesthetics research at the moment.

Middle-level research aims at results that do not presume universal validity, but rather must be carefully contextualized. First, it should be noted that most of the references in this text will be to game genres that respond particularly well to an analysis of simulated illumination: survival horror, stealth, and some action games. In these games, light effects are crucial to both emotional effect and gameplay. The rendering engines for some of the genres—stealth particularly—are specially written to take simulated illumination in the scene into account, which is reflected in the capabilities and behavior of non-playing, artificial intelligence-driven characters (Niedenthal 2007c). The design significance of our results, however, has the potential to extend beyond these genres, though within limits.

Besides these broader genre statements, it is possible to organize simulated illumination in games on a dimension ranging from more abstract forms of light and color representation (as in *Rez* (United Game Artists 2001)), through 'toon- (or cel-) shaded games, to those that approach photo-realism (which incorporate a range of light effects that approximates our visual experience). It should be noted that even many abstract 'toon-shaded games display a limited set of light and spatial effects, such as drop shadows beneath the player's avatar (*Okami*) and stylized light beams (*Jet Set Radio Future* (Smilebit 2002)). (Note: this is paraphrased from compendium text 7). It should also be acknowledged that—when dealing with 2D games, such as *Tetris* for example—there are certain games in which it is no longer meaningful to speak of simulated illumination, and where it becomes more accurate to speak in terms of human response to color. Games played through small or text-based devices, such as mobile phones or PDAs, are also difficult or impossible to include in this research.

4.3 WHY TRANSDISCIPLINARY RESEARCH?

Given these restrictions, it is still best to approach simulated illumination in a methodological manner that allows us to access the richest possible understanding of light effects in games. We should avoid arbitrarily excluding the knowledge of communities of lighting practice simply to maintain disciplinary purity; instead, with a phenomenon as complex as light, we should make communication between scholars and creative practitioners a primary goal. Light is thus an ideal subject for transdisciplinary research.

The development of new digital technologies, and their growing omnipresence in our lives, has, over the past 20 years, given rise to new models of transdisciplinary co-production, research and education. The ostensible reason for pursuing transdisciplinary efforts has been to humanize the products of technology development, and the argument for doing so has been strengthened by reference back to a 40-year-old thesis from C.P. Snow. Snow, a British physicist and essayist, argued that the growing cultural gap between humanistic practices of art and literature on the one hand, and the more empirical approach of sciences on the other, threatened to impoverish our ability to bring about innovative change in the face of social challenges (Snow 1993).

Though his argument was largely concerned with raising the status of the sciences in cultural debate, Snow's "gap" remained associated with the topic of innovation into the '90s, when the rise of new digital artifacts, and the challenge of adapting them to human needs and desires, brought the potentials of collaboration between the humanities and sciences into focus once again (Niedenthal 2002). "The clashing point of two subjects," Snow wrote, "two disciplines, two cultures . . . ought to produce creative chances" (as quoted in Harris 1999, p. 3).

One recurring problem with seeking innovation through transdisciplinary collaboration between humanistic and scientific cultures in university and corporate contexts—particularly those based upon co-production—has been the question of evaluation of results. As Harrris (1999) points out, based upon the experiences at Xerox Parc, corporations have historically not been particularly good at recognizing the potential of the products that come out of their own think-tanks. Similarly, universities and academic cultures are based upon patterns of knowledge production and dissemination within existing categories, and often have a hard time accommodating to the truly new.

Triangulation as a transdisciplinary research method attempts to produce new knowledge by looking for interesting correspondences between coordinated research activities that can be evaluated within existing disciplines. In the case of the contribution of simulated illumination in game worlds to game aesthetics, those disciplines include cognitive/environmental psychology, interaction design, and game studies. Our strategy for conducting aesthetics research has accordingly been to bring methodological richness to bear on a thin section of the aesthetic material of games.

We do so by approaching simulated illumination in game worlds through three perspectives:

1. Empirically-based emotion research
2. Investigations into the lighting attitudes of creative practitioners
3. Critical analysis of existing games, and the articulation of use qualities related to simulated illumination

4.4 EMPIRICALLY-BASED EMOTION RESEARCH

The study of light's emotional effects upon people needs more hard data. This statement is deliberately provocative; after all, why shouldn't the intuitive knowledge of lighting professionals in art, media, and design, as embedded in the artifacts they create, be valued a highly as experimental results? One reason to pursue empirical studies is that the paradoxical nature of light—worshiped in its ideal manifestation but largely ignored in our daily experience—has led to a proliferation of overly flowery writing (Plummer 1987). Though beautiful and compelling, this sort of writing about light doesn't tell us that much about concrete human response to illumination qualities.

Experimental research on the effects of light is taking place in psychology labs, as well as at larger lighting products manufacturers such as Philips. In his overview of non-visual research on light, Knez (2001) points out that much of the empirical research on light has been directed towards establishing standards of illumination (intensity and color) for visual tasks in work, learning, and public environments. The non-visual effect of light upon behavior and emotion is a more recent topic for research. Over the years, a number of mechanisms of influence of light upon emotion and behavior have been posited, through the effects of light exposure upon affect and arousal. Knez himself advocates the use of self-reporting techniques, mediated through a circumplex model of light influence that maps responses on high and low affect and arousal axes (Knez, Hygge 2001). The general conclusion of his work has been that light qualities indeed do influence non-visual psychological processes.

Although there have been studies on the effect of light qualities upon behavior in real-space gambling environments (Stark, Saunders & Wookey 1982), nothing has been done on simulated illumination in virtual play worlds. Research methods from emotion research, environmental and cognitive psychology—in combination with virtual test environments where light variables can be controlled—thus have the potential to explore the analogy between simulated illumination and light in real space. If this connection can be made, further lessons from real-space experiments can be used to shape studies that could help us better understand player behavior in game worlds.

There are, however, certain limitations to an approach to simulated illumination that relies exclusively upon ”experimental aesthetics.” As Kubovy (2000) notes, an empirical approach to visual aesthetics tends to focus upon the response to individual elements of a work of art, such as color, or compositional patterns such as ”the golden section,” which are invariably of secondary interest. This limitation of ”aesthetics from below” is also an issue for simulated illumination research: players don't play games to experience light qualities. Though it is possible to imagine a comprehensive research agenda that attempted to resolve the emotional influence of light vis á vis the contribution of genre, narrative, interaction mode or character, another, perhaps more realistic approach is to contextualize empirical results within a richer understanding of the creative environment of game design and gameplay.

4.5 INVESTIGATIONS INTO THE LIGHTING ATTITUDES OF CREATIVE PRACTITIONERS

Although he had been dead for a year before I arrived at Art Center College of Design in the mid-'80s, Charlie Potts was still a towering figure of lighting education. Standing on a darkened stage in a double-breasted suit, with a silver mane and stentorian voice, Charlie used to introduce generations of photography students to basic lighting practice by intoning ”the laws of light are eternal” (Wong 1984). The unchanging nature of light, and the universal human response to it, was Charlie's message.

The question of whether human response to light is an evolutionary adaptation or a cultural artifact is one that professionals in design and media have wrestled with for years, and the traces of that struggle remain embedded in lighting educations, cinematographer autobiographies, professional publications and lighting handbooks. Like Potts, film noir cinematographer John Alton begins his consideration of illumination fundamentals with a universalist tone: ”Ever since primitive man rose and retired with the sun, daylight illumination has been known to exist” (Alton 1995, p. 30).

What is interesting is how quickly Alton abandons this tone as soon as he begins to analyze the effects of specific lighting setups. In his discussion of ”criminal lighting,” for example, he relates light angles to prototypical lighting setups within earlier films:

> ”Years ago, when in pictures we showed Jimmy Valentine cracking a safe, he usually carried the typical flashlight in one hand, while with the other he worked on the safe combination. In some scenes the flashlight was placed beside him on the floor. In either case the light source was established as a low one. . . . This light, which exaggerates features, became so popular that even in our films of today, when we want to call the attention of the audience to a criminal character, we use this type of illumination” (p. 54).

For Alton, lighting conventions become a powerful means of communication, and constitute a kind of agreement with the audience. In this example, lighting responses are related not to the luminous environment in which we evolved, but rather to our previous experiences of media.

Alton’s book is somewhat unusual as an expression of a cinematographer’s illumination knowledge. Unlike light researchers working in university and industry labs, the community of cinematographers does not tend to organize knowledge in an academic or codified manner (through theoretical texts, reviewed publication, or journals). Cinematography as a profession is organized according to a guild system (the American Society of Cinematographers, for example). Though occasionally published in professional journals, manuals and autobiographies, film lighting knowledge remains largely embedded in films, or is passed directly from one person to another through word of mouth, on film sets or through professional workshops.

A considerable amount of illumination knowledge from lighting professionals thus remains to be accessed as ”tacit knowledge.” This, according to Polanyi, who coined the term (Polanyi 1983), is knowledge that is not expressed verbally, but acted out: ”we know more than we can tell” (p. 5). The connection to the body is crucial. One characteristic of tacit knowledge is tool use—we use tools to ”displace” tacit knowledge away from ourselves. This insight orients us to a potential method for accessing the tacit knowledge of creative practitioners. Creating custom virtual environments and digital lighting tools, employed through design workshops with creative practitioners (Ehn 1988), offers us an opportunity to uncover relevant lighting attitudes.

Why seek to extract the tacit knowledge of creative practitioners when studying simulated illumination in games? Due to the prevalence of modding tools, digital game communities display a greater overlap of roles (creator and player) than exists in most other media. Further, designers have generally refined their habits of raising their experience of light to conscious reflection. Designing the lighting of a game is an established professional practice, influenced by game designers and art directors, executed by level or map designers, technical directors (in the case of computer-generated animation) or digital artists. It is a recognized part of the workflow of producing many games, and it has generated its own practice. Creative teams working on game lighting communicate through reference to illumination qualities from film, photography, painting and architecture, besides other games (Egerup 2007). The practice of game lighting is thus one area in which a number of different art and media types inform the development of game aesthetics.

As with experimental aesthetics, a research approach to simulated illumination based solely upon creative lighting practice has certain limitations. One must be very careful when seeking to extrapolate from designers’ attitudes about lighting to the effects of illumination within specific games. To assume a simple relationship would be to participate in what has come to be called ”the intentional fallacy” in literary studies since New Criticism. Wider studies of lighting attitudes are useful, however, as a means of fleshing out the cultural conventions that underlie our expectations of, and responses to simulated light in virtual play environments.

4.6 CRITICAL ANALYSIS OF EXISTING GAMES, AND THE ARTICULATION OF USE QUALITIES RELATED TO SIMULATED ILLUMINATION

If we are to gain a greater understanding the whole by studying a part, we need an integrating structure in which to contextualize our analysis and interpretations; if we seek to understand digital game aesthetics by looking at simulated illumination, we can anchor our effort in the use qualities of interactive play. According to Löwgren (2006), use qualities are ”properties of a digital design that are experienced in use.” This deceptively straightforward yet rich definition redirects attention from the formal design qualities of an interactive system, towards the experience of a user/player who can manipulate the digital materials of a game at a fundamental level, engaging in the patterns of response, feedback and mutual influence that create the play experience. Beginning with use qualities also allows us to quickly begin to consider play, without a lengthy formal definition of what constitutes a digital game (Salen, Zimmerman 2004).

The key use quality of digital games that Löwgren identifies is ”playability,” which he defines as an optimal balance of player goals, resources and obstacles. The study of simulated illumination in digital games can thus take each of these components as a point of consideration: how can illumination contribute to player goals? How can light support player resources, or contribute to obstacles? As we have seen previously, there are a number of current games in which light functions as a strategic goal, as well as a tactical player resource. Light, and its absence in shadowy places, contributes to the visual obstacles of a game environment, and can support or inhibit action.

Further, individual game genres have their own unique balance of goals, resources and obstacles. In survival horror games, for example, the player goal is survival, not resounding victory. Player resources tend to be more limited and obstacles more daunting. We could thus argue that ”vulnerability” is a use quality of survival horror games, a subset of ”playability.” We can further speculate about the contribution of illumination qualities to the use quality of vulnerability. This in turn can help us better understand the complex manners in which player emotion—specifically the experience of fear—is manipulated in survival horror games.

Use qualities in themselves impose no particular form upon designs, nor do they propose particular emotional effects upon the user. These concerns are of importance, however, in the aesthetic experience, and to designers. As we have seen, the aesthetic experience is characterized by coherence, intensity of emotion and a sense of ”make believe” or fiction. The identification of particular use qualities for supporting research into digital game aesthetics and simulated illumination can thus be further refined and articulated by examining how complex creative systems work towards coherent emotional effect. This has been studied in literary and dramatic theory since Aristotle, and more recently in theories of interactive narrative.

For Aristotle, the key witness (as opposed to use) quality of tragedy is expressed as catharsis, a complex emotional experience of fear and pity, and the means through which catharsis is effected is through the formal and material causes that are at the playwright's disposal: plot, character, diction, thought and spectacle. The formal and material causes at play in the performance of a tragedy are the same; they simply reflect two different perspectives. The formal causes represent the hierarchy through which the playwright acts and catharsis is produced, at the top of which is plot. The material causes of tragedy reflect the perspective of the spectator, the order in which she perceives the elements of the performance, beginning with spectacle (Aristotle 1996).

Aristotle's approach has proven remarkably robust over time. For the neo-Aristotelian scholars of the 1950s, the criticism of a literary work began with the identification of the "peculiar power" of the work's plot, then considered "how far and in what way its peculiar power is maximized by the writer's invention and development of episodes . . (Crane 1957, p. 65)." This type of investigation is clearly relevant to understanding the design task of fashioning literary works—as well as to the possible further development of our understanding of use qualities. As Crane argues, this approach is "the sole method capable of dealing adequately . . . and literally . . . with those characteristics and values in any literary work which derive from its construction as a self-contained whole endowed with a power of affecting us in a particular way by virtue of the manner in which its internal parts are conceived and fitted together" (p. 92). Mateas (2001) has further developed the Aristotelian model to accommodate interactive narrative forms, by introducing player autonomy (drawn from Murray 1997).

Understanding the aesthetic experience of gameplay in this manner means to begin by identifying the key use qualities (or "peculiar power") of a game or genre. One can then speculate as to the way in which simulated illumination contributes to the achievement of that use quality, vis á vis the other elements of the game experience. This critical activity can be used as a method to better understand individual games as designed artifacts, as well as to generate new design principles for game lighting.

4.7 INTERESTING CORRESPONDENCES

Triangulation as a research method thus calls for a range of experimental, investigative and critical tasks to be brought to bear on digital games, as a means of generating new, transdisciplinary knowledge. It calls for examination of existing games, as well as the creation of new game segments and environments. Most importantly, this method calls for a central coordinating presence (a God's eye view) to make sense of these interrelated practices. First, the research activities need to be made relevant to one another. Secondly, the results of the different tasks need to be contextualized within a more complex environment. One can, for example, design parallel experiments and investigations into given illumination qualities, and look for interesting correspondences (rather than simple causality) to emerge. Because it forces the adoption of radically different perspectives on a single subject, this transdisciplinary process is inherently generative and self-critical. It also supports knowledge transfer between communities of practice that care about light and illumination qualities, whether rooted in experimental, design-oriented or critical perspectives.

4.8 SHADOWPLAY: SIMULATED ILLUMINATION IN DIGITAL GAME WORLDS

As an example of how a triangulation study can be structured, we will examine the topic of warm and cool light in digital game environments, as it was explored in the *Shadowplay* project. *Shadowplay* was a two-year (2005-'06), multidisciplinary research project devoted to understanding the influence of simulated illumination in digital game worlds upon the emotions and behavior of the player. Our research goal was to create a conceptual foundation and vocabulary to express the possibilities of game illumination, and to specify how lighting techniques could be applied within game design. We aimed to accomplish this goal by establishing a research platform capable of producing qualitative descriptions and empirical data on how people respond to illumination in simulated spaces. The composition of our multidisciplinary team, including researchers with competencies from cognitive/environmental psychology, interaction design and theatre lighting, allowed us to approach simulated illumination from the three aesthetic perspectives discussed above: emotion research, investigations of the lighting attitudes of creative practitioners, and critical analysis of exiting games from the perspective of their use qualities related to play.

Although we considered a number of illumination qualities in our work together, the main focus of our extended experiments, investigations and critical activities was on one color dimension: warm and cool light. In particular, we focused upon warm and cool environmental lighting and the potential emotional effects on the player through exposure, contrast, temporal effects and lighting patterns. We made this selection for several reasons. First, warm (reddish) and cool (bluish) light comprise one of the most powerful forms of naturally occurring color contrast in light. Warm light has strong associations with domesticity, the hearth, the sun and atmospheric effects, and other ties to our environment. Secondly, from an empirical standpoint, there is an existing body of research on warm and cool light and their effects upon people when experienced in real space (Knez 1997). This gave us both experimental methods and hypotheses to explore—and possibly repurpose—within the simulated spaces of digital games.

The results of our triangulation study of warm and cool light suggest that that illumination does in fact influence player emotion and behavior, but it is not a question of simple causality mapped between a given light quality and a given emotional outcome. Games are complex entities, and the triangulation method, as we shall see in the next chapter, allows us to describe a rich interplay between player activity, expectation, and emotional response.

5. WARM AND COOL LIGHT IN DIGITAL GAME WORLDS

Introduction: Resident Evil 4, Chapter 3-1: The approach to the castle

One begins in the empty entrance courtyard of a castle, silent except for the chirp of crickets and the sound of wind. Night and stillness predominate; the gray stone walls are washed with a silvery blue moonlight. Moving through a doorway (and waiting for a new scene to load), one works around a curved terrace to the left, and then triggers a cutscene that functions almost like a helicopter shot: moving straight up and panning to the side, revealing an enormous castle complex, in which the evening blue is punctuated by warm flickering torchlight.

The effect of the cutscene is complex. It occurs as the player moves into a new segment of the game, after leaving the muted daylight of a village and its surrounding countryside. As an introduction to a new game environment, the cutscene grants the player a foretaste of the qualities of the space to come, but at the same time avoids giving away any information about the adversaries that will be immediately encountered upon moving forward. The foresight granted the player is thus of an aesthetic, rather than strategic nature. The scale of the environment, its labyrinthine complexity, is both breathtaking and daunting. Further, the moonlit castle engages the player in the expectations (and pleasures) of continuing in a particular game genre (survival horror), and, at the same time, experiencing the game through new environments and characters that reference an established literary and filmic genre (the Gothic).

As one moves forward after the cutscene, one hears a low, unintelligible chanting, sound without a visible source. Moving around a corner, one spies sentry monks patrolling on a parapet, circulating perpendicularly to the player, a basic shooting gallery setup. This is a deceptive touch, definitely not the normal experience of the game, in which one fends off approaches from every angle. Instead, the player first encounters opponents who are unaware of the player's presence. A few sniper shots, or a carefully lobbed grenade, and then it is up the stairs, to where the fiery catapults await.

Figure 1: The Castle in Resident Evil 4.

Resident Evil 4 could be described as a game of positioning. As has been noted in game reviews, it is not possible to both run and shoot at the same time, depriving the player of the strafing capabilities of a first-person shooter: "Once you've drawn your weapon, you can't walk, but you can aim. It all feels very deliberate, but it's perfectly countered by the measured speed at which your enemies approach you" (VanOrd 2007). One moves, assesses the environment and its threats, takes a position, and acts. Flight and fight are both good options, but one can't do both, one must make a decision. The importance of positioning is compounded by the slow speed with which one is able to rotate one's perspective. This is a game in which you really do have to watch your back.

The fact that the game is one of positioning means that one must master the environment as much as one must master opponents. The deliberate nature of the game—which is not the same as slow-paced—suspends the player in a particular mode of action and reaction that is characteristic of the survival horror genre. Grodal (2003) points to a class of video games (associated with adventure and mystery) in which "associative processing of perceptual input is just as important as the motor output." These games are experienced as a "mismatch between grandiose input and blocked output" that was, as Grodal notes, called "sublime feelings" by the preromantic and romantic poets." The relationship between game environments and the deliberate nature of player activity constitutes the "peculiar power" of survival horror games, and testifies to a key use quality of these games: vulnerability.

5.1 CRITICAL ANALYSIS: VULNERABILITY AND AWE IN SURVIVAL HORROR GAMES

An encounter with haunted castles and malevolent monks puts one immediately in mind of the Gothic (Note: this section reproduces material from compendium text 5). Broad correspondences between Gothic fiction and survival horror games are immediately apparent when one compares emerging attitudes on the topic:

Gothic fiction: "Prominent features of gothic fiction include terror (both psychological and physical), mystery, the supernatural, ghosts, haunted houses and Gothic architecture, castles, darkness, death, decay, doubles, madness, secrets and hereditary curses." (Wikipedia.org, accessed 13 Dec. 2006).

Survival horror: "Survival horror is a prominent video game genre in which the player has to survive an onslaught of opponents, often undead or otherwise supernatural, typically in claustrophobic environments in a third-person perspective." (Wikipedia.org, accessed 13 Dec. 2006).

These entries suggest an intersection of shared concerns around supernatural themes, haunted and claustrophobic settings, and specific effects upon the reader or player. The psychological effect upon the reader or player—whether described as fear, terror, or horror—is central to both the gothic and survival horror genres. Both genres are vehicles for exploring emotional extremes. To return to the Wikipedia entry:

> "In a way similar to the gothic revivalists' rejection of the clarity and rationalism of the neoclassical style of the Enlightened Establishment, the term "gothic" became linked with an appreciation of the joys of extreme emotion, the thrill of fearfulness and awe inherent in the sublime, and a quest for atmosphere." (accessed 13 Dec. 2006)

But it must be noted that the emotional experience of reading fiction and playing a game are of course very different. Perron (2005a) has drawn upon the film psychology work of Tan, and emotion research of Fridja, to sketch a framework for understanding just how the emotional impact of non-interactive media differs from that of interactive media. Fridja argues that emotions are not just passive experiences, but orient us towards action. Initial appraisals of situations are conducted to determine the relevance to one's interests and well-being, and are followed by an evaluation of what can be done, actions that can be taken. It is thus the capacity to act that differentiates interactive media, such as games, from fiction and film. Fridja's emphasis upon action is of direct relevance to the design of interactive experiences.

One key way in which survival horror games create their effect is by maintaining a state of player vulnerability. Emerging attitudes in Wikipedia emphasize the way in which this achieved through game balance and resources: in comparison to shooter games, for example, "the player is made to feel underpowered, generally fighting alone for the bulk of the game, with limited supplies." This is of course inherent in the paired terms in "survival horror" the first (survival) indicating a player goal, the second (horror) referring to an emotional state as well as an existing film and literary genre. The word "survival" indicates that we are in a world of diminished expectations; it isn't called victory—horror. The primary activity is self-defense. The player is never free enough to go on the offensive, as in a strategy game, but is maintained in a reactive posture.

Defensive struggle is not the only hallmark activity of survival horror games; drawing from earlier adventure games, there is a fair component of puzzle solving. The player is often suspended in a state of incomplete knowledge. This establishes a varied pace in which moments of feverish activity are leavened with moments of cognitive challenge. (It should be noted that puzzle-solving is an important theme in Gothic literature as well, whether explicit, as in the cryptographic challenges of Poe's *The Gold Bug*, or implicit, as in *The Pit and the Pendulum*, in which the narrator has to solve the problem of how to escape a torture device that threatens to vivisect him).

But it is not only game resources and cognitive challenges that contribute to the psychological effect of survival-horror games. Vulnerability is also produced through the perceptual conditions of the game worlds. I recently replayed chapters 3 & 4 of *Resident Evil 4*, with knowledge of how to solve the puzzles, as well as an armory of weapons bolstered by previous trips through the games. My in-game resources and preparation were tiptop, yet the games still produced goose bumps. As in my first time through the games, I was compelled forward to the conclusion, almost against my will. And even in the first time through, I wasn't particularly convinced by the narrative framework for the game or concerned by the plight of Ashley, the abducted president's daughter in *Resident Evil 4*. Understanding goose bumps, our physical and psychological response to these compelling games, directs us to look beyond game resources and narrative, to a deeper consideration of the conditions which lead to the emotions of fear, terror, and awe.

Much has been written on the distinctions between fear, terror and horror, and these distinctions are relevant to our understanding of the survival horror experience. Perron notes that horror is an emotion that is overwhelming and annihilating in character (Perron 2005b). Fear is the relevant emotion; in survival-horror games, as well as non-interactive media, we seek a "bounded experience of fear." Writers of gothic fiction were also very interested in the nuances of this particular emotional range. In her essay *On the Supernatural in Poetry* (1826), the Gothic novelist Anne Radcliffe distinguished between terror and horror, arguing the literary value of the former, as well as outlining a poetics of how terror emerges from imagery:

> "Terror and horror are so far opposite, that the first expands the soul, and awakens the faculties to a higher degree of life; the other contracts, freezes and nearly annihilates them . . . . and where lies the great difference between horror and terror, but in . . . uncertainty and obscurity" (Radcliffe 1826)

Obscurity in this sense enhances a sense of vulnerability 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, or occlusion. Radcliffe compares the experience of reading to that of real life, anticipating the greater range of action possible in survival horror games: "Now, if obscurity has so much affect on fiction, what must it have in real life, when to ascertain the object of our terror, is frequently to acquire the means of escaping it?"

Radcliffe's discussion of obscurity owes a debt to a discourse on the nature of the sublime, which established many of the emotional and aesthetic terms underpinning the Gothic. "Sublime" is a word which has become debased in everyday English usage, and which has been questioned as an aesthetic category, but it has continued relevance to a discussion of how one designs the psychological effect of fictional worlds in which terror is the desired end. Edmund Burke's *On the Sublime* (Burke 1998) contributed the most to the association of obscurity with terror. In it, he attempts to describe the emotion that corresponds to the sublime, and explores the aesthetic means and perceptual conditions by which it can be produced:

> "Whatever is fitted in any sort to excite the ideas of pain and danger, that is to say, whatever is in any sort terrible, or is conversant about terrible objects, or operates in a manner analogous to terror, is a source of the sublime; that is, it is productive of the strongest emotion which the mind is capable of feeling" (p. 86).

Burke's discussion of the sublime object or setting focuses upon issues of scale and qualities of description; vastness is the favored scale, and obscurity is the favored mode of representation:

> "To make anything very terrible, obscurity seems in general to be necessary. When we know the full extent of any danger, when we can accustom our eyes to it, a great deal of the apprehension vanishes" (p. 102).

Burke goes on to look at the ways in which light, color, and other visual phenomena contribute to these particular effects, with attention to the way in which contrasts can be created:

> "I think then, that all edifices calculated to produce an idea of the sublime, ought rather to be dark and gloomy, and this for two reasons; the first is, that darkness itself on other occasions is known by experience to have a greater effect on the passions than light. The second is, that to make an object very striking, we should make it as different as possible from the objects with which we have been immediately conversant" (p. 122).

Burke's emphasis upon scale, vastness and grandeur, coupled with indistinctness of representation, is echoed in contemporary research on an emotion associated with the sublime: the experience of awe. In "Approaching Awe, a Moral, Spiritual, and Aesthetic Emotion," Keltner and Haidt outline a prototypical description of the emotion, with reference to two key features: vastness and accommodation:

> "Vastness refers to anything that is experienced as being much larger than the subject, or the subject's ordinary level of experience or frame of reference. Vastness is often a matter of simple physical size, but it can also involve social size, such as fame, authority, or prestige. . . . Accommodation refers to the Piagetian process of adjusting mental structures that cannot assimilate a new experience . . . The concept of accommodation brings together many insights about awe, including that it involves confusion (St. Paul) and obscurity (Burke), and that it is heightened in times of crisis, when extant traditions and knowledge structures do not suffice (Weber). We propose that prototypical awe involves a challenge to or negation of mental structures when they fail to make sense of an experience of something vast . . . . We stress that awe involves a <u>need</u> for accommodation, which may or may not be successfully accomplished. The success of one's attempts at accommodation may partially explain why awe can be both terrifying (when one fails to understand) and enlightening (when one succeeds)" (Keltner, Haidt 2003).

There are a number of features of survival horror games that also challenge existing mental structures. The theme of the supernatural, for instance (receiving a letter from one's dead wife, or being confronted by zombie monks), requires a thematic accommodation by the player, while the qualities of survival horror game worlds require a sort of perceptual accommodation. Keltner and Haidt also note that the physical marker of awe is piloerection, or goose bumps. Awe, and terror are, as Burke originally noted, two sides of the same emotional coin.

At their best, survival horror games create a compelling play experience because they suspend the player in a state of awe/terror. To cite Frijda's terms, obscurity is one means by which the appraisal period of emotional experience is extended, and the player frozen in a state of uncertainty, in which action is considered but not yet possible (This is one difference between survival horror and first person shooter games, which are much more about reflex action). Often this is accomplished through a combination of visual obscurity, occlusion, and anticipatory sound effects.

As Burke mentions, our experiences are often shaped through contrast; we feel things more strongly when opposites are juxtaposed. The modulation of contrasting perceptual states contributes to the pace and rhythm of playing through *Resident Evil 4*. Spatial perception and visual occlusion in the castle section, the centerpiece of *Resident Evil 4*, for example, is shaped by navigation through environments in which regularity and axial symmetry is contrasted with meandering and labyrinthine features. These spaces correspond to the archetypal spaces of gothic fiction. Hennelly (2001) argues that the figure of the cathedral unites the varying architectonic forces of the gothic, playing vertical aspirations against underlying caverns, natural forms against artificial symmetry. Navigation on the horizontal and vertical axes is also an important contrast in survival horror games. One regularly descends below the ground level, to vaults, and mysterious sub-basements, mines and caverns. Upward vertical movement is also important in the castle sequence of *Resident Evil 4*, in which the climactic boss fight is preceded by a lengthy ascent to the top of a tower.

Purposeful navigation and visual perception on the horizontal plane is often stymied in these games by labyrinthine spaces. Again, these correspond closely to the Gothic prototype. Leatherbarrow (1986) contends that in the literature of Poe,

> "The labyrinth is the form of most . . . interior passages. Spatial movement in Poe's fiction is typically an ongoing negotiation with unexpected obstacles and unforeseen changes in direction . . . In such a place one was always without external reference and fixed orientation. Any sequence is alternately redirected by intermediate walls and panels as well as vertically by steps in ascent or descent." (p. 10)

Labyrinths in survival horror games come in several varieties. There are spaces that are explicit labyrinths, such as the garden labyrinth in *Resident Evil 4* (see p. 177). There are also spaces that are implicitly labyrinthine.

5.2 LUMINOUS CONTRASTS IN RESIDENT EVIL 4

The sorts of illumination contrasts that one experiences in *Resident Evil 4* are day/night, light/dark, and warm/cool. *Resident Evil 4* exhibits a single day/night cycle over the game as a whole, beginning in the daytime, followed by dusk and night, and the final cutscene image is a sunrise. The bulk of the action in the game takes place at night, or under moonlight, though much occurs in interior spaces in which we are less aware of changes in time of day. The differences between day and night illumination are, according to the design team, deliberately dramatic, and are intended to support variations in the way in which enemies are perceived (Capcom 2008). Besides supporting an overall sense of spatial and temporal progression through the game, the distribution of light and dark illumination in *Resident Evil 4* environments also displays a logic that enhances a sense of player vulnerability through obscurity. The darkest environments in the game occur in the middle of the castle sequence, in the almost completely black Storeroom. One plays through this sequence as Ashley, the character with the most limited health and defensive resources, and hence greatest vulnerability. This segment is notable for being the only one in the game in which the source of illumination is a flashlight shining from the perspective of the player's avatar. This is a striking moment, a passage of intense creepiness, a nadir of the game, and one that invites comparison to other survival horror games, such as *Silent Hill 2*, in which the flashlight is frequently the main source of illumination.

Variations in warm and cool illumination in the game environments do not obscure the player's perception of the environment and potential threats, as with darkness, but they do contribute in a subtler and perhaps more interesting way to the player's sense of vulnerability as they play. The castle, occupying the center of *Resident Evil 4*, is the largest and single most complex environment in the game; it takes a long time to clear (which is sometimes perceived as a weakness in reviews). The castle also exhibits some of the greatest illumination contrasts in the entire game—besides the darkest environments, the coolest and warmest illumination environments can be found here as well.

A strategy guide (Glaser, Merken & Yamada 2005) breaks the castle down into 50 mapped environments (PS2 version). Of these, 10 are exterior spaces, cool, lit predominately with moonlight. In addition, there are several more cool interiors (Ballroom access, Ballroom) and subterranean environments (Sewers, Large cave) in which the predominant source of illumination is moonlight, shining through apertures and windows. The distribution of warm and neutral light in the interior environments in the castle is (to a certain extent) naturalistically motivated; that is, there is an attempt to link the color spectrum of the apparent source of artificial illumination in the scene with the rendered color of the environment. The warmest interior spaces in the game (Dragon hall, Melting furnace) are apparently lit by lava and molten metal. There are several fire sources in the interior spaces, including candles and candelabras (the warmest), and small torches, as well as larger torches with a bit of blue in the flame that cast a more neutral light. The most neutral interior spaces are those that are ostensibly lit with incandescent light bulbs and arc sources (Mine). Some environments exhibit mixed illumination, including moonlight/torches (Tower) and incandescent light/torches (Mine); these spaces combine one or more apparent sources of illumination, with attendant variations in warm or cool light qualities. There is also a recurrent, non-naturalistic blue flame that marks the position of the weapons merchant who appears from time to time.

Figure 2: Warm light in the Dragon Hall.

Figure 3: Cool moonlight on the Tower.

The resulting luminous environment contains warm/cool patterns that are experienced in time through virtual space; their variation is dependent upon player movement from one environment to another. This variation is important in itself as a source of maintaining interest through contrasting visual qualities. But the variations between warm and cool also contribute in a subtle manner to developing patterns of player expectation, tension and release. After the initial foray into the castle, only 1 of the remaining 8 cool exterior environments (Ruins) involves combat, the other 7 give the player a breather (PS2 version). Exterior moonlight comes to be associated with lack of opponents, a momentary dropping of the guard. Conversely, 30 of the 40 or so interior environments involve encounters with enemies. One important aspect of player vulnerability—the likelihood of encountering opponents—is thus mapped into the warm and cool contrasts of the environment. Further, certain opponents come to be associated with specific luminous environments. The wasp-like Novistadors only appear in interior environments that are illuminated by moonlight shining through apertures in the roof (Sewers, Large cave, Ballroom). This is perhaps explained by the fact that the winged Novistadors like to drop in on the player through the apertures, but it again establishes a sensory association. If the light is cool and the space echoing, listen for their approaching buzz.

5.3 EMPIRICALLY-BASED EMOTION RESEARCH: EXPOSURE TO WARM AND COOL LIGHT IN DIGITAL GAME WORLDS

In a 1982 study, test subjects were asked to play a card game in a gambling setting under red or blue illumination (Stark, Saunders & Wookey 1982). Noting that current understandings of color and arousal suggested that red was "associated with increased frequency and intensity of responding as compared with green or blue" (p. 95), the authors of the study hypothesized that the volunteers exposed to red light would be likely to gamble more frequently and take more risks than those playing under blue light. This proved to be the case. Although conducted in real space, this experiment raises interesting questions for game aesthetics and the study of simulated illumination. Virtual game worlds, like casinos, tend towards the dramatic and hyper-real. Risk taking and decision-making are behaviors that are just as important in *Doom 3* as they are at the Mirage.

The study of simulated illumination as a sensory stimulus complements our understanding of how virtual light inflects the gaming experience. We have seen that illumination contrasts comprise a portion of the aesthetic fabric of games, and that they contribute to the use qualities of a particular genre of existing games. But do light qualities in simulated environments merely support the aim of creating a sense of architectural verisimilitude, serving the needs of the game fiction, and functioning as a marker of player progression through the game world? Or are light qualities experienced as emotionally meaningful in themselves? If so, what is the contribution of lighting to the whole effect of digital games upon the emotions and behavior of the player?

One of the main goals of the *Shadowplay* project was to repurpose research methods on light and emotion from real space experiments to the virtual environments of game worlds. The work of Knez (2001) has indicated that light in and of itself can influence affect, and, since games are played purely for enjoyment, the possibility of a link between simulated illumination and player emotion is of immediate consequence for the practice of game design. For our first study, we chose to limit ourselves to the variable of light color, specifically warm (reddish) and cool (bluish) light, since Knez's previous work had indicated that this was a meaningful variable, one which is interpreted emotionally in different ways by men and women (1997). It is also a variable that is often experienced as simulated illumination in game worlds that include interior and exterior day and nighttime spaces (Note: this section refers to and paraphrases material from compendium text 6).

In order to produce experimental results that are meaningful within the world of game studies, it is necessary to explore player response to simulated lighting while engaged in a genuine game task. We accordingly constructed three maze sequences in the *Half Life 2* engine Hammer, through which players navigated in virtual space under three different lighting conditions: neutral, cool and warm lighting. The maze form was chosen because spatial navigation is a feature of almost all games that are experienced as 3D simulations; indeed, the experience of navigable space has been acknowledged as one of the hallmarks of new media artifacts (Manovich 2001). Further, as we have seen, the labyrinth is a common form in Gothic-inflected survival horror games. Care was taken to ensure that the spatial configuration of each maze was different and yet equivalent in size and complexity (by flipping the model), and histograms (a representation of the distribution of values, from light to dark, in the scene) were compared as a means of lighting for consistent values between the variants. Our prediction was that warm and cool color of lighting in digital game worlds might, as in the real world, influence the non-visual psychological mechanisms of affect in different ways, which in turn might enhance or impair the players' performance.

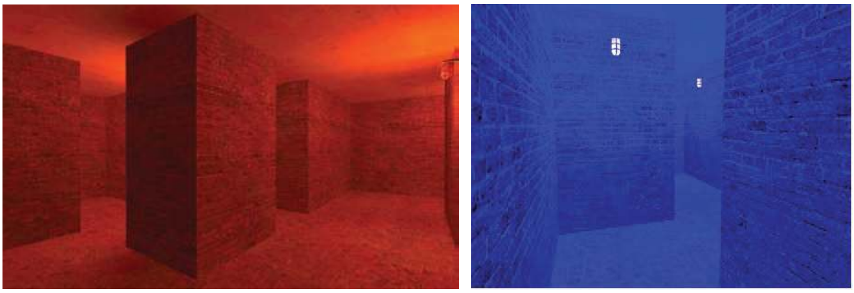

Figure 4: The Maze, warm and cool versions.

We conducted playtests with 38 subjects (14 women, 24 men) under controlled conditions, in which subjects navigated through the maze and base affect was evaluated. Play performance was measured by the time (minutes and seconds) it took to clear the maze. We interpreted affect in the context of a circumplex affect instrument (Knez, Hygge 2001). At the end of each game, the participants were asked to rate their affect by rating forty-eight adjectives representing the eight affect states on 5-point scales from "little or not at all" to "very much", in reply to the question: "How do you feel right now?"

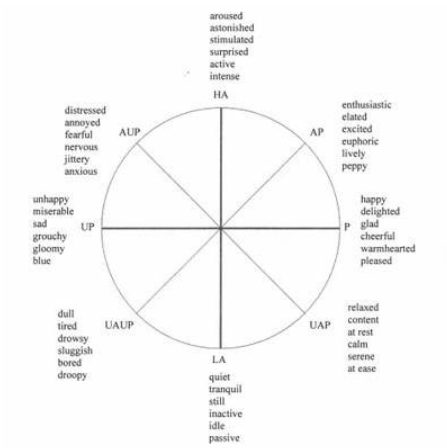

Figure 5: Circumplex affect instrument (Knez).

Our general aim was to extend experimental psychology findings on influences of real world surroundings on affect and cognition—and on influences of affect on cognition—to the digital game world. We predicted that simulated warm and cool lighting in digital game world would affect the players' feelings and game performance, and we obtained data that point toward a similar influence of the color of light in a digital game world as in the real world on the psychological processes of affect and cognition. More precisely, we learned that the players performed fastest in a game world lit with a warm as compared to a cool lighting. Concerning the players' affect, it was indicated that they felt better playing in a warm than in a cool digital world. That is, they felt happier and gladder and more enthusiastic and peppy in the former compared to the latter color lighting condition. In line with Knez' suggested line of influence: lighting influences affect and, consequently, cognition, it was tentatively indicated that the pleasantness induced by a warm lighting might have improved the players' game performance in that condition.

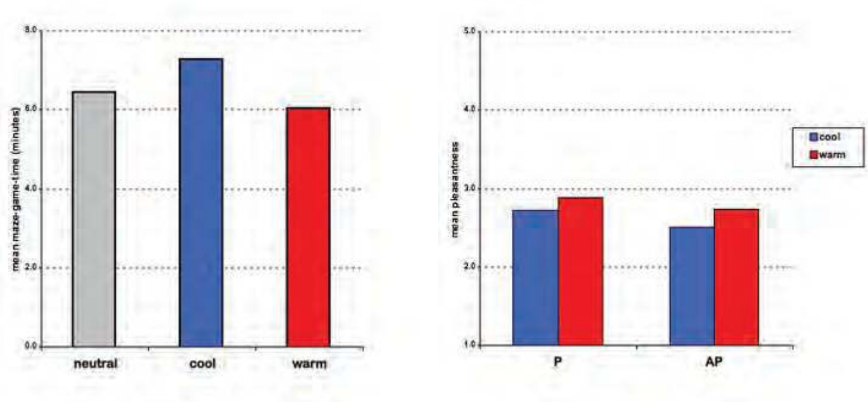

Figure 6: Effect of warm and cool light upon performance (l.) and affect (r.). Warm light conditions encouraged better performance and more positive affect.

As for the impact upon interactive media and game design, our results suggest that—given a basic game task—color qualities of simulated illumination can, in and of themselves, influence the feelings of the player. Simulated illumination matters. Perhaps most importantly, the results support our contention that the influence of simulated illumination is in some ways analogous to our experience of light in real space. This opens the design space of simulated illumination to lighting knowledge that originates not just with media practitioners, but also those who work in architecture, performance and installation art. Further, it is possible to argue that exposure to particular qualities of simulated illumination are associated with certain base emotional and physiological responses, providing a kind of subtle "bass line" to our aesthetic experience of games (to use a musical analogy). This contention is also supported by the analysis of existing games. The results of the *Shadowlab* experiment regarding exposure to warm and cool light while performing a game task would appear to be in alignment with the luminous environments of *Resident Evil 4* in one respect: warmer illumination hues—with associations of increased arousal, greater positive affect and enhanced performance—predominate in those environments that place the greatest demands upon player defensive capabilities.

This contention, however, needs to be immediately qualified. We wish to avoid simplistic claims about the influence of simulated illumination in game worlds. There are a number of ways in which the *Shadowlab* experiment fails to capture gameplay in *Resident Evil* 4, and is thus insufficient for fully understanding player experience in other games, or serving as the foundation for successful game designs.

First, the player experience in *Resident Evil 4* is much richer and more complex than we have done justice to in the lab. Obviously navigation is important, but one also engages in immediate defensive actions, plans strategies, and solves puzzles. The emotional experience of the player is not felt as a single state or simple binary opposition, but is much more subtle. Any encounter in *Resident Evil 4* can involve surprise, fear, dismay or triumph in rapid succession. Secondly, the visual environment of *Resident Evil 4* is much more complicated than what we recreated in the labyrinth. There are a number of environments with mixed lighting, in which warm and cool light alternate and blend. Further, lighting qualities such as shadowing, shadow density, and visible light effects are not recreated in our labyrinth model. Finally, narrative content and genre associations are missing from our experiment. We must remember that a digital game is a complex artifact composed of discrete elements that are experienced as a whole.

5.4 THE ATTITUDES OF CREATIVE PRACTITIONERS TOWARDS WARM AND COOL SIMULATED ILLUMINATION IN GAME WORLDS

It is a truth universally acknowledged among lighting practitioners that—besides having an indeterminate impact upon mood and the emotions—lighting design must ultimately serve some greater good: supporting narrative or illustrating character in the case of film, for example (Alton 1995, Calahan 2000, McCarthy, Samuels 1993). Enhancing performance, sketching architectural form, or creating conditions for good gameplay are other goals of lighting design within different design practices. This attitude testifies to the observation that our aesthetic experience of illumination is highly contextualized. Creative decisions regarding light are thus often taken with various contexts in mind, be they the demands of site, narrative, genre or game state. Many lighting decisions made by creative practitioners are done with reference to these contexts on the basis of "fitness" or "appropriateness" of light choice; these decisions are often made not just in relation to individual scenes or environments, but with thought given to the creative stance and intended impact of entire work of art (Bergholz 2007). Cohesiveness is thus an important consideration for creative activity regarding light; it is also, as we have seen, a component of the aesthetic experience.

The sorts of lighting decisions made by creative practitioners in a given work often involve more complex lighting patterns that consist of specific combinations of individual light qualities. "Film noir lighting," for example, could be described as combining particular angles of light direction with particular qualities of shadow edge definition and shadow density. If employed in a striking manner, over time these lighting patterns can become lighting conventions, which can in turn be associated with particular genres, and subsequently give rise to particular expectations in the viewer. Whether or not these conventions are rooted in human emotional and behavioral response, they become a sort of cultural agreement that is entered into by creative practitioners and their audiences. John Alton's use of "criminal lighting," as we have seen, became a kind of visual shorthand for communicating with the audience. Appealing to lighting conventions is also one of the ways in which the complexity of the lighting task becomes more manageable.

Lighting conventions of this type are often not recorded formally; they are embedded in media. Some conventions, as apparent in the Alton quotation, above, find their way into print in lighting handbooks or cinematographer autobiographies, or are sometimes noted in academic studies of media and art. Otherwise, lighting conventions can be tough to capture. The structuring of lighting knowledge in cinematography, as has been noted, is much more informal than in the academic world; much remains to be accessed as "tacit knowledge."

5.4.1 Novem Corda

Accordingly, we structured an investigation in the *Shadowplay* project in which we took exactly the same qualities of warm and cool light that served as variables in the *Shadowlab* experiment, and asked creative practitioners to design with them. Instead of posing a gameplay task, we gave a lighting task. Since design of simulated illumination generally occurs in a context, we created a 3D environment in the Hammer game engine that would allow for various game scenarios to be played out. Based upon a walk-through heart model found at several museums of science (and, specifically, found at the Museum of Science and Industry in Chicago in the 1960s and 1970s), we developed a museum setting which could, with reference to the fluid symbolism of the heart, be used to suggest game environments for a pedagogical game, a relationship game, and a survival horror or stealth game.

It was our intention to employ this interactive tool (which became known as ”*Novem Corda*,” or Nine Hearts) at workshops, or individually with lighting professionals who might not have a lot of time to spare. We accordingly designed an environment in which non-programmers could quickly experiment with a limited range of light qualities—intensity or brightness, shadowing and warm/cool hue. We also sought to allow the designer to simultaneously compare several light states, as many lighting decisions involve incremental changes based upon relative comparisons. An initial, top view of *Novem Corda* shows nine identical environments with different base lighting (varying hue and brightness). Using the teleporting capabilities of Hammer, one could enter any of the environments and navigate within the space under the base illumination; one could also go back and forth to the ”God's eye” view to compare or change rooms.

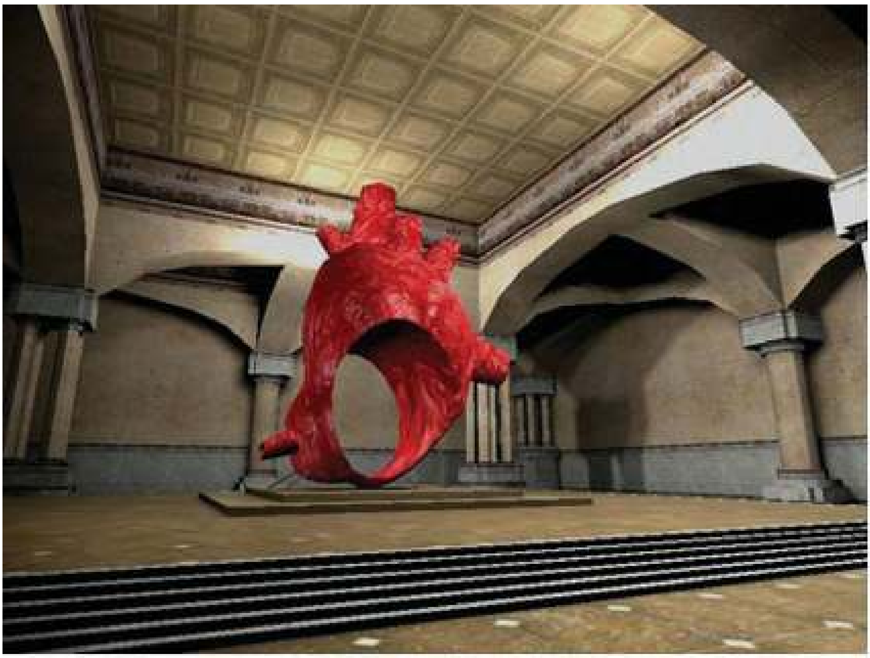

Figure 7: The walk-through heart of Novem Corda

Within *Novem Corda*, we asked designers to light three different game scenarios:

Exercise 1: MyBody, a pedagogical game
Game genre: pedagogical game for young people 11-13 years old
Scenario: in this segment of the game, students learn about the circulation of blood in the body
Aim: good comprehension of the learning material

Exercise 2: a relationship game

Genre: relationship game (dating? sex? planning a wedding? Valentines day? Sims extension?)

Scenario: (open for the designer to develop)

Aim: Ecstatic abandon/warm coziness/quiet satisfaction/desperation (as appropriate for the scenario)

Exercise 3: a survival-horror or stealth game

Genre: stealth or survival-horror

Scenario: the room as site for an interrogation or assassination (stealth) or evasion of undead adversaries (survival horror)

Aim: an environment that challenges to player to avoid detection and master the environment (stealth), or that enhances felt player vulnerability (survival horror)

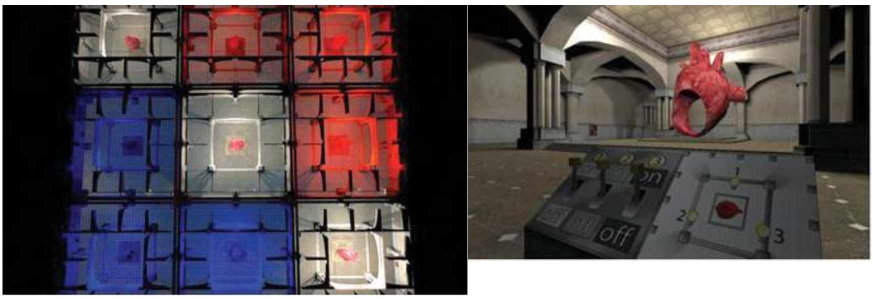

Figure 8: "God's eye view" and lighting panel of Novem Corda

Once the designer made a decision regarding which of the nine illumination environments was roughly appropriate for the specific scenario they were lighting, they teleported into that environment, and could directly manipulate lighting in the room through a control panel. This turned lights on and off. They could then navigate around the space to study the effect of their tuning.

When the designer was satisfied with the lighting in the scene, they documented their design by printing the screen. Since we reduced the number of lights available in the environment, for simplicity's sake (as well as due to technical limitations of Hammer), we also encouraged customization of screen grabs to produce expressive concept art (via Photoshop).

5.4.2 Novem Corda Workshop, The Amsterdam Assassination, January 2007

We first employed *Novem Corda* in a participatory design workshop with a group of 24 students of game design and virtual architecture at the Royal Academy of Art/School of Architecture in Copenhagen. The students were taking part in a one-month workshop in which their assignment was to design a level for a game called *The Amsterdam Assassination*. IO Interactive, a game development company known for its *Hitman* series of stealth games, supported this workshop. Our 6-hour workshop introduced the students to the concept of game lighting through general principles and inspirational examples, and then we asked them to light the three scenarios in *Novem Corda*. We also asked them to write a brief reflection on the choices they made.

Figure 9: A participant in the Amsterdam Assassination lighting workshop at the Royal Academy of Art/School of Architecture in Copenhagen.

Unlike the sort of statistical analysis we performed on the Maze tests, the *Novem Corda* images that resulted from the workshop are rich documents that allow for different types of analysis. Individually, they have status as creative and cultural documents; the student included pop culture references to TV shows and movies (ranging from CSI and forensic shows, in the case of the pedagogical game scenario, to the Bachelor in the case of the relationship game and James Bond in the stealth scenario). By grouping thumbnails of the final images, we can also draw larger conclusions about lighting attitudes in relation to genre by looking for broader patterns. Finally, since we left some freedom in the scenario, we can seek to correlate the final lighting designs with attitudes towards color of light and intended emotional effect that are present in the written reflections.

The images that resulted from the pedagogical scenario demonstrated the greatest usage of the neutral lighting option, though a number of the Photoshop alterations display quite strong and non-naturalistic color. This discrepancy reflects two predominate attitudes: first, that neutral lighting environments are best for communicating information and performing learning tasks, and secondly that children respond positively to strong color.

Figure 10: Thumbnails of the lighting solutions for the pedagogical game scenario.

The relationship scenario elicited the greatest uniformity in lighting choices, which favored warm and low-key (overall dark) lighting. Dramatic effects were favored: post processing in Photoshop involved substantial usage of light effects to create pools of light and visible beams, as well as lens flares and overall blurring of the image.

Figure 11: Thumbnails of the lighting solutions for the relationship game scenario.

Both warm and cool light were seen as appropriate choices for the stealth and survival-horror scenarios, with a slight edge given to cool light. More than in the other scenarios, shadow quality, shadow density and point of view were seen as key components of the luminous environment for these genres.

Figure 12: Thumbnails of the lighting solutions for the stealth-survival horror game scenario.

Leaving the intended emotional effect open for the designers to define themselves allowed us to trace lighting conventions and attitudes related to the intended emotional effect on the player. One group (Stine and Matilda) discussed their lighting choices in the survival–horror scenario:

> Det er mørkt og uhyggeligt – næsten råddent! Vi ville også gerne skabe fokus ved hjertets indre, da vi forestiller os, at der er placeret et hjælpemiddel eller selve missionens mål.
> Det er der, det sker! Vi har benyttet et koldt lys for at forstærke følelsen af frygt og ubehag.
> Ligeledes er skyggen og kontrasterne i billedet vigtige.

> It is dark and unpleasant, almost terrifying! We also wanted to focus on the inside of the heart, where we could imagine that there is some sort of player resource or goal for the mission.
> That is where it happens! We have utilized a cold light to intensify a feeling of fright and discomfort.
> The shadows and contrasts in the image are important.

Stine and Mathilda's reflection on their relationship scenario also shows them thinking about the emotional character of warm light:

> Vi ville gerne opnå følelsen af et brændende hjerte – kærestesorg.

Vi har valgt den stærke røde farve for at intensivere følelsen af sorg – det er næsten som om, at det er ved at eksplodere, hvilket fremhæves ved at karrene er meget tydelige. Den øverste del af hjertet flyder næsten som blod ud af hjertet!

Lyset kommer bagfra og er forstærket. Ligeledes er fokus på det brændende hjerte – det er det, der er interessant.

We wanted to create the feeling of a burning heart—the melancholy of love.

We have chosen strong red color for an intensive feeling of sorrow, it is almost as if it is exploding, which is evident in the clear definition of the veins. The top of the heart is almost flowing like blood!

The light comes from behind and is intense. The focus is on the burning heart, that is the center of interest.

Figure 13: Stine and Mathilda's stealth (l.) and relationship (r.) lighting solutions.

One interesting feature of the relationship scenario is that while most of the students employed red light as a means of conjuring up a feeling of intimacy, the specific emotions they sought to engage were quite different. Some, as in the case of Stine and Matilda, sought to evoke loss, heartbreak or melancholy—others were drawn to themes of dreams, love and romance. The associations of warm light, then, seem to be somewhat labile with respect to specific emotions, but are considered thematically relevant to the topic of intimacy.

5.4.3 Talk aloud sessions with art directors and level designers

As a continuation of the *Novem Corda* investigations, we conducted interviews and talk-aloud sessions with an art director and a level designer working for game companies. These investigations also revealed attitudes towards warm and cool light that testify to particular lighting conventions. We also learned more about how designers think about the complex of choices that face them when they light a game scene.

The art director we spoke with used an example of designing with warm and cool light in a game scene when asked about how creative teams communicate during game development:

> (When speaking with a colleague about a particular scene, I might say, for example,) "I want this scene to be warm, we want warm colors, because . . . the character has just done this, and we want it to feel welcoming, and we want to feel like this is something I want to enter, and this room is supposed to be cold, and you don't want to go there, and it should be scary . . ." (Bergholz 2007)

There appears to be an assumption about domestic (hearth, home, protected) vs. exterior (night) lighting embedded in this attitude towards warm and cool light. In a later part of the conversation, he again draws upon shared experiences of warm illumination, in this case associated with atmospheric effects: "I haven't met anyone who doesn't like the light when the sun is setting." It should be noted that his general coupling of warm light and positive affect is in rough alignment with our *Shadowlab* results, though it does not exactly correspond to the experience of the luminous environment of *Resident Evil 4*, in which warm environments can be very scary and cool ones refreshingly quiet. This incongruence will be addressed in the next chapter.

5.5 CONCLUSION

We have seen that illumination contrasts compose a portion of the aesthetic fabric of games, and that they contribute to the use qualities of survival horror games. Our *Shadowlab* experiment demonstrated that warm and cool simulated illumination have an influence on subject affect and play performance, and our investigation with the interactive *Novem Corda* tool suggests that qualities of simulated illumination, including warm and cool color qualities, have genre associations through shared lighting conventions.

6. DISCUSSION: GAMES, SIMULATED ILLUMINATION AND PLEASURE

Over the past years, a great deal of scholarly effort has been directed at developing new methods of understanding the emotional experience of playing games. The expansion of the digital games industry, the growing power of games as a cultural phenomenon, and the complexity of games as interactive artifacts have added urgency to the search for novel metrics for understanding just what happens when people play. As I have argued in this introduction, the aesthetic experience of digital games focuses upon, and can begin to account for the sensory and emotional experience of play; concurrently, a number of experimental techniques from social sciences and psychology have been redirected towards understanding this aspect of digital entertainment, ranging from various sorts of self-reporting techniques (such as those we used), observation and video analysis of facial expression (Fisher, Sanderson 1996), and physiological metrics (Salminen, Ravaja 2007). As in the broader area of emotion research, all of these techniques have their strengths and weakness, but none of these methods have established themselves as a "gold standard" for understanding emotional experience in its fullness (Larsen, Fredrickson 2003).

In the absence of a single overarching theory or technique for understanding what happens when people play, I have argued that the aesthetic experience of playing games can best be explored through a process of coordinated triangulation working across existing disciplines. In the *Shadowplay* project, we began with formal analysis and articulation of the use qualities of existing games. This first step allowed us to grasp the "peculiar power" of specific games, to see how simulated illumination contributes to the overall effect, and to generate topics and variables for further experiments and investigations. We then explored simulated illumination as a sensory stimulus in a lab setting, and further sought to uncover lighting attitudes of creative practitioners. We observed that warm and cool simulated illumination function as sensory stimuli with differing effects upon player affect and performance, and that warm and cool light also engage existing knowledge structures (conventions) related to genre, theme and gameplay. In the end, we were able to identify an interesting correspondence between the positive effect of warm light upon player affect and performance, and lighting designers' attitudes towards the attractive and repellant effects of warm and cool simulated illumination (respectively) in game level design.

6.1 TOP-DOWN AND BOTTOM-UP PROCESSING

Our focus upon simulated illumination both as a sensory phenomenon and as interpreted through preexisting knowledge structures echoes two main approaches to understanding perception and how we make sense of our world. In bottom-up processing, we construct an understanding of our environment through what comes in to us through the senses (Goldstein 2002). Top-down processes enhance our understanding by allowing us to interpret our sense experience in the light of existing knowledge structures and schemas. In our triangulation study of warm and cool light, we were able to choose appropriate techniques for understanding both bottom-up and top-down influences upon our experience of simulated illumination in games. Emotion psychology affords us methods for studying the effects of sensory stimuli. But our experience of simulated illumination is also strongly flavored by our attitudes and expectations related to genre and media. Psychology as a discipline is good at describing mental processes, but not as good at helping us grasp what is actually in people's heads at any one time, the cultural component, which is of course of interest to designers. For this reason, interaction design techniques can help us to extract the attitudes that people bring to their everyday encounters with interactive media. The strength of triangulation as a means of studying game aesthetics is that it could further be applied to studies of other elements of games, including sound and music, virtual form, and emerging haptic engagement.

In support of this approach, it should also be noted that there are other related areas of aesthetic inquiry in which simultaneous top-down and bottom-up processes have been proposed. In a more "interactionist" (Reber, Schwarz & Winkielman 2004) and phenomenological take on traditional aesthetics, Roman Ingarden argues that the aesthetic experience inheres neither in the sensory properties of the object of aesthetic contemplation, nor purely in the mental structures (attitudes, education, taste) of the beholder; rather, the aesthetic potential of a work of art is "realized" by the activity of the beholder in relation to the work of art (Mitscherling 1998). That activity, in the case of a work of literature, involves reader "concretization" of the various semantic "strata" of a literary work, through which the aesthetic potential of the work is made manifest.

6.2 ACCOUNTING FOR CONTRADICTORY RESULTS IN OUR TRIANGULATION STUDY

Although a transdisciplinary triangulation approach to the effects of warm and cool simulated illumination in games has produced an interesting correspondence, our studies did turn up one important inconsistency. Specifically, while both our experiment on warm and cool light as sensory stimuli and our investigation into designers' lighting attitudes pointed to the positive and attracting qualities of warm illumination, we also analyzed a very enjoyable existing game in which the opposite was true. In *Resident Evil 4*, environments in which one encounters opponents tend to be interior spaces lit with warm light, while cool environments invite the player to momentary repose and a relaxation of tension. How are we to understand this? One possible explanation is that the influences of simulated illumination are simply too weak in relation to the other elements in a game to be felt meaningfully by the player. However, a richer understanding of the emotional experience of gameplay can help us understand this contradiction, without forcing us to jettison an important aesthetic component of games. We can do so by moving beyond a focus on single emotions in games, and towards a more complex understanding of the sequences of emotions that comprise gameplay pleasures, and the way that we learn in time-based media.

6.3 THE PLEASURES OF GAMES

The emotional experience of gameplaying is, as noted in the previous chapter, complex. Isolated plottings of affect and arousal do not capture the experience of working through a level of *Resident Evil 4*, which can involve fear, dismay, wonder, and triumph in rapid succession. Some efforts have been made within the area of game studies and in the writings of user experience consultants to consolidate this complex under the informal term "fun," but perspectives on the enjoyment of games that emerge from game studies literature remain limited (Klimmt 2003) and diffuse. Although producing a "fun" game is a self-evident and compelling design goal, writers on the topic of fun tend to break down the term in a way that emphasizes the social, competitive, challenge-based and exploratory nature of game enjoyment. Lazzarro (2004), for example, proposes four sources of gameplay enjoyment: "hard fun" (challenge), "easy fun" (immersion in the game), "altered states" (largely having to do with self-esteem) and "the people factor" (sociability). Hunicke et al (2005) similarly subdivide game "fun" in a more comprehensive way into game-related "aesthetic" components of sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission. Media psychologists such as Klimmt (2003) have approached game enjoyment by further developing an "excitation transfer theory" that roots positive game emotion in the way in which arousal is transferred from negative to positive through suspense and relief. Salen and Zimmerman's (2004) discussion of game pleasure, which deals with the sensory roots of pleasure only with reference to "overwhelming sensation" (echoing Ermi and Mäyrä, above), is largely based upon how games achieve a flow state (Csikszentmihalyi 1990). Lauteren (2002) identifies pleasure with, among other things, resistance to "structures of preference" within a text. However, none of these approaches are rooted in our direct sensory experience. Indeed, those wishing to develop a comprehensive understanding of sensory and embodied pleasure of games will have to look elsewhere for support. How, for example, is our experience of playing a game pleasurable in comparison to eating a good meal or drinking a glass of fine wine, listening to music, fishing, witnessing or enacting a good deed?

More promising from this perspective is the conception of pleasure as it is currently elaborated within phenomenological philosophy and the new practice of hedonic psychology. Duncker's (1941) phenomenological analysis of pleasure provides a foundational taxonomy for later development within hedonic psychology by Rozin (2003). Duncker proposes three main types of pleasure: sensory (in which "the immediate object is of the nature of a sensation," such as drinking wine), joy (in which the primary pleasure does not inhere in sensations or perceptions themselves, but rather in the "consciousness of the situation," such as pleasure in "the victory of a good cause"), and aesthetic (in which sensations take on an expressive and communicative role: "Aesthetic enjoyment is the principal . . . instance of enjoying something expressed in the process of expression" p. 405). Of particular interest to the topic of games is Duncker's concept of "dynamical joy:"

> "Dynamical joys are based upon a kind of experience that lies somewhere between emotion proper and sensation: the tensions, excitements, thrills and reliefs of acting and resting. Here belong the delights of driving at high speed, of fishing and hunting, of playing games, of following a plot (e.g. in reading a good detective story), etc" (p. 403).

Rozin (2003) builds upon Duncker's taxonomy, with focus upon sensory pleasure and the contact senses, particularly related to food, as a means of uncovering basic principles of more complex hedonic systems. Citing Kahneman, Rozin points out that the pleasures associated with food take place within a temporal frame that is extended to include not only experienced pleasure, but also anticipated and remembered pleasure. Rozin continues his paraphrase of Kahneman: "experienced pleasure is on-line and momentary, like brightness, and hence a sort of primitive. Integrated pleasure . . . is a mentally constructed entity, which is accessed and/or reconstructed in remembered and anticipated pleasure. . . . Experienced pleasure . . . function(s) to influence the behavior of the moment; anticipated and remembered pleasures may guide ongoing behavior, but they also may participate in decisions and evaluations of future courses of action" (p. 112). Indeed, Rozin concludes that "most sensory pleasure is experienced in the remembered or anticipated domains, as opposed to the online (experienced) domain" (p. 129). This extended temporal frame of sensory pleasure has interesting implications for game design, in which most decisions are made with respect to the immediate experience of gameplay. Anticipation, motivation, and memory are also important targets for an aesthetic approach to game design.

Kubovy's (2003) approach to hedonic psychology in "On Pleasures of the Mind" complements Rozin's investigation of pleasure of the contact senses by attempting to provide a psychological foundation for distinguishing between Duncker's categories of sensory pleasure and joy. He does so by relating each type of pleasure to current emotion theory: pleasures of the mind (corresponding to Duncker's joys) are "collections of emotions distributed over time" (p. 137), while pleasures of the body produce immediate "hedonic states" (p. 135). Pleasures of the distances senses are a special category of the pleasures of the body. Unlike pleasures of the contact senses, pleasures of the distance senses (seeing and hearing) are not localizable in the same way, we don't feel the beauty of a sunset in our eyes the way we enjoy wine in our mouths. But like the contact senses, the distance senses can create hedonic states, and pleasant stimuli that we perceive through our eyes can create "the context for the generation of pleasures of the mind" via levels of arousal and affect: "it is likely that levels of arousals and moods are facilitators of sequences of emotions" (p. 139). Kubovy goes on to propose an introductory taxonomy of pleasures of the mind via the objects of emotions associated with each: curiosity, which is based on the unknown, and which gives rise to the pleasure of learning and discovery, and virtuosity, the pleasure of doing something well, related to mastery and performance. Järvinen (2008) has demonstrated just how well these concepts translate to an understanding of games as emotional experiences.

The conception of pleasure as it is being developed within hedonic psychology has much to recommend itself to the current practice of game studies. First, it is able to address a range of experience, from concrete sensory pleasures to complex patterns of feeling. The expanded temporal frame of pleasure encourages us to examine not just the immediate experience of gameplay, but also the ways in which we make sense of our experience when we are away from the console. Focusing on the sequences of emotions that take place within a pleasurable experience also affords the designer some suggestions regarding structures that may provide greater pleasure within a game. Kubovy points out that "pleasures of the mind are collections of emotions distributed over time whose global evaluation depends on the intensity of the peak emotion and favorability of the end" (p. 138). He links this observation to the frequently noted emotional sequence of tension and relaxation that can be identified in story structure: "Many stories have a structure that parallels the prior state, onset, change and equilibrium pattern episodes in human life. They begin with an exposition, introduce a complication, and end with a dénouement . . ." (p. 138). Although making similar formal statements about games is difficult (what constitutes a whole, complete play session?), the formulation still directs our attention to focus on peak moments in the game. Finally, hedonic psychology can begin to provide a basis for a consideration of the embodied nature of gameplay, though with a few qualifications. Both Rozin and Kubovy focus on sensory systems, but neglect the wider context of the body. Current understandings of the embodied nature of emotion also incorporate musculature, including the way that gesture and facial expressions are closely intertwined with our feelings (Niedenthal 2007a) and thus contribute to our pleasures.

6.4 THE PLEASURES OF SIMULATED ILLUMINATION IN GAMES

Interpreted through the conception of pleasure as developed in phenomenological philosophy and hedonic psychology, then, simulated illumination in digital game worlds affords the designer the opportunity to directly influence the player's experience, and, in so doing, create "eliciting conditions" (Kubovy 2003) for more complex gameplay pleasures. There are perhaps two ways in which this can happen. First, we have seen from our *Shadowplay* tests that the hue of simulated illumination can have a direct impact upon player affect, arousal and, consequently, performance. Warm illumination led to more positive affect and enhanced performance when navigating virtual space. We can thus propose a contribution from illumination qualities to player affect, to the way in which the player evaluates her situation in the current game state. As Järvinen (2008) notes, "in terms of emotion theory, flashy graphics are not just eye candy but an important antecedent of the play experience as an emotional experience" (p. 15). A concrete example of this can be demonstrated in *Assassins Creed* (Ubisoft 2007), in which an early mission is conducted in bustling Damascus, illuminated warmly from a low angle sun. The transition to the burnt-out and ravaged Crusader town of Acre, illuminated in a notably cooler manner in keeping with seaside atmospherics, is quite palpable. The somewhat oppressive emotional effect of that change has the potential to inflect the player's relationship with the narrative, including their evaluation of the town and the motivations of the ruling party.

Further, it can be argued that lighting patterns experienced by players as they move through sequences of game environments over time can have a higher-level effect: these patterns can construct a subtle, complimentary expectation/fulfillment system that supports gameplay ends. There is a long tradition of conceiving the emotional trajectory of non-interactive art forms in terms of expectation systems, and this model has also recently been applied within studies of interactive media. Inferences that the reader of a story forms unconsciously, on an ongoing basis, regarding possible outcomes for the characters of interest in a narrative, have been conceived as providing the foundation for emotional structures of tension and release in forms ranging from dramatic tragedy (Aristotle 1996), film (Tan 1996) and literature (Gallie 2000). This has been further developed in game studies literature (Klimmt, 2003) in relation to player activity. The creation of expectations that are formed during our experiences of artworks that unfold over time are an example of what Kubovy (2003) calls implicit learning: "a process whereby people learn rules (a) without having been told that what they are trying to memorize is governed by rules, and (b) without realizing that they are learning the rules" (p. 144). As an example, we learn over time in Chapters 3 & 4 of *Resident Evil 4* that large echoing spaces lit coolly from above tend to house Novistadors. This prepares us intuitively to face a particular challenge.

The relationship between contextual implicit learning (developed according to the inner logic of the game) and the sorts of expectancies we bring along with us into time-based artworks from our previous experience is further developed by Narmour (paraphrased in Rozin) with relation to the mental activity of a listener enjoying music. Narmour holds that there exists a bottom-up "set of innate expectations for sequences of auditory inputs." Superimposed upon it is a "top-down, acquired (learned) style expectation system" that is learned: "the result is that modest violations of innate expectations by composers continue to produce the arousal or tension that prevents boredom. And it is this tension resolution that would seem to be at least some of the source of the aesthetic pleasure of music" (p. 128). One source of appeal of this approach is that—in a wider aesthetic interpretation of simulated illumination—it allows us to do justice to both our experience of the primal power of light, as well as our awareness of light's plastic ability to be shaped by cultural convention. In a more immediate application, Narmour's argument that "modest" violations of innate expectations can be arousing and can contribute to aesthetic pleasure can help us interpret some of the contradictory findings from the *Shadowplay* project. According to our studies, warm illumination appears to have positive associations, and evokes positive affect within game worlds, but it is the cooler environments that restore us in *Resident Evil 4*. Again, according to Kubovy (2003), "the emotions that characterize pleasures of the mind arise when expectations are violated, causing autonomic nervous system arousal and thereby triggering a search for interpretation" (p. 134). When our experience of the quiet of cool exterior illumination in *Resident Evil 4* is repeated in the course of playing through chapters 3 & 4, we also tacitly learn (as per Kubovy, above) when we can relax. Thus, we could argue that our sensitivity to simulated illumination establishes a system of expectation and fulfillment, tension and release, that complements the contributions of the other aesthetic elements (sound, haptics, narrative and game actions) that comprise the multi-modal environment of digital games.

6.5 TRANSCENDENCE

Because light is almost always a background phenomenon in our experience (as opposed to music, or narrative, or various forms of activity), the system of light response outlined here is a subtle one—analogous to the bass line in music that is more felt than consciously perceived. But there are of course moments when one becomes more consciously aware of light—usually these are moments of extreme or unnatural color saturation (the green glow in the cave in the first level of *Splinter Cell: Chaos Theory*, for example), of strong contrasts (color, intensity, or time of day), or moments at which light is made visible (the moonbeams in *Resident Evil 4* are a good example). Extremes of light dynamism, such as the fireworks and light effects that accompany spell casting or fighting in some games are also such moments, as are those times at which the player consciously interacts with the illumination of a scene through flashlights or removing light sources.

We have seen that the constructs of hedonic psychology are a useful framework for interpreting the results of our exploration of the emotional effects of warm and cool environmental lighting, which focus upon the bottom end of our taxonomy of light influence: exposure, contrast, temporal change and lighting patterns. But we must also remember that light doesn't just bathe our senses, it can also be felt by us through metaphor, when light stands for something beyond itself. Perhaps more than any other sense phenomenon, light has been associated with divinity. For this reason, we cannot expect psychology discourse, with its roots in considerations of brain structure and evolutionary adaptations, to provide all we need to understand light in games. The metaphorical power of light is also an aesthetic phenomenon that is associated with awe, and it can strongly inflect the gameplay experience. For this, we are best attuned to the way in which light has been made manifest through cultural sources in art, literature and media, even cosmologies, magic, and alchemy. The moment that light leaves its background role and makes itself felt in a conscious way—when we marvel at shafts of sunlight or moonlight in a virtual environment, or at the fireworks that accompany the casting of a spell or achievement of a winning condition—light gives up its subtle effects and becomes magic, pure and simple.

6.6 SHADOW OF THE COLOSSUS: FIFTH COLOSSUS

> "The next foe casts a colossal shadow across a misty lake as it soars through the sky… To reach it is no easy task…"

When the deity speaks in *Shadow of the Colossus*—which it does in every level, to give the player the next assignment—it speaks from within impenetrable brilliance shining in through the oculus of a temple. The game is a good example of the ways in which a play experience can be structured within a luminous environment that has its own internal logic and effect, and at the same time draws upon the metaphorical power of light that people bring with them to the play experience.

Perhaps the best expression of a key use quality in *Shadow of the Colossus* is "identification with the landscape" (Indeed, Järvinen (2007) has wisely suggested that anyone seeking to design an environmental game should check it out). This is not a typical game use quality, but neither is *Shadow of the Colossus* a typical game. The main player activities include riding (for long periods of time), followed by intense bouts of climbing, holding and stabbing of colossi, giant opponents who must be felled in order to resurrect the hero's beloved.

The world of *Shadow of the Colossus* is magical. Executed at a level of slight abstraction, the environment is capacious and rich. It is also largely empty and windswept, which gives a slightly melancholy, lonely feeling to being there. The color palette is composed of desaturated greens, browns and grays. From a rendering standpoint, the world is represented with a relatively low level of light/dark contrast; indeed, in many environments, the only really dark values are to be found in the hero's clothing and the horse's coat, which has the effect of directing attention to them within the synthetic scene. The low contrast level in the frame is enhanced, and motivated by a fair amount of atmospheric perspective created by mist that extends the depth of the game environments. Low contrast and absence of sparkle is also motivated by the apparent weather in the world, patchy high clouds and, sometimes, filtered sunshine, which, particularly in the areas surrounding bodies of water, gives rise to very pale cast shadows. There is a slightly greenish overall cast that sometimes gives rise to effects of simultaneous contrast: a lavender sky (at least on my TV). The lack of direct sunshine, with an attendant lack of hard shadows and contrast, also plays an important role in the main game mechanic of scaling the colossi. While playing the game, one quickly learns the affordances of fur on the colossi—it is only on certain surfaces that one can get a handhold. Moreover, the colossi are often in rapid movement, and the orientation of surfaces on which one must maintain balance shifts almost constantly. An environment of higher contrast and active shadow casting would make for an impossible complex visual environment for quick action.

Although considered an action game, *Shadow of the Colossus* resembles a survival-horror game in that it evokes a measure of awe; but there is also a dose of melancholy. As in the previous discussion of survival-horror games, mist in *Shadow of the Colossus* serves an occluding function, obscuring full perception of scenes, and heightening the dramatic effect of the colossi when they appear. This, combined with the vastness of the colossi, evokes the sorts of sublime emotion that Burke (1998) describes, and that Grodal elaborates upon above.

But there is melancholy as well. Not only is the landscape depopulated and the visual environment muted and devoid of sparkle, but achievement of the goal of defeating the colossi does not render a feeling of "triumphant aggression." Every time a colossus dies, its "soul" enters the hero in a paroxysm of pain. The emotional blend of awe and melancholy, evoked by the game world and realized through gameplay, supports the chief use quality of "identification with the landscape." This use quality is also reinforced through other game mechanics: first, the player spends an inordinate amount of time (for a game) traversing ground. We thus spend a fair amount of time, as Grodal (2003) points out, in a state of "associative processing of perceptual input" from the landscape, in which we are capable of only limited action. Also, the colossi themselves often seem to be hewn directly from the surrounding scene, acting almost as forces of nature. The ultimate slaying of colossi brings them back to the landscape, and is accompanied by the melancholy feelings noted above.

At the beginning and end of every level are cutscenes that draw upon shared metaphors concerning light. Levels begin with the deity speaking to the hero out of a beam of brilliant light. Beams of light provide a wayfinding function, through the hero's sword. And at the end of each level, as the hero recovers from slaying a colossus, he moves into a tunnel of light, a "near death" experience, in which he can sometimes hear the voice of his beloved. *Shadow of the Colossus* thus manifests an organic, unified blending of the evocative power of illumination—functioning as sense stimulus, aesthetic medium, as well as metaphor—as a component of the gameplay experience.

6.7 CONCLUSION

It has been the contention of this thesis that the study of simulated illumination can tell us something about digital games as aesthetic experiences. This is because the design of light qualities in games engages, and can contribute to all the different characteristics of the aesthetic experience: wholeness, coherence, absorption, emotion, and make-believe. It is precisely because light is most often experienced as a background phenomenon that reflecting consciously upon it is so useful. We have seen that warm and cool light have particular effects upon player affect and performance, and that people describe their experiences of warm and cool illumination in a way that reveals a similarly powerful hold upon the imagination. We have also seen that the response to illumination in a game is contextual—we can implicitly learn to reverse our expectations about light environments in the course of playing. Even a mismatch between the illumination expectations we bring to a game, and our experience of a game world, can be pleasurable. Good designers will learn this, and learn how to further modulate our experience of simulated illumination in relation to gameplay beyond the current, genre-based patterns.

It has been my intention in this thesis to enrich our understanding of simulated illumination as an aesthetic component of digital games, and at the same time to complicate the task of game designers. Game lighting is not just about supporting verisimilitude in game environments; simulated illumination can have an effect on player emotion, and create a fertile environment for the development of more complex game pleasures. It should be manipulated with a similar degree of thoughtfulness and care as the other, more foregrounded elements of game construction, such as game mechanics, narrative, character and sound. Light has a unique capacity to shift from background to foreground phenomenon, from the barely noticed (yet still felt) luminous environment, to the attention-grabbing effect and sublime metaphor. The fugitive nature of illumination is one that is waiting to be explored in relation to shifts in the game state, theme, event and mechanics. I hope that the advent of new types of games, new rendering technologies, and new play environments will offer the opportunity to explore the full contributions of simulated illumination to the sensory and emotional experience of the player, and I share the excitement and impatience of Antonin Artaud who, in 1932, speculated about a new theatre of the senses:

> "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).

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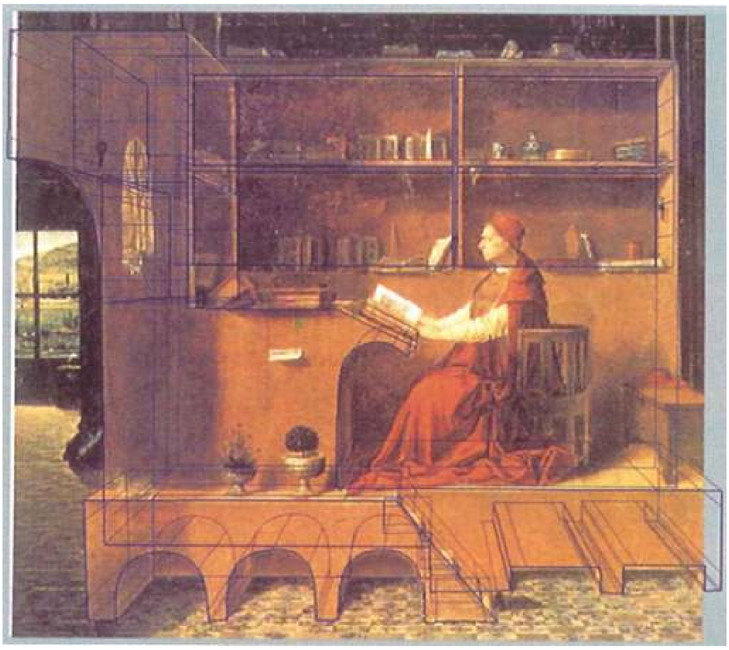
THE COMPENDIUM TEXTS

COMPENDIUM TEXT 1:

SIX ST. JEROMES: NOTES ON THE TECHNOLOGY AND USES OF COMPUTER LIGHTING SIMULATIONS



Simon Niedenthal

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ABSTRACT

Computer-generated images have become commonplace in recent years; just as commonplace is the absence of rich and compelling illumination and surface definition. The advent of radiosity rendering--which models light behavior much more accurately than existing rendering modes--signals a major advance in the capabilities of computer simulations. “Six St. Jeromes” is a digital recreation of a detail from a painting of St. Jerome in his study by Antonello da Messina from about 1460, and is comprised of six versions of the scene under different lighting conditions. William Mitchell’s The Reconfigured Eye serves as inspiration for this project, specifically the chapter in which he traces digital image synthesis from the simplest to the most complex with reference to the corresponding changes that occurred in painting from the Renaissance to contemporary works. This project does not propose to “correct” da Messina’s original, or produce works of art that aspire to a comparison; rather, “Six St. Jeromes” attempts to explore the behavior of light in an environment that was never built--a task uniquely well-adapted to computer simulation--and to use the process of historical reconstruction as a means of refining the quality of digital images. Ultimately, the collision of a fifteenth-century painting with current rendering technology suggests new uses for lighting simulation, and calls for consideration of the significance of computer-generated light.

I’d like to begin with a quotation by St. Bonaventure: “Light is the substantial form of bodies; by their greater or lesser participation in light, [bodies] acquire the truth and dignity of their being.” (1) I’m sure I don’t have to make it clear that by “bodies,” Bonaventure is referring not to our physical being, but rather to matter itself; his argument takes place in the context of the great medieval metaphysics of light. In a similar vein, Robert Grosseteste begins *De Luce*, his 13th century treatise on light, with the assertion that: “Light of its very nature diffuses itself in every direction in such a way that a point of light will produce instantaneously a sphere of light, unless some opaque object stands in the way . . . Corporeity [that is, the capacity of matter to take form and occupy space], therefore, is either light itself or the agent which performs the aforementioned operation and introduces dimensions into matter in virtue of its participation in light.” (2) Light is portrayed by both theologians as the mechanism by which the cosmic x, y and z axes are defined, the first of a number of intriguing echoes of medieval thought on light and optics that one encounters in digital image synthesis.

In a less metaphysical sense, an understanding of the power of light to define things underlies foundational lighting curricula everywhere (including my own). A quick survey of some notable photographs demonstrates the way in which light and value are central to the perception of pictorial form, surface qualities, space, and volume. Qualities of light, moreover, have the capacity to wield emotional influence through association with primal visual needs. And as with all visual experience, what we see and the way we think about light is informed by cultural traditions. As sensory phenomenon and interpretive touchstone, light yields to both scientific and cultural analysis, and serves as a useful starting point for a consideration of new applications of digital technologies to the subjects of art and architectural history.

In his seminal work *The Reconfigured Eye*, William J. Mitchell traces the development of digital image synthesis from simplest to most complex technique with reference to corresponding changes that occurred in painting during the Italian Renaissance and afterwards. His opening argument establishes a dialogue between photography and painting, two media with differing manners of engaging value and representing light effects. "Synthetic-shading procedures" Mitchell writes, " are used to develop perspective views into closer approximations to--even simulations of--photographs. (Thus they are closely analogous to the procedures Renaissance artists employed to convert line cartoons into tonal and colored paintings)." (3) The process of creating a digital image based on a 3d scene begins with the fashioning of a wireframe model to express the physical boundaries of surfaces and objects. In the early days of digital image generation, the boundaries were denoted as a list of vertices in 3d Cartesian space, though now we have become accustomed to manipulating wireframe models through interfaces as graphic representations. Once the objects and spaces of a scene have been modeled, surface characteristics are associated with each formal element, light qualities and positions are specified, and the scene is rendered. The rendering program takes into account the geometry, surface qualities, and lights of a scene and renders a 2d representation of that scene from a given viewpoint.

Mitchell goes on to explore digital image rendering from simple flat shading to the most complex radiosity calculations, referring along the way to artists as diverse as Reynolds, Vermeer and Paul Gauguin. The easiest way to render a surface in the computer is to simply specify a single color for each point on the surface, but over time rendering algorithms have been refined to allow the calculation of shading and light effects of progressively greater complexity and fidelity to visual experience. One conceptual breakthrough was the development of raytracing. The rationale for raytracing is that while there are billions of light photons bouncing around in any visual environment, the ones that really matter are those that enter the eye. (4) In the raytracing process a virtual picture plane composed of a grid of pixels is defined, and a ray is traced from an eyepoint through each pixel into the scene until it reaches a surface. The light environment informs the surface characteristics of each point, and the resulting hue is used to color the pixel. The process continues until all pixels in the grid have been colored. Raytracing is, as Mitchell points out, analogous to the way in which a perspective is constructed, and quotes Leonardo:

> "'Obtain a piece of glass as large as a half sheet of royal folio paper and fasten this securely in front of your eyes, that is, between your eye and the thing you want to portray. Next, position yourself with your eye at a distance of two-thirds of a braccio from the glass and fix your head with a device so that you cannot move at all. Then close or cover one eye, and with the brush or a piece of finely ground red chalk mark on the glass what you can see beyond it.' Thus each ray (Mitchell continues) in the viewing pyramid projects a color from a point in the scene to a point on the picture plane . . . "(5)

Besides the similarities to perspective construction, the process of projecting rays from the eye to a surface beyond is reminiscent of Euclid's theory of vision, which was considered viable at least until the optical work of Al-Hazan, though popular long into the medieval period. (6)

Although raytraced renderings allow the simulation of more sophisticated visual phenomena, such as accurate reflections and refraction, the products of this sort of rendering still lack a sense of the real presence of light. Specifically, the interreflection and color bleed from one surface to another are not calculated. In any room, we could say that there are areas of direct illumination, where lights are shining directly on surfaces, and other areas of indirect illumination that are lit by the light bouncing from surfaces. The indirect illumination is not calculated in a raytraced image. Practically speaking, simulating accurate light presence in a raytraced image calls for a procedure that combines a photographic process--setting lights within the space of the 3d interface--with a practice in which areas of light and dark value are applied directly to surfaces in a manner more analogous to painting. In the words of the old cinematographer's saw, "if you can't paint with light, light with paint."

So following Mitchell's lead, I have rendered a simple scene using techniques of progressively greater complexity. This is a simulation of a room with a skylight and several cubes in it, rendered under default lighting. Default lighting in Alias is, as you see, the computer graphics equivalent of Grosseteste's formless universe. Anyone who has looked at light for a while can noodle around for a few minutes and produce something that demonstrates a more convincing impression of light in the environment. The Phong shading algorithm appears complex, yet it renders a fraction of the effects of light in a real space; in fact, it is so limited a model that I had to paint many of the subtle shadows and gradations in this figure directly on the surfaces, rather than relying upon the algorithm's inadequate simulation of surface-to-surface interreflection.

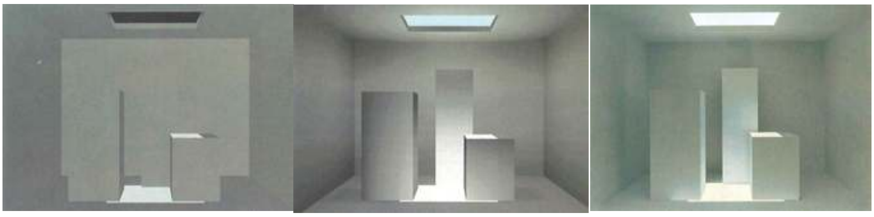

Figure 1: (from left) Default lighting (Alias), raytraced (Phong), radiosity.

The advent of radiosity rendering--which models light behavior much more accurately than other rendering modes--signals a major advance in the capabilities of computer simulation. Radiosity rendering derives originally from methods developed by thermal engineers in the 1960s to simulate heat transfer between surfaces, as a means of designing jet engines, among other things. In the mid-1980s, computer scientists at Cornell University began to apply these techniques to the modeling of light with the computer. Radiosity calculations are based upon the principle of conservation of energy. When light is introduced into an environment it illuminates some surfaces directly, and, depending on surface characteristics, some of the light is absorbed and the rest reflected back into the environment. Most current renderers do not calculate the contribution of surface-to-surface interreflection to the illumination in a scene. Radiosity software models interreflection by creating a mesh which stores the illumination values associated with each surface. After distributing energy from the light sources, the algorithm checks each surface and determines which has the most energy to reflect back into the environment. The progressive distribution of light energy continues until all of the energy in the environment has been absorbed, or until the process is stopped.

Architectural historians eager to simulate unbuilt or destroyed buildings have seized upon rendering technologies of greater sophistication, and examples abound of reconstructions of everything from Frank Lloyd Wright buildings to the castle of Mad King Ludwig of Bavaria. (7) Notable works that have pioneered the use of radiosity rendering technology in an architectural context include Kent Larson's 1993 simulation of Louis Kahn's unbuilt Hurva synagogue. (8) Larson's most recent work continues the exploration of light and surface in Kahn's unbuilt projects for Scripps at La Jolla. (9) Also beautifully realized is MIT colleague Takahiko Nagakura's visualization of Terragni's unbuilt Danteum. (10) These projects are not the rule, however, for although computer-generated images have become commonplace in recent years, just as commonplace is the absence of rich and compelling illumination qualities and surface definition.

Mitchell's contention that the development of techniques of digital imaging are analogous to painting procedures is both encouraging and problematic; encouraging, because it suggests that processes we are currently engaged in can be informed by study of the past, problematic because it fails to address significant differences between digital and analog. Making precise distinctions is central to thinking critically about media, yet we continually witness the bleeding of art terminology into the realm of the digital. Early on I was struck by the way in which filmic and photographic concepts are embedded in software. Consider, for example, the camera icon from Maya software. But the analogies in software go far beyond the photographic. In computer graphics we refer to renderings, we employ software called Painter and Piranesi, and, while waiting for an action to be performed, my laptop executes a little version of the Mona Lisa instead of showing the usual clock face. Another amusing example of the intersection of painting vocabulary and interface design is the creation icon in 3d Studio Max, a hand with a spark at the fingertip that is a cross between the ceiling of the Sistine Chapel and ET. But anyone who has performed a task as elementary as "drawing" a curve in a 3d package understands just how limited the analogies between digital and other media really are. I always think of defining a C.V. curve as being more like an abstract type of wood bending, of applying forces to a ductile material and editing the points until the desired profile has been achieved. Any notion of the gestural component of drawing pretty much goes out the window in 3d software.

The construction of painting space in a digital medium is one means of exploring Mitchell's painting/rendering analogy, and, in fact, the last few years have seen a number of examples. Though the simulation of a painting in 3D space is often seen as striking a blow against the ascendancy of photorealism in computer rendering, some projects seek a wider scope, including "Rouen Revisited" by Paul Debevec at the University of California, Berkeley. The Rouen project uses Monet's 30 or so canvases of the cathedral as well as historical and contemporary photos to allow a viewer to reconstruct the front facade from a range of viewpoints at different times of day or seasons. Debevec describes his project as follows:

> "Fascinated by the play of light and atmosphere over the Gothic church, Monet systematically painted the cathedral at different times of day, from slightly different angles, and in varied weather conditions. Each painting, quickly executed, offers a glimpse into a narrow slice of time and mood. We are interested in widening these slices . . ."(11)

While this project undoubtedly advances the technology of image generation, it raises questions about the uses of digital construction. Architecture atleast aspires to 3 dimensions in its built form. There are many reasons that the Kahn and Terragni projects, for example, remained unbuilt--often financial ones--but there is still something to be learned about the modulation of light that can be usefully approximated by computer simulation. Construction of painted architectural space is a bit more problematic. After all, a painting is quite content to remain in two dimensions.

3D simulation of painting space is useful when it goes beyond merely expanding the work to another dimension, and instead adds an additional facet to our understanding of the work at hand. Applying photoreal simulations of light behavior to a painting can serve, for example, as a means of throwing the painter's value choices into relief. Thus the tasks of the *Six St Jeromes* project: first, to reconstruct some of the intellectual context of a painting, and, secondly, to rethink the dangers, uses and legitimate pleasures of this sort of simulation. The goal of this project as it was initially conceived was to put Mitchell's thesis to the test, to collide a 15th century painting with the most recent rendering technology and see what emerges.

St Jerome in his Study by Antonello da Messina dates from somewhere between 1450 and 1475; there seems to be some uncertainty (according to Little) as to whether the painting represents Antonello's early work, or was produced during his later stay in Venice. The French novelist Georges Perec, who kept a print of the painting on his wall, nicely grasped the snug bookishness of the study:

> "The whole space" Perec writes "is organized around the piece of furniture (and the whole of the piece of furniture is organized around the book). The glacial architecture of the church (the bareness of the tiling, the hostility of the piers) has been cancelled out. Its perspective and its vertical lines have ceased to delimit the site simply of an ineffable faith; they are there solely to lend scale to the piece of furniture, to enable it to be inscribed. Surrounded by the uninhabitable, the study defines a domesticated space inhabited with serenity by cats, books and men." (12)

The St Jerome painting offers itself for several reasons: first, because da Messina was among the first artists to work with oil paints and glazes, and the new materials allowed him a greater range of tonal and light effects. He was also active in a period in which the changes documented by Mitchell were becoming fully felt; the painting, moreover, responds well to conceptions of light in the art theory of da Messina's contemporaries.

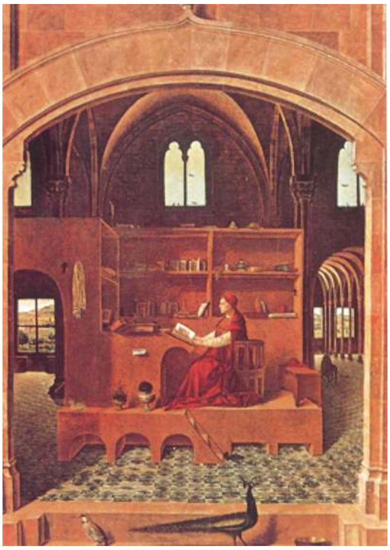

Figure 2: St Jerome in his study, by Antonello da Messina

The project began with the construction of a wireframe model of St. Jerome's study, corresponding to the perspective of the painting. A preliminary shaded version of the scene with default lighting and basic texturing was brought into Lightscape software for radiosity processing. Once the model was set up in an environment that roughly corresponds to the painting, it became possible to begin a series of "what if?" renderings: what would it look like if sunlight were coming from the other side? What if the light coming in the doorway was very cool and flat? What if soft light was coming in exclusively from the clerestory windows above? What if Jerome decided to burn the midnight oil?

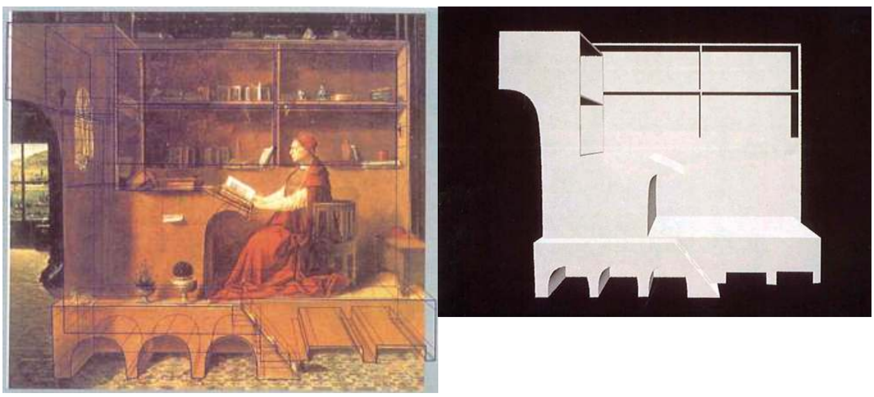

Figure 3: Wireframe and shaded version of the desk.

At this point it struck me that I had achieved only an inverse appreciation of the light of the painting—that is, none of my variations seemed as interesting as the original. To pursue this hunch, I attempted in my fifth and sixth versions of St Jerome to reconstruct the lighting environment suggested by the painting, and

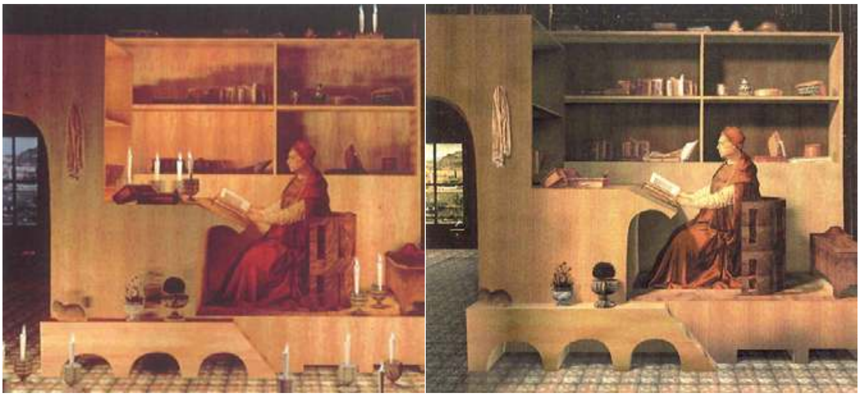

Figure 4: (from l.) St. Jerome by candlelight, final rendering.

used whatever techniques necessary to replicate the values on the surfaces. In doing so, I learned that the painting manifests a close relationship to theories on light of near contemporaries like da Vinci. The painting exhibits, of course, a wonderful chiaroscuro:

> "The first intention of the painter is to make a flat surface display a body as if separated from this [picture] plane, and he who most surpasses others in this skill deserves most praise. This accomplishment, with which the science of painting is crowned, arises from light and shade, or as we may say chiaroscuro." (13)

Further, the treatment of the saint's face echoes other writings of Leonardo on the rendering of facial form:

> "The utmost grace in the shadows and the lights is added to the faces of those who sit in the darkened doorways of their dwellings. Then the eye of the beholder observes the shaded part of the face thrown into deeper shade by the shadows from the aforesaid dwellings, and sees brightness added to the illuminated part of the face by the radiance of the atmosphere. Because of such increases in the shadows and light the face acquires great relief . . . " (14)

Besides his "St Jerome," Antonello's portraits also frequently demonstrate this strategy.

In his treatise on light in Renaissance theories of art, Moshe Barasch distinguishes two schools of thought on the concept of illumination. In the first, a "functional" conception, the major task of light is to illuminate bodies and render them visible, while the function of shadows is to produce relief and the semblance of corporeality. The second approach emphasizes the relation of light to contents and themes. (15) “St. Jerome in his Study” responds to both of these conceptions. Close scrutiny reveals careful delineation of the form of the desk, apparent in the touches on the panel that do not reference the suggested light environment--gradations, for example, where one surface meets another. And as we have seen, the treatment of Jerome’s face echoes da Vinci’s advice on how to make a body emerge from the picture plane. But the presence of light in the painting also references iconographic themes. In her study of the painting, Penny Howell Jolly notes the presence of Marian symbolism and the similarities of the Jerome painting to an Annunciation. “Like Mary at the Annunciation,” Jolly writes, “Jerome is bathed in a celestial light and visited by a divine presence.” (16)

Ultimately this project suggests possible uses for radiosity rendering as a tool of art scholarship. One could use computer simulation and radiosity processing to check a 2D representation against a 3D structure upon which it was based, to help visualize the behavior of light and simulate the space of unbuilt or lost projects, to aid in the process of renovation or historic preservation, or to study the illumination environment of works of art. This is especially useful in cases where the conditions of illumination in a space have been altered over time.

As a field of study in itself, however, computer-generated light has barely been explored. One good critical touchstone to apply to the generation of new digital projects is the question: could this project have been done if the computer did not exist? (17) Could it even have been thought of? One thing that sets computer simulations apart from light in real space is the light algorithm itself, and gaining an understanding of computer-generated light calls us to contemplate the differences between the algorithm and real light behavior. For example, one unique quality of light simulated by algorithm is that the algorithm can be reversed: if the intensity of a source in most 3d packages is set to a negative number, the source extracts light from the scene. “The light that shineth in darkness” becomes “the light that shineth darkness,” inverting the process with which I opened this paper: “Light of its very nature diffuses itself in every direction in such a way that a point of light will produce instantaneously a sphere of light . . .” The capacity to simulate the inverse of light behavior—to create spheres of darkness—is clearly one path to explore with algorithmic light, and offers the possibility of new modes of spatial visualization that philosophers like Grosseteste could never have conceived.

Notes:

1 Umberto Eco, *The Aesthetics of Thomas Aquinas* (Cambridge, MA: Harvard University Press, 1988) p. 110

2 Ibid.

3 William J. Mitchell, *The Reconfigured Eye* (Cambridge, MA: MIT Press, 1992), p. 137.

4 This insight is taken from the Lightscape Visualization System *Getting Started,* p. I-7.

5 Mitchell, *The Reconfigured Eye*, p. 139.

6 David Park, *The Fire Within the Eye: A Historical Essay on the Nature and Meaning of Light* (Princeton NJ: Princeton University Press, 1997), p. 78.

7 B.J. Novitsky, "Reconstructing Lost Architecture," *Computer Graphics World*, December 1998, p. 25. See also the April '99 issue of CGW.

8 Vincent Scully, "A Virtual Landmark," *Progressive Architecture*, Sept. 1993, p. 80ff.

9 *Architecture*, Feb. 1999.

10 These images are taken from the 1998 *Siggraph* reel.

11 from Paul Debevec Home Page, alberti.cs.berkeley.edu/~debevec/. Another project involving the 3d for its own sake is the stomach-churning flythrough of Van Gogh's Yellow Room on the artmuseum.net website.

12 Georges Perec, *Species of Spaces and other Essays* (New York: Penguin, 1997), p. 86.

13 Mitchell, *The Reconfigured Eye*, p. 139.

14 *Ibid*, p. 143.

15 Moshe Barasch, *Light and Color in the Italian Renaissance Theory of Art* (New York: New York University Press, 1978), pp. xi-xiii.

16 Penny Howell Jolly, "Antonello da Messina's St. Jerome in his Study," *Art Bulletin*, June 1983, p. 252.

17 I am indebted to an editorial by John Lansdown in *Leonardo* magazine (1998) for this test.

COMPENDIUM TEXT 2:

LEARNING FROM THE CORNELL BOX

Simon Niedenthal

Presented at the *Digital Arts and Culture conference (DAC2000)* in Bergen, Norway, July 2000, and published in *LEONARDO* (2002), vol. 35, no. 3, p. 249ff.

Abstract:

The Cornell Box serves as a visual emblem of the divide between arts and sciences first articulated by C.P. Snow over forty years ago. To historians of American art, "Cornell Box" refers to the shadow boxes of Joseph Cornell; in the world of computer graphics the Cornell Box is the evaluative environment in which the Cornell University Program of Computer Graphics refined its radiosity rendering algorithms. Considering both boxes with reference to the perceptual thought of James J. Gibson allows us to generate a site for collaboration at the intersection of light and art for designers and computer scientists devoted to the development of new digital media.

1. Snow's Gap

Though Art Center College of Design and Caltech are located no more than 5 miles apart in Pasadena, California, the institutions have over the years developed highly specialized academic cultures. A few students take advantage of the opportunity to cross-register for classes, but otherwise we share no infrastructure; we lack even a common academic calendar. Recently however the presidents of both institutions established an initiative to build a new relationship that would include project-based collaboration. Rather than inaugurating the process with a large investment, or new interdisciplinary study center, we have chosen to begin by researching existing relationships that have formed between students and faculty at the two institutions. Despite the obstacles, students from our schools have met and conducted informal collaborative projects. In one example, an input device for a Caltech doctoral student's gesture-based 3d drawing program was developed using the silicone casting techniques of one of our graduate design students. We hope to take what we learn from our research and build new institutional structures that will foster this sort of give and take.

This summer we began our first joint effort, and the experience was illuminating. Caltech and Art Center applied jointly for a National Science Foundation grant to fund post-graduate fellowships in entrepreneurship that would team students from our institutions. Some of our counterparts at Caltech, however, thought of design as something to be applied near the end of the product development process: there was lots of talk of "form factors." At Art Center, we have been trying to move away from the sort of understanding that reduces design to a thin veneer of "look and feel.” Conversely, I have spoken with Caltech researchers who resent being treated by their collaborative partners as lacking in creativity and useful only when harnessed for their programming skills. I’m getting tired of quoting C.P. Snow, but it is clear to me that his forty-year-old thesis is still valid. Art and scientific communities still fail to communicate adequately and this lack of communication is reinforced by educational structures. “Closing the gap between our cultures,” Snow wrote, “is a necessity in the most abstract intellectual sense, as well as the most practical.”(1) But I also firmly believe that this “clashing point,” as Snow puts it, offers “creative chances”(2) to spark the development of new ways of thinking and seeing.

Besides developing new institutional structures to address this gap, I propose a complimentary academic practice. A discipline devoted to navigating the gap between art and science would be of value if it helps us better understand the creative processes embedded in art and scientific artifacts, and to do better science and design. As a means of outlining the way in which this practice could be pursued, let us consider the Cornell Box. Mention “Cornell Box” to art aficionados and they are likely to conjure up an image of “Untitled (Medici Prince)” (see figure on the title page) or another of the shadow boxes of the American artist Joseph Cornell. To computer graphics researchers, on the other hand, “Cornell Box” refers to the evaluative environment in which the Cornell University Program of Computer Graphics developed its radiosity rendering algorithms (see figure on the title page).

2. The Two Cornell Boxes

Joseph Cornell’s shadow boxes occupy a unique place in the history of 20th century American art. Originally shaped by the Surrealist taste for assemblage, Cornell’s work also resonated with the subsequent movements of Neo-Romanticism, Abstract Expressionism and Pop Art. Cornell began to create his small, glass-fronted boxes in the mid ‘30s, working for the most part in series. His obsessive interests, which included movie actresses and 19th century ballerinas, informed the vocabulary of the boxes, and their physical design was influenced by the traditions of the diorama and wunderkammer, as well as vernacular sources such as the peepshow and the arcade game. Critical appraisal has focused on the poetic nature of Cornell’s work, its capacity to evoke wonder and the processes of memory. “Founded in the magic and mystery of the poetic experience,” one critic writes, “his collages, films, and constructions are affirmations of serenity, recollection, enchantment, beauty, the extraordinary."(3)

The Cornell University Box (and here I alter the name slightly for clarity) is a physical object that corresponds to a computer-generated model, and it is used to test the predictive accuracy of light propagation algorithms. Beginning in 1984, researchers headed by Professor Donald P. Greenberg published studies that altered the way in which people thought about modeling light behavior in the computer, and led to substantially improved computer-generated renderings.(4) The use of the box was central to their approach. Light algorithms can only be predictive, the reasoning goes, if the results can be verified in a real-world environment. Further, computer generated renderings of an environment can be only considered accurate if they are proven indistinguishable to the eye from a built version of that environment.(5) So the results of the calculations from the virtual box were compared with light meter readings from the physical box, and perceptual studies were run to compare the rendered results to a viewing of the box itself . Since its first publication, the box has become the defacto testbed for advanced rendering systems, and, as more challenging materials are attempted, the renderings have begun to take on the strange sense of displacement one finds in the paintings of de Chirico, for example. The box had no name in the early papers. When queried about the name and Joseph Cornell's artwork, Greenberg offered only that the box gained the Cornell moniker after a number of publications from the University.(6) The lack of kinship between the two boxes, and the two cultures, would appear to be complete.

3. Joseph Cornell's Basement

Fiction can help us navigate this gap between computation and art. In his 1986 novel *Count Zero*, William Gibson conceives of a machine capable of producing the Cornell boxes of the future:

> "There were dozens of ... arms, manipulators, tipped with pliers, hexdrivers, knives, a subminiature circular saw, a dentist's drill . . . Two of the arms, tipped with delicate force-feedback devices, were extended; the soft pads cradled an unfinished box."(7)

Orbiting the earth in an abandoned mainframe core, the machine is surrounded by a whirling drift of weightless objects used to fill its boxes, including "A yellowing kid glove, the faceted stopper from some vial of vanished perfume, an armless doll with a face of French porcelain . . ."(8) The machine's activity of selection and rejection creates a kind of dance through which the it fashions its constructions, which embody, as Gibson puts it, "the solid residues of love and memory."(9) The construction of Cornell boxes in *Count Zero* serves as a metaphor for the working of the creative mind. The creative act always involves rejection of options: the excised or obscured element, the brush stroke withheld. But the archives of the collage artist constitute a rich store of visual material that has not found its way into a completed piece.

Cornell's work lends itself to this sort of fictional treatment because of the fascinating way in which much of the artist's creative process can be visualized spatially. Unlike the boxmaking machine in *Count Zero*, Cornell was an ambulatory gatherer. In his journals and published statements, the artist attributed much of his inspiration to strolls around Manhattan, including the seminal insight to put objects into boxes. If moving through the world in search of material was one pole of Cornell's working process, the other was sorting his finds in his basement workspace and filtering them into boxes. Photographs of his workspace would appear to confirm his biographer's contention that the odds were one in a thousand that a piece of archived material would actually end up in a box.(10) The sheer quantity

Figure 1: Joseph Cornell's basement. Photo by Hans Namuth.

of material directs critical attention to the importance of filtering in his method; indeed his biographer calls Cornell's art an art of "distillation."(11)

4. The Creative Algorithm

Creative algorithm generation can similarly be appreciated as a process of distillation. The behavior of light in even a simple space is an exceedingly complex phenomenon; in this room, for instance, there are billions of photons bouncing around. The development of algorithms for modeling light behavior is a thus great place to explore creative thought in graphics research. An important conceptual breakthrough in the history of rendering was the development of raytracing. The principle of economy that makes raytracing effective is the recognition that while there are billions of light photons bouncing around in any environment, the photons that really matter are those that enter the eye.(12) The group at Cornell University further refined the raytracing principle of economy. The photons that are important are those that enter the eye, and the eye itself has limitations and needs. The thresholds of the visual system inform the parameters of the algorithm. Moreover, the eye also has needs that are not met by the raytracing process, and it is here that the Cornell group made its greatest contribution to rendering. Raytracing algorithms fail to produce renderings that captured the richness of a scene because they are not complex enough to take into account most of the secondary reflections that occur

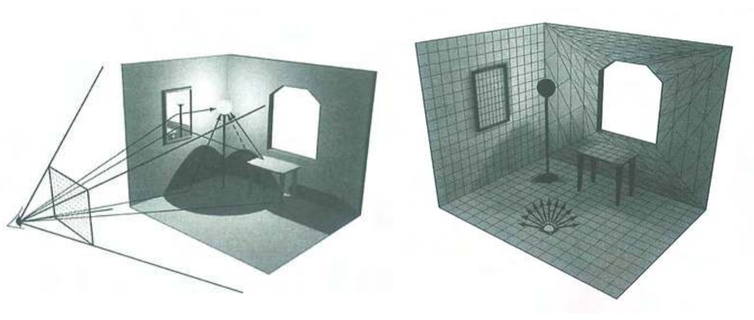

Figure 2: (from l.) raytracing, radiosity.

from surface to surface in real space. In any environment we might say that there are surfaces directly illuminated by light from sources, and surfaces that are illuminated indirectly by the light reflected from other surfaces. This indirect illumination we call ambient light.

The conceptual breakthrough that led to the modeling of ambient light in the Cornell radiosity algorithm was recontextualizing existing models of thermal energy transfer to address the problem of light propagation.(13) Greenberg himself prefers to emphasize the incremental advances, the give and take of collaboration, and the insights that allowed some vexing problem to be solved.(14) Radiosity algorithms model interreflection by creating a mesh which stores the illumination values associated with each surface. After distributing energy from the light sources, the algorithm checks each surface and determines which has the most energy to reflect back into the environment. The progressive distribution of light energy continues until all of the energy in the environment has been absorbed, or until the process is stopped.

5. The Light-filled Space

Reversing our strategy, and examining Joseph Cornell's work through the lens of the Cornell University Box, has the benefit of directing our attention to the theme of light in Cornell's work, a consideration that has drawn little critical attention. One of the defining characteristics of Joseph Cornell's Boxes is that they present just enough depth to engage light on objects in real space, while still drawing upon 2D pictorial conventions. The way in which Cornell boxes engage their illumination environment is crucial to the play of dimensionality that is one of their most interesting features, and the exquisite sensitivity to light and its effects that emerges from the artist's journals suggests that this feature was carefully considered. Indeed, Cornell was a master of raising his perception of light to conscious reflection. A journal entry from 1945 celebrates the exhilaration of an early bike ride. "effects of light striking & shining through—now indistinct as though filled with smoke"(Cornell's emphasis).(15) It is instructive to see Cornell practicing his sensitivity to light in his day to day environment; the light of his dreams is equally transcendent. In 1963 Cornell recorded this journal entry after waking from a nap: "in a large whitish room—sense of light strong—spacious . . .great sense of everything white—but more than just physical ambience—a sense of illumination."(16)

The artist also exhibited considerable care for the interaction of his boxes with the light of their environment. It is sometimes difficult to speculate about the ways in which artists design light interaction into their work; after all, it often isn't possible for the artist to control the conditions of viewing upon giving up the work, unless it was designed for a particular place. There were, however, certain illumination environments in which Cornell presumably did have a say: his gallery exhibitions.

Figure 3: Cornell's aviary series at the Egan Gallery. Photo by Aaron Siskind.

Cornell's exhibition at the Julian Levy gallery in 1939 was one in which darkness prevailed. The "lights were turned down, and thimbles, dolls and bits of broken glass could be found both in and out of shadow boxes."(17) The effect of this subdued level of illumination upon Cornell's work of the period would create deep boxes, obliquely lit dramatic spaces. The exhibition at the Egan Gallery in 1949 had much more of a high key look; if Joseph Cornell and the researchers at Cornell University made something together, perhaps it would look like this space. In the design of the space, the Cornell box is projected into a full 3 dimensions: the internal divisions of the boxes are extruded out to become wall elements, and the space itself is transformed into a light environment which echoes the illumination layout of the 1985 Cornell University Box. Let us reverse this dynamic imaginatively, and consider Cornell boxes as spaces in which light effects are explored. The photo shows a white room bathed in even light. The aviary boxes in this series featured white linings, some presenting a kind of flatness of aspect that echoes the work of Cornell's Abstract Expressionist contemporaries, others offering hidden recesses and depth. The play of flatness and depth, reflection and transparency, is clearly a major source of the power of Cornell's work.

6. Light and Surface

A further benefit of considering art and scientific artifacts together is the possibility of identifying or generating shared vocabularies and terms of reference that can help support collaboration. Both types of Cornell Box enable a kind of vision that is informed by the perceptual psychology of James J. Gibson (and, for clarity, further mentions of Gibson will refer to James, not William).(18) Gibson's concept of natural vision takes the human body and its environment as its starting point; it "depends on the eyes in the head on a body supported by the ground."(19) Moreover, Gibson's model assumes a moving perceiver, afoot not in three-dimensional Cartesian space, but in a medium with vertical polarity that corresponds to our experience of the pull of gravity. And unlike the geometrically-defined world of classical optics—in opposition to which Gibson framed his theories—the world of ecological optics is rich and nuanced, full of surfaces and clutter which afford the moving perceiver the visual information necessary to make sense of their surroundings.(20)

The spatial assumptions from which Gibson proceeds are as different from the process of computer generated rendering as they are from classical optics, a fact which helps explain the gut aversion that many have to the "cold" look of early computer graphics. A glance at a shading algorithm makes it clear why this is so. The ambient term in the most rendering algorithms is an arbitrary constant, and has nothing to do with the real dynamics of surface-to-surface interreflection in an environment. And, as Gibson points out, it is the visual information conveyed by ambient light that most powerfully orients us in our environment. Gibson is drawn to light that reverberates, from particle to particle, surface to surface.(21) One can easily understand why, given his presumption of a moving observer. The information transmitted by ambient light is view-independent, and provides the constant—or "invariant," in Gibson's terminology—that helps people understand their environment as they move through it. The radiosity algorithm developed at Cornell adds the missing component of ambient light to the digital rendering process. "Reverberating" light is made present in the algorithm by considering each object in the environment as "a secondary light source,"(22) and visual needs are thus inscribed in the radiosity algorithm.

7. Perceptual Limits

Figure 4: Skyspace, James Turrell

The status of Joseph Cornell's boxes as objects of perception can best be grasped through contrast to the work of James Turrell, a light and space artist whose work—like Cornell's—tends to evoke critical praise for its mysterious, spiritual qualities.(23)

Some of Turrell's light installations also bear a resemblance to the 1985 version of the Cornell University Box. It is no surprise that Turrell's work engages issues of visual perception; he studied psychology in college and participated collaboratively with Dr. Edwin Wortz—a physiological psychologist—in the Art and Technology program at the Los Angeles County Museum of Art in the late '60s.(24) Together Turrell and Wortz explored the Ganzfeld effect, producing small hemispheres in which a viewer experienced a homogeneous, undifferentiated light field. In the Ganzfeld effect the retina is stimulated by light but no visual detail is present, a phenomenon that played a central role in the development of Gibson's theories of thresholds and visual information. Gibson described Metzger's experiment, the original exploration of the Ganzfeld effect in the 1920s, as follows:

> "He faced the eyes of his observer with a large, dimly lighted plaster wall, which rendered the light coming to the visual system unfocusable . . . The total field (Ganzfeld) was, as he put it, homogeneous. Under high illumination, the observer simply perceived the wall . . . But under low illumination, the fine-grained texture of the surface was no longer registered by the human eye, and the observer reported seeing what he called a fog or haze or mist of light."(25)

The implications of the Metzger experiment were highly significant to Gibson. "The experiment provides discontinuities in the light to an eye at one extreme," he wrote, "and eliminates them at the other."(26) This allowed Gibson to differentiate his theories from classical perceptual psychology precepts of stimulus and response. In darkness, Gibson writes, "vision fails for lack of stimulation. In homogeneous ambient light, vision fails for lack of information."(27)

If we were to consider the art of Cornell and Turrell in terms of Metzger's experiment, letting Cornell boxes stand for the fine-grained wall surface, and letting Turrell's work correspond to the Ganzfeld, we can then see that each artist is exploring a perceptual limit. As objects of perception, Cornell boxes offer the body intimate clutter, small, easily manipulated spaces that are progressively subdivided to the level of micro texture, affording the eye plenty of the information it craves.(28) The reach of the arms defines the scale of the box, and within that range the box is easily scanned by the area of the retina that specializes in the resolution of fine detail. The experience of a Turrell Ganzfeld space is nearly the opposite. It is an encompassing space that is full of light but devoid of visual information, and the effect on the body can be striking. Some visitors to a Turrell Ganzfeld installation at the Stedelijk museum in Amsterdam felt so disembodied they had to crawl through the space on hands and knees; eventually, a path had to be cut through the exhibition on the floor.(29)

Rather than creating works that encompass the viewer, Cornell's work is characterized by the process of miniaturization and progressive refinement of textures. Cornell's working method supports this focus on texture. His biographer noted that after constructing the shell of a box, Cornell tried to make the surfaces of the interior look antique: "He might line a box with blue velvet, aged wallpaper, or torn-out pages from a nineteenth-century book. Or, using house paint, he might apply six or seven coats to the interior walls of the box, until the surface looked crusty and acquired a seeming patina of age."(30) Cornell used other techniques to speed up the aging process, such as baking his boxes in the oven.(31) Moreover, he reworked his boxes frequently over time, and much of the recursive effort he documents in his journal was directed towards refining the textures of the boxes: "Cleaned up some and got at a box started long time ago. Good accidental antique effect by applying black stain after surface had been treated with paste filler (years ago)."(32)

One obvious practical strategy for collaborative design—if one accepts the perceptual significance of the art of Turrell and Cornell—would be for artists and scientific researchers to explore other threshold experiences that one encounters in perceptual psychology. What could one make that would allow the viewer to feel extremes of low-light environments, or the boundaries between textured and non-textured spaces?

8. Humanizing the Infinite

One winter night, when Cornell was home from Andover Academy as a youth, he walked into his sister's room, trembling violently. According to his biographer, Cornell "walked to the window, gazed into the darkness, and explained that he had been studying the concept of infinity in his astronomy class."(33) In the end, both Joseph Cornell and the graphics group at Cornell University were trying to humanize the infinite. Whether one trembles before a starry sky or the expanse of unbounded Cartesian cyberspace, the fact is that the human visual system is nourished by clutter, the microtexture, the light that is reflected under the desk. By learning from this tale of two Cornell boxes, we can hope to design new interfaces and experiences that combine the richness of Joseph Cornell's box with the complexity afforded by computing.

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Endnotes:

1. C.P. Snow, *The Two Cultures: and A Second Look* (Cambridge: Cambridge University Press, 1965), p. 50. Snow begins by considering the cultures of scientific and literary intellectuals, but extends his comments to artists more overtly in "A Second Look" (see p. 73).
2. As quoted in Craig Harris, *Art and Innovation* (Cambridge, MA: MIT Press, 1999), p. 3.
3. Kynaston McShine, ed., *Joseph Cornell* (New York: Museum of Modern Art, 1980), p. 9.
4. This study draws upon several articles from the Cornell group. Cindy M. Goral et al, "Modeling the Interaction of Light Between Diffuse Surfaces" (*Computer Graphics*, July 1984) is considered a classic of computer graphics research by the Siggraph 98 History Project (www.siggraph.org/publications/newsletter/v32n3/contributions/). Also crucial is Michael F. Cohen and Donald P. Greenberg, "The Hemi-Cube: A Radiosity Solution for Complex Environments" (*Computer Graphics*, vol. 19, n. 3, 1985).
5. This approach is elaborated in Gary W. Meyer et al, "An Experimental Evaluation of Computer Graphics Imagery" (*ACM Transactions on Graphics*,

January 1986), and more recently in Donald P. Greenberg, "A Framework for Realistic Image Synthesis" (*Communications of the ACM*, August 1999).

6. Email from Donald P. Greenberg, 21 December 1999: "I have no idea when it was first called the Cornell Box. It wasn't really our name, but as it has appeared in so many publications and has been measured extensively, it is the unofficially accepted title."

7. William Gibson, *Count Zero* (New York: Arbor House, 1986), p. 246.

8. *Ibid*, p. 246.

9. *Ibid*, p. 219.

10. Solomon, p. 255.

11. *Ibid*, p. 59.

12. This insight is taken from the Lightscape Visualization Systems *Getting Started,* p. I-7.

13. Greenberg, email 5/23/00. "Ken Torrance provided significant insights on the thermo-dynamics when Cindy Goral was doing her first paper in 1984."

14. Greenberg, email 2/15/00. "It was obvious that one could apply models of thermal transfer to modeling light propagation, so there were no particular insights, but I do remember a couple of breakthroughs. One, when we tried to solve the first radiosity equation (which appeared in Goral's paper), it was difficult because the form factor would blow up when the distance between patches went to zero. We were able to circumvent this problem by using Stoke's line integral equation and this led us to the first solutions. The second recognition occurred when we realized that the differential area we were computing shrunk to a point. Although this would be physically impossible in thermodynamic terms, it represented the same sort of solutions to be used in a Gouraud shading algorithm. I remember having some substantial disagreements in convincing people that this could be done. Three, while it may be obvious today, Michael Cohen's recognition that by using spherical coordinates, solutions near the "North Pole" would not be unique, and thus he came up with the hemicube for a functional rectilinear format. The recognition that the hemicube could be solved with an item buffer based on work previously done by Weghorst, Hooper and myself made things relatively easy. A lot of people contributed to the steady progress of this algorithm including Eric Chen's recognition of the progressive nature of a solution if you reordered the Gaussian elimination equations, and kept track of the unspent energy."

15. Mary Ann Caws, ed., *Joseph Cornell's Theater of the Mind* (New York: Thames and Hudson, 1993), p. 133.
16. *Ibid*, p. 303.
17. Solomon, p. 105.
18. I must introduce Gibson's thought with some qualifications. First, the work at Cornell University—as the photos bear witness—is based more on stimulus-response perceptual psychology than on Gibson's work. Nevertheless, I think the Cornell work has significance in a Gibsonian scheme. Secondly, diehard Gibsonians might object to the concept of visual "process" that has found a place in this article. After all, Gibson touted "direct perception," the idea that rather than processing a 2D representation on the retina, we directly extract and use visual information from the environment. Direct perception is the aspect of Gibson's thought that seems to have drawn the greatest reservations from the perceptual psychology community—see E. Bruce Goldstein, Sensation and Perception, p. 228. My sense that the distinction between "direct perception" and "nonconscious visual process" may not be so great as it appears. Greenberg offers the following anecdote: "By coincidence, when I first wrote my original graphics proposal to the National Science Foundation starting in the last 1960s, I approached James Gibson to see if he would work with us on perception. Unfortunately, and to my dismay, despite my great respect for the man, he really did not understand the potential ability of the computer to mimic the physical world. Ulrich Neisser, a cognitive psychologist in the department, was the primary person who lent his support but he soon left to take a chair position at Emory University in Atlanta (email, 5/23/00)."
19. James J. Gibson, *The Ecological Approach to Visual Perception* (New Jersey: Erlbaum Associates, 1986), p. 1.
20. J. Gibson, p. 78.
21. *Ibid*, p. 50.
22. Cohen et al, p. 31.
23. Adam Gopnik, "Blue Skies" (*New Yorker*, July 30 1990), p. 74.
24. Craig Adcock, "Perceptual Edges: The Psychology of James Turrell's Light and Space" (*Arts Magazine*, Feb. 1985), p. 124.
25. J. Gibson, p. 151.
26. *Ibid*, p. 151.
27. *Ibid*, p. 54.
28. James Fenton, "Monuments to Every Moment" (*New York Review of Books*, August 14, 1997), p. 30. Fenton reminds us of the importance of

manipulating Cornell's work—especially the sand fountain series. Obviously this impulse cannot be gratified in a museum setting . . .

29. Peter Noever, ed., *James Turrell: The Other Horizon* (Vienna: MAK, 1999), p. 226.
30. Solomon, p. 137.
31. *Ibid*, p. 215.
32. *Ibid*, p. 119.
33. *Ibid*, p. 29.

COMPENDIUM TEXT 3:

DOCUMENTS OF LIGHT: THREE CASE STUDIES AND A PRELIMINARY MODEL FOR ORGANIZING LIGHT KNOWLEDGE

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Abstract:

The area of Documentation studies offers a useful framework for the consideration of transdisciplinary subjects that do not respond fully to critical theories currently prevailing in the humanities and social sciences. This paper will apply a documentation approach to the study of light by examining case studies drawn from theatre, architecture and computer science. According to Documentation studies' extended definition of what constitutes a document, a theatre lighting plan, a computer algorithm, or even a light installation or fireworks show could be considered a document. One consequence of the breadth of this definition is that it allows us to seek common organizing themes in a range of lighting practices. Scholars, scientists and lighting practitioners create, employ and perform documents that encode illumination knowledge, which can be understood as the manifestation, simulation or manipulation of light to a particular end. Taking a cue from computer lighting algorithms, which attempt to construct a symbolic description of the propagation of light in space, we can suggest a means of classifying documents of light in the broader sense, in a way that places the human body and sensorium in a central position.

1. Documentation studies and the study of light

The transdisciplinary study of light serves as a quintessential test of our commitment to question existing disciplinary boundaries, and to form new disciplines that better serve human needs. Indeed, light is in many ways an ideal subject for our times. Light remains a puzzling scientific limit case to in so many ways: it represents the ultimate in speed, though researchers have recently succeeded in stopping it by sending it through clouds of supercooled particles. Its nature as both wave and particle make light the quintessence of modern uncertainty. As a design substance it could be claimed that light will be the construction material of the 21st century. Illumination has long been acknowledged as the basis for our perception of form and space, but there is a renewed awareness of its importance in the world of digital design. Through laser technology, the control of fiber optics and the phosphors of new digital media, light will bear the imprint of communication, record and expression. Light and its effects are richly evocative—light can be studied and manipulated as sense phenomenon, as mood regulator, electromagnetic radiation, or as the binding element of filmic media and architecture. Light is simultaneously physical and metaphysical. As a multifaceted phenomenon, light offers a perfect locus for developing new interdisciplinary discourses that attempt to bridge the gap between art and science that has drawn so much attention over the last 40 years (Snow, 1993).

But the study of light has been awaiting new critical tools. Light as a transdisciplinary subject responds incompletely to two common interpretative models within the humanities and social sciences: semiotics and media theory. Although at least one writer has productively explored "codes" of illumination, it can be argued that the linguistically-derived study of signs offers a constrained, even counter-intuitive starting point for a deeper exploration of how a physical phenomenon such as light can "subconsciously matter (Boone, 1997)." The limitations of semiotics as a means of interpreting sense experience has in fact recently spurred critical efforts aimed at decoupling our understanding of the senses and sense phenomena from linguistics, and insisting upon exploring the way in which the body creates its own meanings (Howes, 2005). This approach acknowledges the contributions of McLuhan, whose media theory places the human body and sensorium in a central position.

Any consideration of light from a purely media theory perspective, however, quickly founders upon the fact that light can be either naturally occurring or artificially produced, and thus does not really qualify as a "medium" (one could, perhaps, substitute the older, more painterly definition of medium as a "binding substance"). McLuhan's simplest usage can serve as a test: a medium can be defined as a human process or artifact that functions as an extension of the senses (McLuhan, 1998). Moreover, the strength of media theory is in exploring the ways in which meanings arise within, and are inflected by conversations between media (Bolter and Grusin, 1999). The difficulty here of course is that light is manifested both within and outside of our experiences of media. We encounter illumination in representations, simulations and real space. The relationship between the domains is crucial. Let us presume a situation in which one views a movie of a dark alley, then leaves the theatre and walks down a dark alley. Are the two experiences analogous? If so, then media theory cannot provide an exclusive vocabulary for our response to light. Some portion of our experience of light can survive abstraction to the film screen (to a 2nd plane), scaling (to a portion of our visual field) and dislocation in time and space. A transdisciplinary light studies can begin to provide terms of reference to help us understand this relationship.

So in order to move forward, it is clear that the study of light requires an expanded critical toolbox. One could begin by drawing from other obvious sources in the social sciences, including perceptual psychology, as well as natural sciences. But if one is to avoid fragmented and confusing arguments, it is also important to identify a framework of scholarly practice that can provide a kind of intellectual superstructure. Documentation studies, as outlined by Niels Windfeld Lund, can supply this sort of scaffolding: “Documentation Studies is defined as a new discipline dealing with forms of documentation by studying the production as well as reproduction of documents of all kinds (Lund, 1999).” One of the sources of Documentation studies’ appeal is that it grows out of library and information sciences (LIS), and so is a capacious practice. As such, the discipline offers the “possibility to transcend the borders of film, literature, paintings, and other media, which are normally dealt with in a number of specific scientific disciplines for each kind of documentation (Lund, 1999).” Another benefit of Documentation studies’ roots in LIS is that it inherits some of the taxonomic rigor of the parent practice. This is especially useful when dealing with the subject of light. A survey of writings on light uncovers a tendency towards flowery and poetic excesses, perhaps an unavoidable overcompensation that results when attention is directed towards a phenomenon whose omniscience and subtlety of effect leave it frequently ignored. Indeed, the sketching of sense phenomenon taxonomies is one of the key tasks in the post-semiotic effort to recognize and reclaim our sense experience. Finally, documentation studies offers a vocabulary for moving beyond the prevailing reception theories, and allows us to redirect attention to the processes of making and using artifacts (Lund, 1999).

As a means of testing the usefulness of the documentation studies approach in the exploration of the processes of the documenting light scholar and lighting practitioner, I propose examining case studies drawn from three diverse and challenging domains: Shakespearean theatre scholarship, night architectural illumination, and computer lighting algorithm construction.

2. Lighting the Shakespearean stage

Imagine the plight of the Elizabethan theatre scholar: almost all of her conclusions regarding illumination in Shakespearean performance must be drawn from the indirect evidence of court expense accounts, second-hand reports from travelers’ journals, and a few graphic sources. It is only in the past few years that theatre reconstructions (such as the new Globe) have enabled scholars to do photometric readings in environments that are themselves the result of speculation documentary evidence in the form of physical infrastructure and written material. Faced with these constraints, the theatre historian has had to become a masterful interpreter and manipulator of documents. In *Lighting the Shakespearean Stage*, R. B. Graves argues that the illumination qualities in outdoor and indoor theatres were not as different as previously thought, and that, unlike the highly directional lighting to which we are accustomed in the contemporary theatre, "early English lighting emanated from all around the actor, surrounding him with soft, indirect light. . . . The actors moved in the same light all Londoners moved in everyday (Graves, 1999)." The organization of each of Graves' chapters follows a similar pattern: an argument is constructed that ultimately allows the visualization of an illumination environment. This from the conclusion to his chapter on illumination of the outdoor playhouses: "The general picture of the amphitheatres that emerges is one of a well-shaded stage with neither artificial light for general illumination nor the extreme contrasts of light and dark due to direct sunlight. As an actor came forward toward the foot of the stage, the light would increase slightly because the cover overhead intercepted less light." Besides the rigor of his arguments, Graves' work is compelling because it allows us to more fully imagine the conditions of Elizabethan performance.

Although one can certainly savor the line of Graves' arguments, it is important to list the types of documents that he marshals to defend his thesis, and note the manner in which he employs each type. Graves' reasoning tends to move from what is known about an illumination environment to what can be deduced or must be argued, then back to more direct photometric evidence and interpretation. In his chapter on "Daylight in the Indoor Playhouses," for example, he begins by interrogating the written evidence concerning performance times, as this information allows the author to determine exterior light levels, given time of day and presumed atmospheric conditions. He then looks at court expense accounts to determine patterns of candle purchase, which allow for arguments on artificial light levels. The next step is to examine existing examples of halls whose dimensions are similar to those of indoor playhouses, noting the placement of windows and predominating light qualities, as well as taking photometric readings of the light levels. Graphic sources are employed to several ends: architectural cross sections demonstrate spatial relationships and suggest illumination directions from windows, and an engraving from a book frontispiece shows the sort of relationship between window light and artificial sources that may have existed. Graves' concludes that though light levels were lower in indoor than outdoor playing spaces, the difference was well within the range of human visual adaptation: "In consequence, we must not think of the adult private theatres as dim, at least not in the early afternoon. On the contrary, we may imagine them as satisfactorily lit even by our own standards and entirely adequate by medieval and early modern standards."

We may draw several broad conclusions about Graves' use of light documents:

1. Written evidence is often (though not always) used to support arguments about light levels, the quantity of light present in the environment.
2. Graphic evidence is often employed for spatial understanding, and to answer questions such as: where were lights positioned with reference to the stage? Where were windows located? Where would shadows fall? Given that light intensity diminishes as it moves from its source, how much light could be expected to reach the acting area? What was the predominating light direction?
3. Photometric evidence is used to determine absolute illumination levels, and interpreted in conjunction with what we know about human visual response to light.

By nimbly manipulating these types of light documents, Graves is able to conjure a vivid imagining of the qualities of light under which Shakespeare's work was first performed.

3. Writing light

But scholars aren't the only ones who must master documents of light. Lighting practitioners who rely upon documents to communicate their designs to clients must, by necessity, be quite knowledgeable about what documents can, and cannot communicate about light. The conditions of night illumination offer a particular challenge to the documenting lighting practitioner, as nocturnal contrast ratios are often beyond the capacity of most filmic materials, and photographic results do not correspond well with the eye's visual range and capacity to adapt. Lighting designer Louis Clair has produced a number of large-scale light installations for urban spaces in Europe, Asia and Canada. In "Écrire la lumière," Clair wrestles with the limitations of different kinds of light documents, and proposes a technique of describing light "ambiances" as a means of constituting a communicable "light writing" that can eventually aspire to the precision of musical notation (Clair, 2000) Clair's development of the concept of illumination ambiances grows out of his dissatisfaction with the current media of light representation: "The lighting designer . . . creates images to present his project, but the images themselves remain subject to interpretation. They are unable to fully simulate contrasts of color or the perception of light in real space." Though digital media offer the semblance of greater fidelity, 3d graphics fall short for similar reasons. "Digital images remain, in spite of this precision, approximations, for, like other techniques, they can communicate neither the effects of vision in real space, nor the capacity of the eye to perceive gradations of light much greater than analog or digital media can reproduce."

Clair seeks to expand the realm of light documentation by moving away from imaging media towards literary description and the development of a taxonomy of light effects. His survey of light documents begins with the standard documentation that accompanies a project proposal. The light plan is "an inventory of elements to illuminate and several recommendations regarding the urban context in which they are found." Far more important to the designer's intent, however, is the development of the appropriate ambiances. Clair derives the term ambiances from cinematography, but his use of the term is strongly influenced by literature: "The client couches his expectations in literary terms describing the feelings inspired by the light environment. The lighting designer must translate these terms into the values and vocabulary of light in order to create ambiances." Clair outlines eight types of ambiances: festive, convivial, majestic, discreet, romantic, theatrical, poetic and functional. Each term is associated with specific social models and light qualities—"Festive ambiances are those which preserve the illumination qualities of festivals, fairs, etc. They are characterized by the presence of numerous sources of multicolored light in the space, quite brilliant, even aggressive." The "values and vocabulary" of light through which the ambiances are conveyed include:

1. Characteristics of light:
    quantity of light: flux in lux
    quality of light: color rendering index (IRC)
    color of light: color temperature in degrees Kelvin
    colored lights: expressed in usual terms, or in spectral curves (or in terms of color filters)
2. Lighting direction:
    elevation: high, low, frontal
    plan: face, profile, reversal of daylight
3. Shadows:
    density, edge quality of shadows
    existing shadows or those imposed by sources

4. Contrasts:
    hardness, positive or negative contrasts
    contrasts of color temperature or filtration
5. Illumination in the visual field:
    qualities of the illuminated areas
    composition of illuminated areas
6. Character of light sources:
    quality of the sources
    disposition of the sources
7. Animation of light and shadows:
    used infrequently in permanent installations

Clair thus attempts to impose a higher-level taxonomic order upon the shared, often parametric vocabulary of the lighting designer. If his effort falls short, it is because his 8 ambiances—though perhaps useful—certainly cannot be considered an exhaustive list of the illumination environments one might want to create, and the mapping between higher-level ambiances and basic light parameters is not always made explicit.

4. The Phong algorithm

Night illumination and digital lighting algorithms share an important condition: it is always night in the computer. All computed illumination simulations must take into account everything we know about light and instantiate that knowledge in a way that imposes various economies upon the highly complex behavior that we observe in real space. Lighting algorithms, then, demonstrate a kind of abstract, meta-level, though incomplete organization of light knowledge. The Phong shading algorithm can serve as an example. In 1975, Bui Phong at the University of Utah proposed a shading technique which proposed to advance the quality of computer generated images of three-dimensional scenes: “Human visual perception and the fundamental laws of optics are considered in the development of a shading law that provides better quality and increased realism in generated images (Phong, 1975).”

Here is a shading algorithm based on Phong's work (Manchester University notes on computer rendering):

$$I = k_d I_a + \frac{I_p}{d + d_0}\left[k_d(\mathbf{N} \bullet \mathbf{L}) + k_s(\mathbf{R} \bullet \mathbf{V})^n\right]$$

The algorithm exhibits several key elements:

1. Vectors (N, R, L, and V), which represent spatial information about position of the viewer (V), the reflected ray (R), position of a light source (L), as well as the orientation of the surface at the point being shaded (N).
2. Exponential and fractional terms, the remnants of the inverse square law, which introduces falloff to the solution, the diminishing of intensity of light as it moves away from its source.
3. Material constants (ka, kd, ks) that represent the characteristics of the surface being shaded.

What sets Phong's function apart from previous solutions (including Gouraud) is the more accurate rendering of the specular highlights that appear on glossy surfaces:

> "The first step in accounting for the specular properties of objects and the position of the observer is to determine the normal to the surface at each point to be shaded . . . it is only with this knowledge that information about the direction of reflected rays can be acquired, and only with this information can we model the specular properties of objects." (Phong, 1975)

Phong tested his algorithm by comparing computer renderings with photos of glossy spheres to demonstrate the presence of specular highlights.

As a system of organizing light knowledge, the algorithm draws upon three main historical threads. The observation that light bounces off a shiny surface at the same angle as it approaches was noted in a text on mirrors ascribed to Euclid, the Catoptrics, which had practical applications for those wishing to start fires (Park, 1997). The vectors (R), (L) and (N) instantiate this knowledge in the algorithm. The second historical document present in the algorithm—the inverse square law—is drawn from Newton's body of work, and applies to forces in addition to light (such as gravity) that emanate from a point source. The final historical echo is Johann Lambert's cosine law, which describes how the bright a diffuse (matte) surface appears depending on its orientation to a light source, first published in the Photometria from 1760 (Seds.org). The dot products, surface constants and vectors represent Lambert's insight in the algorithm. But of course it was Phong's elegant solution that brings the knowledge together in a form that allows a subset of light's behavior and effects to be efficiently demonstrated in computer renderings.

5. A Preliminary model for organizing light knowledge

The shading algorithm's character as a kind of meta-document gives us clues as to how to begin organizing light knowledge. However, for the algorithm to be truly useful we must expand our model beyond Phong's more limited intention. In insisting on a richer conception of the receiver of light than Phong's simple view vector, we can hope to accommodate more capacious understanding of light's significance and meaning to people. As we have seen in our examples of thought on light from theatre history, night illumination and computer graphics, light documents can be organized by imagining the human body in illuminated space. More particularly, we can examine light documents with respect to the way in which they encode the following kinds of knowledge about light:

1. Knowledge of the body and embodied mind
2. Spatialized knowledge of light
3. Knowledge of light sources
4. Knowledge of surfaces

Knowledge of the body and embodied mind obviously incorporates everything we know about perception and psychology, the visual and non-visual effects of light, our ways of thinking about light and its associations. Spatialized knowledge of light behavior informs our understanding of how light reverberates through a space, and, as we have seen in our survey of writings on light, can be extracted from graphic materials or encoded in algorithms—as Phong did—through the language of vectors. Knowledge of light sources encompasses everything we can observe and conceive about the sources themselves, often expressed through measurements such as color temperature and photometric readings, but also able to accommodate our poetic and artistic understanding. Finally, our knowledge of surfaces, so important to our evolutionary development and survival (Gibson, 1987), accommodates both our tacit knowledge of things and all the ways we have developed to describe, represent and make surfaces. Obviously, many types of documents encode more than one type of light knowledge, so the model is something less than a rigorous taxonomy, but at least it can begin to help organize discussions about light between those who care about it.

6. Conclusion

Anyone proposing to reorganize existing knowledge structures has the burden of demonstrating the potential benefits of the task. I would argue that cutting a fresh cross-section through existing knowledge structures will have the benefit of bringing lighting practitioners and lighting documents into conversation with one another in a way that does not privilege existing disciplinary practices. A quick survey of current lighting design and research shows a range of recording practices. Cinematography and film lighting still exhibit a guild-like organization in which light knowledge is often tacit and passed from masters (or directors of photography) to apprentices (grips, gaffers, camera operators, etc). There is in effect no such thing as "cinematography research." Much of the lighting knowledge of great cinematographers inheres only in their film work, and accessing that knowledge is a very different task from, say, reading the sort of documents that emerge from the current scientific research on light. It is the aim of a study of light documents to facilitate the transfer of light knowledge from one group to another. The potential benefit of this transfer would be the application of light knowledge to new domains of illumination practice, with the goal of enriching our experience of light in our daily lives. It is through this sort of exchange that light can fulfill its potential as the construction material of the 21st century.

7. Acknowledgements

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COMPENDIUM TEXT 4:

SHADOWPLAY: SIMULATED ILLUMINATION IN GAME WORLDS

Simon Niedenthal

Presented at the Digital Games Research Association in 2005 conference in Vancouver, Canada, June 2005 (selected Best Paper), and published in *worlds in play: International Perspectives on Digital Games Research*, eds. S. de Castell & J. Jenson, Peter Lang, New York, p. 221ff. (Note: this is the version of the paper as presented at the conference, which has material not included in the published version)

ABSTRACT

Despite the fact that there are currently a number of enjoyable digital games in which light plays a key role, we lack a vocabulary with which to discuss simulated illumination in game worlds. An understanding of lighting practices in other media, such as 3d computer-generated animation and film, must be supplemented with an awareness of real-space disciplines if we are to grasp the complexity of the game lighting design task. But game design is more than a repository for existing lighting practices; the interactive nature of games allows for an extended range of visualization possibilities and a self-reflexive sensitivity to light to emerge, most clearly manifested in games described as "stealth," and "survival-horror" games.

It has long been a commonplace in gaming communities that "good graphics does not equal good gameplay." Originally growing partly out of resistance to industry agendas, this platitude has, in extreme expressions, ossified into a simple and ultimately less-than-useful dichotomy. But given the capacity to dynamically engage the senses that is inherent in interactive media, a better question for us to pose is "what sort of visual experiences best support gameplay?" One way to approach this rather large question is to move beyond a narrow consideration of "graphics" and focus instead upon our experience of simulated illumination in gaming environments. For, despite skepticism towards game graphics, the fact is that there are currently a number of very enjoyable games in which light plays a key role. In stealth and survival-horror games, such as those of the *Thief*, *Splinter Cell* and *Silent Hill* series, a consideration of light can be found not only in the way in which the game spaces are illuminated, but also in the sensorium that is encoded into the game's AI. In this sense, both players and non-playing characters respond to illumination decisions made by game designers, as well as gamers themselves.

But before we investigate illumination decisions further, it is necessary to create a framework for analyzing the contribution of simulated illumination to the gaming experience. Quite clearly, we lack a vocabulary with which to speak and think about light in games and the effect upon the player. According to industry accounts, game development companies are eager to make use of illumination knowledge. David Polfeldt, Vice president of Malmö-based Massive Entertainment, points out that though receptive, the industry lacks a means of adequately expressing lighting concepts. Many game developers and artists tend to speak a recursive language, in which invoking *Doom 3*, for example, calls up a whole host of real-time lighting and shading effects.

This paper will argue that a foundational understanding for studying lighting design in game environments can be forged by first surveying existing illumination practices. Pre-rendered 3d computer animation is created using similar digital tools, and the field has begun to develop it own form of cinematography. But the free navigation afforded by games requires us to look to other practices outside of filmic media, such as real-space lighting. Finally, games as interactive experiences must be examined for their own unique potentials. After all, in a game the player sees and is seen, illuminates and is illuminated in turn.

I will begin by contending that it makes sense, from both a game development and research perspective, to consider simulated illumination as a significant contributing element of the gaming experience. Whether one is a programmer or digital artist working at a game company, or a gamer using a level editor to produce something for their own enjoyment, there is a cluster of design decisions around the problem of light that can be made well or poorly. Light contributes powerfully to the "gameplay gestalt," defined by Craig Lindley as "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." Finally, if we hope that games might touch the same profound places that dreams do, I believe that illumination has an important role to play.

As media artifacts and interactive experiences, games draw from various sources of knowledge about light to achieve their effects. The existing professional practice perhaps closest to game illumination is computer generated animation. As with films such as *Toy Story*, many digital games are created within 3d software packages that take film technologies as organizing metaphors. In 3dsmax, Softimage and Maya, surface geometry is refined with a combination of texturing tools and simulated light sources. Lighting decisions for a game must be constantly balanced with the need to maintain a frame rate adequate for real-time playback, and the quantity of lights possible in a game scene is determined by the rendering engine. Some rendering engines allow the digital artist to employ 8 lights; really good engines up the number considerably [9]. Although in the past the real-time demands of digital games have limited the use of complex lighting setups and effects, a number of new rendering engines, techniques and workarounds allow game designers increasing control of the illumination spaces of their games, opening to them the sorts of choices that were afforded digital animators a decade ago.

Since then, the computer-generated animation industry has begun to generate its own form of cinematography, led by companies such as Pixar, whose aesthetic draws heavily upon traditional film lighting practice. Sharon Callahan [3] identifies five objectives of lighting in a digital animation scene:

1. Directing the viewers eye
2. Creating depth
3. Conveying time of day and season
4. Enhancing mood, atmosphere and drama
5. Revealing character personality and situation

If we apply these objectives to an analysis of the survival horror game *Silent Hill 2*, we can see that there are useful contributions, as well as important limitations to a filmic approach. First, light qualities are employed to direct the player's the eye, an important part of locating useful objects in any adventure game. Health drinks, medical packs and ammunition to be acquired in a space leap out through contrast and specularity. Depth in exterior scenes is simultaneously created and limited through atmospheric perspective of fog, as well as darkness. Although "Silent Hill 2" is largely an interior game, played out in decayed, boarded-up spaces, larger lighting decisions do convey time of day and interact in an interesting way with the player's felt sense of time. The game begins in daytime, then after leaving Brookhaven hospital the player emerges into a nightscape. A grey dawn permeates the final stage of the game at the Lake Side hotel; thus *Silent Hill 2* is played out over one day (and of course other current games introduce their own day/night cycles of varying duration). Depending on how skilful the player is, this may or may not correspond to the player's own sense of game time. A cinematic sensitivity to the power of light to enhance mood, atmosphere and drama is readily apparent in *Silent Hill 2*. The overall low-key lighting strategy in *Silent Hill 2* is perfectly in tune with the horror genre, and provides one of the greatest sources of pleasure in the game. Finally, one can point to a number of ways in which illumination helps to sketch character and motivation in a cinematic way.

In the opening expository pre-rendered scene, James Sunderland, the game's protagonist, stares into a mirror and relates the receipt of a letter from his dead wife. This scene introduces us to a somewhat ambiguous character, and as the game plays out we are called upon to speculate about James' motivations and role in his wife's death. The illumination here, coming from above and leaving his eyes in shadow, is a cinematic convention often associated with characters whose motivations are unclear. In "The Godfather," for example, cinematographer Gordon Willis chose the same lighting strategy to make the title character appear more mysterious (besides accommodating Marlon Brando's oral prostheses) [13]. The case of top lighting the face in such a way that the eyes remain in darkness is an example of the way in which a lighting convention can come into dialogue with deeply ingrained behaviors. According to studies of how humans read faces, we devote great mental energy to analyzing the gaze of others. It follows then that the obscuring of the whites of the eyes and the specular highlight from the eyeball through shadowing [1] would tend to leave us somewhat unsettled.[1]

As the foregoing example makes clear, a cinematic approach to game lighting is appropriate as a means of analyzing pre-rendered cut scenes, as well as useful in helping us understand larger lighting strategies that relate to game genres, time of day, narrative elements and mood. But it is also quickly apparent that games as interactive experiences differ from films in significant ways. First, a film scene is of limited duration, and generally must communicate a quantity of information in that time. Games, on the other hand, allow free exploration and examination. In addition, film scenes are lit to be recorded from the camera. A fixed perspective for viewing a game environment of course cannot be assumed (though some games have context sensitive framing that is a kind of middle state between free exploration and fixed perspectives). So though a film lighting perspective is useful for our understanding of how games function as media artifacts with certain narrative elements, the task of lighting the interactive game world, also participates in some of the opportunities and limitations of real-space practices.

I would argue that we respond to simulated illumination in games not only from our accumulated experiences from film and other media, but also as perceiving and feeling embodied beings accustomed to acting in the world. If we accept that our experiences of simulated illumination are analogous to our experience of light in real space,[2] there is a body of research on the effects of light that can be re-purposed within game design. Recently there has been increased interest in studying

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1 Thanks to Steve DiPaola for this insight.

2 This assumption requires a sub-argument. In the late '60s a debate emerged between J.J Gibson and Goodman on the nature of the experience of viewing a picture. Goodman's position was that we learn to "read" a picture, that it functions as a kind of text. Gibson countered that the experience of looking at a picture is analogous to how we see in real space: "a picture is a surface so treated that (it) contains the same kind of information that is found in the ambient optic arrays of an ordinary environment." He also writes, more succinctly, that "interpretation depends on sensations." I take Gibson's side, and believe further that his stance can be transferred to a consideration of dynamic simulations such as games. The argument of this paper is that our experience of simulated light is not just informed by our experiences within media and by ingrained "codes" of light, nor are our perceptual systems simply cultural constructs. What makes light so interesting is the way in which socially informed media conventions come into dialogue with our bodies and senses, which have their own codes.

the qualitative and non-visual effects of light, the ways in which illumination levels and color influence how people feel and behave. Several themes have emerged from current research. Some gender differences occur; men and woman show different levels of emotion depending upon color temperature of light [5]. Risk-taking also appears to be a phenomenon that is affected by our luminous environment [8].

According to Greg Costykian, decision-making is one of the defining hallmarks of the gaming experience [4], and interesting implications for game design emerge from experiments on the effect of light on decision-making in real space. In a study of the effects of light on mood and decision making, CLB McCloughan claims that decision times decrease, and heuristics use increase under lower illumination levels. Further, Belcher and Kluczny also suggest that in particular illumination conditions we are more likely to employ quicker heuristic strategies rather than engage in detailed analysis in our actions. *Silent Hill 2* is an excellent environment in which to trace this line of thought. There are a number of different types of decision that one is called upon to make in the game: should I blast this zombie? How do I solve this puzzle? Clearly some decisions are on the level of reflex, others require considered analysis. Belcher's model suggests that tasks such as killing approaching zombies, which are solved best by applying heuristics rather than launching into elaborate planning, are supported by luminous surroundings that would be described as poor or low acuity lighting, often the case in Silent Hill. The significance of this for the game designer is that there is room for subtle modulation in the matching of the lighting environment to the desired game experience.

To summarize our overview of filmic and real-space illumination practices, then, we can reduce lighting aims to two broad categories: functional and evocative lighting. The functional objectives prompt lighting designers to consider the adequacy of light to fulfill basic needs—as appropriate for the world to be simulated—such as dealing with the technological constraints of the renderer, ensuring that the world is described visually, and that the sort of tasks that the game calls upon the player to perform can, in fact, be performed. Much lighting design in games so far has occurred at this level. Evocative lighting decisions allow the designer to manipulate the qualities of light—colour, shadow characteristics and lighting direction—as a means of influencing the player's emotions and behavior during the game.

We may employ a simple game taxonomy to map real space and cinematic sources of light knowledge appropriately to game design. Craig Lindley proposes a triangular model integrating ludology, narration and simulation. Lindley's ludological definition of a game is "a goal-directed and competitive activity conducted within a framework of agreed rules;" a narrative is defined as "an experience structured in time;" and simulation is "a representation of the function, operation or features of one process or system through the use of another "[7]. One benefit of generating such a taxonomy is, as Lindley points out, is that it can help us apply knowledge to game design in a productive way: "The distinctions of the taxonomy . . . allow us to see where techniques from other fields can be applied."

Overlaying illumination practices upon this game taxonomy also demonstrates how other types of lighting knowledge can contribute to game lighting design. Narrative can clearly be supported by illumination techniques coming from 3d computer animation and film, especially relevant in pre-rendered cut scenes. Our understanding of how light influences people in real space has consequences for the "goal directed and competitive" activities of ludic behavior, through arousal, affect, risk-taking and decision-making. Knowledge of the digital simulation of light has come to games from computer graphics, and an example of how our experience of light can be foregrounded in simulations can be seen in fireworks simulators [10].

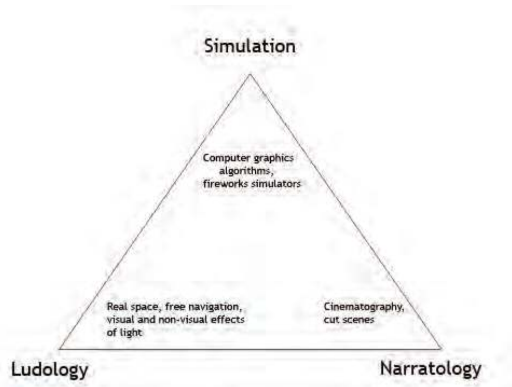

Figure 1: Simulated illumination concerns mapped onto Craig Lindley's game taxonomy.

So far in this paper the argument has moved in a single direction, projecting from existing lighting practices from filmic media and real space onto game forms. But of course, games are uniquely interactive experiences, mediated by responsive computing systems and shaped by the player's agency. Any consideration of simulated illumination in games must take into account not just reaction to light, but player proaction in a luminous environment that is often partly under their own control. I have been concentrating upon illumination decisions made by professionals, but what is interesting about games is that these decisions are increasingly being made by players. Tactical lighting decisions by the player mid-game are an important part of the experience of the current crop of stealth and survival-horror games, and we can begin by distinguishing between additive player lighting activity, in which the player illuminates the scene with light sources, and subtractive activity, in which the player, conversely, eliminates existing light sources in the scene.

An example of how additive player lighting activity affects game balance can be observed in *Silent Hill 2 & 3*. Early on in the games, one acquires a flashlight, and must continually decide whether or not to use it. With the light on, objects to be acquired in the environment leap out through contrast and specularity. The light itself is comforting; without it, one moves through a twilight gloom almost sub-aquatic in character. The player must choose from moment to moment how to illuminate the scene, and the decisions are crucial for survival and continued forward-movement in the game. Konami's website tips the player off to the significance of illumination in balancing the game's risks and rewards:

> "The monsters have eyes and ears, and will use these to locate James. If they are not alerted to James' presence, they may not attack. Turning off the flashlight and carefully bypassing unnecessary confrontations is advised, however, with the flashlight off, James cannot search or look at the map and his accuracy with projectile weapons is severely impaired." [12]

The attention to light in *Silent Hill 2* thus goes far beyond storytelling and world definition; it also directly engages the player and becomes a key part of survival-horror gameplay. Another example of additive player lighting activity and its role in game balance can be seen in *Doom 3*, in which use of the flashlight inhibits defensive action.

Examples of subtractive player lighting activity are common in stealth games, in which the game experience is built around avoiding detection while accomplishing missions. In the *Thief* series, players can act over distance to douse torches with water arrows, while their counterparts in *Splinter Cell* can do the same with more modern projectile weapons. Doing so makes the player's avatar less visible to adversaries. The significance of moving in areas of low illumination in these games is reinforced by interface elements (such as the "glowing crystal" in *Thief* and the stealth meter in *Splinter Cell*) that provide feedback on the degree of illumination of the player's current position.

As these examples of additive and subtractive lighting suggest, illumination decisions in these games do not just affect the player's surrogate and perspective, they also shape the conditions for interaction with non-playing characters through the game's artificial intelligence. For the game *Thief*, a sensory system was developed with the aim of increasing the suspense of possible discovery. Tom Leonard relates the aim of the game's developers:

> "The primary requirement was creating a highly tuneable sensory system that operated within a wide spectrum of states. On the surface, stealth gameplay is about fictional themes of hiding, evasion, surprise, quiet, light and dark. One of the things that makes that kind of experience fun is broadening out

> the grey zone of safety and danger that in most first-person games is razor thin. [6]"

AI vision in *Thief* is framed in terms of "awareness" and "visibility." Visibility is defined "as the lighting, movement, and exposure (size, separation from other objects) of the entity . . . the lighting of the player is biased towards the lighting near the floor below the player, as this provides the player with a perceivable way to anticipate their own safety."

Not only do players have the capacity to alter the luminous game environment, they can also choose how to perceive the energy of their environment. Besides visible light, *Splinter Cell: Chaos theory* offers player night, thermal and EMF visual modes. Each of these modes has interesting affordances and drawbacks, and the game encourages a sort of visual choreography as one proceeds through the environment: one might move in natural illumination or night mode, pausing to scan in thermal or EMF mode as one enters a new space, depending upon one's mission and the state of one's adversaries. Night vision diminishes contrast and raises value, allowing one to see into the shadows. On the negative side, it is monochromatic, so color information is lost. Hightlight areas also blow out and lose detail. Since it simulates a system in which infrared energy is projected and detected directly from the user's position, it also tends to make depth perception more difficult. So while one can navigate in this mode, one sometimes bumps into things. Both themal and EMF modes are more useful for locating objects than navigating. Thermal mode provides strong color contrast indicating areas of warmth, useful for quickly locating adversaries in complex environments, while EMF indicates areas of pulsating electrical activity.

Alternate visual modes in games have interesting implications for illumination design. First, thermal and night representations may make native sense to pit vipers or other animals, but they are not natural parts of the human sensorium, and thus are abstractions that reflect the vocabularies of surveillance and military technologies, among other references. These are certainly appropriate for the Tom Clancey world of *Splinter Cell*. Secondly, extending the player's sensorium affects the relationship to one's surroundings that have, I believe, particularly important consequences for stealth games, which are as much about mastering one's environment as mastering one's adversaries. Survival-horror games, on the other hand, depend more upon maintaining a certain degree of player limitation and vulnerability; I can't imagine that the experience of playing a Silent Hill game would be improved by having night vision capabilities.

Based on some of the unique characteristics of game forms that we have examined, we can see that game developers face several key strategic illumination decisions (moving from lower to higher-level concerns):

1. Defining the basic characteristics of the environment's illumination, in both time and space. Given that the player might relight the scene by adding or subtracting light, the designer's task is to define the base ambient illumination, the essential shadow density, sketching the visual affordances of the world. Here we can speak, in the parlance of film, of broader "high-key" or "low-key" strategies, in reference to the overall distribution of value in the scene. High-key is traditionally associated with comedy and lighter fare, and gives us *Super Monkey Ball*. A histogram of a sample frame demonstrates a preponderance of middle to high range value. Lower-key strategies are of course appropriate for survival horror and stealth.
2. Defining the capabilities of the player. As we have seen, the energy of a game scene can be represented in different ways. Offering the player a range of visualization choices, as in *Splinter Cell: Chaos Theory*, extends player capabilities, and creates the illusion, at least, of a greater degree of mastery over the environment. Once again, these choices need to be made in relation to the game genre.
3. Integrating illumination concerns within the whole game experience. This includes harmonizing visual capabilities of the player with other sense modalities, most importantly sound. It also includes considering the issue how to balance risk and reward, to make the choices available to the player (as actor or designer) meaningful within the game genre, according to the desired emotional complex of the game experience.

But of course the experience of being in a game world involves not just responding to the consequences of overarching design strategies, it also about feeling the fine-grained texture, variations, and rhythms of light in simulated space. So let's take a luminous tour the first mission of *Splinter Cell: Chaos Theory* and see how light is used to shape the game experience.[3]

Our first introductions to the game, from the still images of loading screens and mission information to pre-rendered cut scenes, partake of the illumination aesthetic of portrait photography and film. The mysterious and threatening Sam Fisher of the first loading screen, eyes veiled in shadow ("he sees you but you don't see him"), knife and night vision goggles radiating specularity and 2-point star filter highlights, respectively, contrasts with the softer and fuller illumination of

3 *This reading refers to the PC version of Splinter Cell: Chaos Theory*

the somewhat weary-looking Sam about to be sent back into the fray. But together with other stills of key characters we encounter before we enter the game world, the illumination is characterized by fairly conventional strong back lighting that separates characters from the background. The cut scenes, further, maintain a cinematic practice of apparently motivated, directional lighting that defines contours, directs attention, and creates an ambiance appropriate for various media, military and control room settings.

Once we enter the game world we find ourselves in a luminous environment in which players—far from being directed where to look—have to actively engage in visual meaning-making, in dark and complex spaces, using the visual modes at hand. We begin on a beach, below a castle and lighthouse. It is a dark and stormy night, thunder and lighting effects punctuate the darkness, a moon tries to shine through the cloud cover, and wind motivates a number of (now requisite) swinging light fixtures. The seaside location is misty, and the light beams tend to be visible in the moisture, directing our attention to pools and shafts of light. We proceed from the beach through cave and castle settings, to a final rendezvous in the lighthouse. The environments of the first mission, though uniformly dark, define a full palette and spectrum of light types and colors, ranging from yellow-red candles, fire effects and incandescent lights, to cooler moonlight and arc lights, as well as non-naturalistic green phosphorescence in the cave scenes. There are several moments at which narrative events or adversary presence are communicated through moving shadows, and other moments of shadow ambiguity, in which a threatening movement turns out to be just another swinging light. The passage from dark beach to the lighthouse frames the action of the mission; the last action before extraction is to turn off the lighthouse lamp, and the level ends with Sam's brief concluding statement of relief: "darkness."

In conclusion, illumination decisions in digital games take many forms, are made by both designers and players, and have strategic and tactical consequences for the game experience. But whether one is seeking to evoke a world or set up the conditions for perception and interaction, light allows us to advance our goals for the felt game experience, be they the evocation of suspense, dread, comfort or ecstatic abandon. Light engages us through our bodies, our nervous systems, and our collective social interactions. Digital games, in which light is made present through a combination of media conventions, computer graphics algorithms and sensory phenomena, thus represent an arena in which the aesthetics of light and the mechanisms of perception are open for exploration and redefinition by designers and players alike.

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COMPENDIUM TEXT 5:

PATTERNS OF OBSCURITY: GOTHIC SETTING AND LIGHT IN RESIDENT EVIL 4 AND SILENT HILL 2

Simon Niedenthal

Presented at the *Gothic and horror in literature, film and computer games conference* at Lund University, Sweden, 2006, and submitted to *Gaming after Dark* (collected essays on survival horror games, edited by Bernard Perron)

Obeying an urgent summons contained in a mysterious letter, the narrator approaches his destination on a "dull, dark, and soundless day in the autumn of the year, when the clouds hung oppressively low in the heavens" (Poe 2003, p.90). Although this opening is taken from Poe's *Fall of the House of Usher*, it also applies in an almost literal way to the first cut scenes and misty environments of the survival-horror digital game *Silent Hill 2* (Konami 2001). Echoes of the themes, settings and ambience of Gothic literature are so frequent in games from the *Silent Hill* and *Resident Evil* series that it is possible to argue that survival-horror games constitute a new form of the Gothic, one in which player activity drives the unfolding of the action. The emotions resulting from enforced player vulnerability—hallmark of the survival-horror genre—as experienced within the narrative themes, player tasks and virtual architecture of the game worlds, offer a new venue for exploring the depths of fear, terror, and the sublime that were first plumbed by writers such as Anne Radcliffe, Edgar Allen Poe, Matthew Lewis and H.P. Lovecraft. Supplementing historical texts with contemporary eyetracking technologies and emotion research demonstrates that these games depend as much upon architectural setting and ambience as they do upon traditional narrative concerns or game balance for the unique power of the emotions they elicit. Patterns of obscurity set the groundwork for the player's ability to appraise and act upon challenges in their environment, as they move through the castles, caverns and labyrinths of this gruesomely satisfying gothic new media genre.

Broad correspondances between Gothic fiction and survival-horror games immediately become apparent when one compares emerging attitudes:

> Gothic fiction: "Prominent features of gothic fiction include terror (both psychological and physical), mystery, the supernatural, ghosts, haunted houses and Gothic architecture, castles, darkness, death, decay, doubles, madness, secrets and hereditary curses." (Wikipedia.org, accessed 13 Dec. 2006).

> Survival horror: "Survival horror is a prominent video game genre in which the player has to survive an onslaught of opponents, often undead or otherwise supernatural, typically in claustrophobic environments in a third-person perspective." (Wikipedia.org, accessed 13 Dec. 2006).

These entries suggest an intersection of shared concerns around supernatural themes, haunted and claustrophobic settings, and specific effects upon the reader or player. Deeper resemblances can also be traced, and I will argue that an understanding of the Gothic genre, and more particularly the sense qualities of Gothic settings, such as illumination, can enrich our understanding of the experience of survival horror computer games. But first, we need to look more closely at the ways in which our experiences of fiction and other non-interactive media, such as film, differ from that of interactive media.

The psychological effect upon the reader or player—whether described as fear, terror, or horror—is central to both the gothic and survival horror genres. Both genres are vehicles for exploring emotional extremes. To return to the Wikipedia definition of Gothic fiction:

> "In a way similar to the gothic revivalists' rejection of the clarity and rationalism of the neoclassical style of the Enlightened Establishment, the term "gothic" became linked with an appreciation of the joys of extreme emotion, the thrill of fearfulness and awe inherent in the sublime, and a quest for *atmosphere*." (accessed 13 Dec. 2006)

But it must be noted that the emotional experience of reading fiction and playing a game are very different. Perron (2005a) has drawn upon the film psychology work of Tan, and emotion research of Fridja, to sketch a framework for understanding just how the emotional impact of non-interactive media differs from that of interactive media. Fridja argues that emotions are not just passive experiences, but orient us towards action. Initial appraisals of situations are conducted to determine the relevance to one's interests and well-being, and are followed by an evaluation of what can be done, actions that can be taken. Perron further quotes Grodal (2003) as an example of how this process can work in the case of digital games:

> "In video games, . . . "[i]t is the player's evaluation of his own coping potential that determines whether [a] confrontation with a monster will be experienced as fear (if the evaluation of his coping potential is moderate), despair (if he feels that he has no coping potentials), or triumphant aggression (if he feels that he is amply equipped for the challenge). This entails that the emotional experience will vary over time, due to the learning processes leading to a change in coping potentials" (p. 150)

It is thus the capacity to act that differentiates interactive media, such as games, from fiction and film. Fridja's emphasis upon action is of direct relevance to the design of interactive experiences.

One key way in which survival horror games create their emotional effect is by maintaining a state of player vulnerability. The Wikipedia entry emphasizes the way in which this achieved through game balance and resources: in comparison to shooter games, for example, "the player is made to feel underpowered, generally fighting alone for the bulk of the game, with limited supplies." This is of course inherent in the paired terms in "survival-horror" the first (survival) indicating a player goal, the second (horror) referring to an emotional state as well as an existing film and literary genre. The word "survival" indicates that we are in a world of diminished expectation; it isn't called victory—horror. One primary activity is self-defense. The player is never free enough to go on the offensive, as in a strategy game, but is maintained in a reactive posture. But defensive struggle is not the only hallmark activity of survival-horror games; drawing from earlier adventure games, there is a fair component of puzzle solving. The player is also suspended in a state of incomplete knowledge. This establishes a varied pace in which moments of feverish activity are leavened with moments of cognitive challenge. It should be noted that puzzle-solving is an important theme in Gothic literature as well, whether explicit, as in the cryptographic challenges of Poe's *The Gold bug*, or implicit, as in *The Pit and the Pendulum*, in which the narrator has to solve the problem of how to escape a torture device that threatens to vivisect him..

But it is not only game resources and cognitive challenges that contribute to the psychological effect of survival-horror games. Vulnerability is also produced through the perceptual conditions of the game worlds. I recently replayed *Silent Hill 2* and chapters 3 & 4 of *Resident Evil 4* (Capcom 2005) with knowledge of how to solve the puzzles, as well as armories of weapons bolstered by previous trips through the games. My in-game resources and cognitive preparation were tiptop, yet the games still produced goosebumps. As in my first time through the games, I was compelled forward to the conclusion, almost against my will. And even in the first time through, I wasn't particularly compelled by the narrative framework for either game, whether concern for the plight of Ashley, the abducted president's daughter in *Resident Evil 4*, or James' hunt for his dead wife in *Silent Hill 2*. Understanding goosebumps, our physical and psychological response to these compelling games, directs us to look beyond game resources and narrative, to a deeper consideration of the conditions which lead to the emotions of fear, terror, and awe.

Much has been written on the distinctions between fear, terror and horror, and these distinctions are relevant to our understanding of the survival-horror experience. Perron notes that horror is an emotion that is overwhelming and annihilating in character, and that our experience games such as *Silent Hill* has little to do with it. Fear is the relevant emotion; in survival-horror games, as well as non-interactive media, we seek a "bounded experience of fear" (Perron 2005b). Writers of gothic fiction were also very interested in the nuances of this particular emotional range. In her essay *On the Supernatural in Poetry*, the Gothic novelist Anne Radcliffe (1826) distinguished between terror and horror, arguing the literary value of the former, as well as outlining a poetics of how terror emerges from imagery:

> "Terror and horror are so far opposite, that the first expands the soul, and awakens the faculties to a higher degree of life; the other contracts, freezes and nearly annihilates them. . . . and where lies the great difference between horror and terror, but in . . . uncertainty and obscurity"

Obscurity in this sense enhances 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, or occlusion. Radcliffe compares the experience of reading to that of real life, anticipating the greater range of action possible in survival horror games:

> "Now, if obscurity has so much affect on fiction, what must it have in real life, when to ascertain the object of our terror, is frequently to acquire the means of escaping it?"

Radcliffe's discussion of obscurity owes a debt to a contemporary discourse on the nature of the sublime, which established many of the emotional and aesthetic terms underpinning the Gothic. "Sublime" is a word which has become debased in everyday English usage, and which has been questioned as an aesthetic category, but it has continued relevance to a discussion of how one designs the psychological effect of fictional worlds in which terror is the desired end. Edmund Burke's *On the sublime* (1757) (Burke 1998) contributed the most to the association of obscurity with terror. In it, he attempts to describe the emotion that corresponds to the sublime, and explores the aesthetic means and perceptual conditions by which it can be produced:

> "Whatever is fitted in any sort to excite the ideas of pain and danger, that is to say, whatever is in any sort terrible, or is conversant about terrible objects, or operates in a manner analogous to terror, is a source of the *sublime*; that is, it is productive of the strongest emotion which the mind is capable of feeling" (p. 86).

Burke's discussion of the sublime object or setting focuses upon issues of scale and qualities of description; vastness is the favored scale, and obscurity is the favored mode of representation:

> "To make anything very terrible, obscurity seems in general to be necessary. When we know the full extent of any danger, when we can accustom our eyes to it, a great deal of the apprehension vanishes" (p. 102).

Burke goes on to look at the ways in which light, color, and other visual phenomena contribute to these particular effects, with attention to the way in which contrasts can be created:

> "I think then, that all edifices calculated to produce an idea of the sublime, ought rather to be dark and gloomy, and this for two reasons; the first is, that darkness itself on other occasions is known by experience to have a greater effect on the passions than light. The second is, that to make an object very striking, we should make it as different as possible from the objects with which we have been immediately conversant" (p. 122).

Burke's emphasis upon scale, vastness and grandeur, coupled with indistinctness of representation, is echoed in contemporary research on an emotion associated with the sublime: the experience of awe. In "Approaching Awe, a Moral, Spiritual, and Aesthetic Emotion," Keltner and Haidt (2003) outline a prototypical description of the emotion, with reference to two key features: vastness and accommodation:

> "Vastness refers to anything that is experienced as being much larger than the subject, or the subject's ordinary level of experience or frame of reference. Vastness is often a matter of simple physical size, but it can also involve social size, such as fame, authority, or prestige. . . . Accommodation refers to the Piagetian process of adjusting mental structures that cannot assimilate a new experience . . . The concept of accommodation brings together many insights about awe, including that it involves confusion (St. Paul) and obscurity (Burke), and that it is heightened in times of crisis, when extant traditions and knowledge structures do not suffice (Weber). We propose that prototypical awe involves a challenge to or negation of mental structures when they fail to make sense of an experience of something vast. . . . We stress that awe involves a <u>need</u> for accommodation, which may or may not be successfully accomplished. The success of one's attempts at accommodation may partially explain why awe can be both terrifying (when one fails to understand) and enlightening (when one succeeds)."

There are a number of features of survival horror games that also challenge existing mental structures. The theme of the supernatural, for instance (receiving a letter from one's dead wife, or being confronted by zombie monks), requires a thematic accommodation by the player, while the qualities of survival horror game worlds require a sort of perceptual accommodation. Keltner and Haidt also note that the physical marker of awe is piloerection, or goose bumps. Awe, and terror are, as Burke originally noted, two sides of the same emotional coin.

At their best, survival horror games create a compelling play experience because they suspend the player in a state of awe/terror. To return to Frijda's terms, obscurity is one means by which the appraisal period is extended, and the player is frozen in a state of uncertainty, in which action is considered but not yet possible (This is one difference between survival-horror and first person shooter games, which are much more about reflex action). Often this is accomplished through a combination of visual obscurity, occlusion, and anticipatory sound effects.

As Burke mentions, our experiences are often shaped through contrast; we feel things more strongly when opposites are juxtaposed. The modulation of contrasting perceptual states contributes to the pace and rhythm of playing through *Silent Hill 2* and *Resident Evil 4*. Spatial perception and visual occlusion in the castle section, the centrepiece of *Resident Evil 4*, for example, is shaped by navigation through environments in which regularity and axial symmetry is contrasted with meandering and labyrinthine features. These spaces correspond to the archetypal spaces of gothic fiction. Hennelly (2001) argues that the figure of the cathedral unites the varying archetectonic forces of the gothic, playing vertical aspirations against underlying caverns, natural forms against artificial symmetry:

> "The artifice in Gothic cathedrals mocks the natural models of forest trees, stressing especially the vertical tension between spiritual spires and charnel/carnal catacombs, what The Monk terms "vaults above and caverns below"."

Navigation on the horizontal and vertical axes is also an important contrast in both of survival horror games. One regularly descends below the ground level, to vaults, and mysterious sub-basements, mines and caverns. In *Silent Hill 2*, vertical movement often takes the form of jumping into darkness, where one cannot see the bottom of the pit. Confronting this primal fear within the safe confines of the game is the only way to move forward. It has been argued that there is an aesthetic of the vertical in computer games (Johansson 2003); in virtual spaces devoid of gravity one is freer to play on this dimension. And indeed, one experiences a kind of extension of the vertical dimension in the middle section of *Silent Hill 2*, in which one jumps and descends repeatedly, seemingly travelling great vertical distances to go a very little way in the actual space of the game world. Upward vertical movement is also important in the castle sequence of *Resident Evil 4*, in which the climactic boss fight is preceded by a lengthy ascent to the top of a tower.

Purposeful navigation and visual perception on the horizontal plane is often stymied in these games by labyrinthine spaces. Again, these correspond closely to the Gothic prototype. With reference to Poe, David Leatherbarrow (1986) contends that:

> "The labyrinth is the form of most of Poe's interior passages. Spatial movement in Poe's fiction is typically an ongoing negotiation with unexpected obstacles and unforeseen changes in direction . . . In such a place one was always without external reference and fixed orientation. Any sequence is alternately redirected by intermediate walls and panels as well as vertically by steps in ascent or descent" (p. 10).

Labyrinths in survival horror games come in several varieties. There are spaces that are explicit labyrinths, such as the garden labyrinth in *Resident Evil 4* (see title page). There are also spaces that are implicitly labyrinthine. Perhaps most fiendish, and effective, is the labyrinthine section of *Silent Hill 2* in which navigation through a banal interior space is rendered much more difficult when the map function, upon which the player has relied, becomes unreliable. It is only updated to show player progress; it cannot be used to plan one's movement.

The architectural settings of *Resident Evil 4* draw predominately upon vastness for their effect, and are rendered with clarity that speaks of the designers pride in their creation. The castle itself, bastion of a family of inbred Spanish nobility, serves as the key locale for the central section of *Resident Evil 4*. Upon reaching the castle, and entering its grounds, we are treated to an overview of its vastness that functions as a set piece not unlike the first glimpses of Radcliffe's castle of Udolpho (Radcliffe 1794):

> "Emily gazed with melancholy awe upon the castle, which she understood to be Montoni's; for, though it was now lighted up by the setting sun, the gothic greatness of its features, and its mouldering walls of dark grey stone, rendered it a gloomy and sublime object. As she gazed, the light died away on its walls, leaving a melancholy purple tint, which spread deeper and deeper, as the thin vapour crept up the mountain, while the battlements above were still tipped with splendour. From those, too, the rays soon faded, and the whole edifice was invested with the solemn duskiness of evening. Silent, lonely, and sublime, it seemed to stand the sovereign of the scene, and to frown defiance on all, who dared to invade its solitary reign. As the twilight deepened, its features became more awful in obscurity, and Emily continued to gaze, till its clustering towers were alone seen, rising over the tops of the woods, beneath whose thick shade the carriages soon after began to ascend."

Awe functions here in a very complex way, within a game context, because awe constitutes not only a gameplay emotion, but also an artefact emotion (Perron 2005a). The player feels not just "this is a huge place, how am I going to get through," but also "this is not like any other space I have seen in a digital game."

The sorts of illumination contrasts that one experiences in *Resident Evil 4* and *Silent Hill 2* 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 in which we are not aware of changes of natural light. Interior spaces in *Resident Evil 4* tend to be warm, and 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.

Strategies of obscurity involving both fog and darkness are exploited most fully in *Silent Hill 2*. In contrast to the prototypical gothic environments of *Resident Evil 4*, the settings of *Silent Hill 2* owe more to the N. American small town gothic of David Lynch. No castles here; rather, the haunted house becomes the haunted community. In this sense, the environments of *Silent Hill 2* contain fewer the traditional settings of the gothic sublime, but rather participate in the "uncanny," the unheimlich. As Vidler (1992) writes,

> "for Freud, "unhomliness" was more than a simple sense of not belonging; it was the fundemental propensity of the familiar to turn on its owners, suddenly to become defamiliarized, derealized, as if in a dream."

In many parts of the game, when one is on the streets of the town, large portions of the frame are simply rendered as darkness or atmospheric fog. Against a background of anticipatory sound, indicated by growls and radio static, obscurity enhances the sense of vulnerability and suspense. Eyetracker studies conducted by Gustaf Berg, Niklas Norin, Staffan Persson & Johan Ögren of Gotland University indicate that visual obscurity in expansive versus claustrophobic environments has different effects. In exterior, fogbound environments, players spent 31.5% of their time scanning the fog edge, the transparent areas just on the border of visibility, versus just 5% for the darkness edge in interior sequences, which are mostly played out in small rooms and tight hallways. One interpretation is that this as a function of felt vulnerability. In expansive, outdoor environments, sources of danger can approach from almost any direction, while in claustrophobic spaces there are much more limited angles of access.

Monsters can come at you from anywhere in these games, but the sort of threats they pose are quite different. In both games, the monster is, as Perron (2005b) notes, "at the core of the videoludic experience of fright." The zombies and monsters of *Resident Evil 4*, however, are all threatening, and can all be defeated, if one has the skill and resources. Conversely, many of the monsters of *Silent Hill 2* are relatively weak beings that can be easily evaded, and are reminiscent of the "floundering, squealing white thing on which Sir John Clave's horse had trod one night in a lonely field" in H.C. Lovecraft's *Rats in the walls* (1923). But the central boss of *Silent Hill 2* is the magnificent Pyramidhead, who is unstoppable and can only be survived, never defeated. Player vulnerability is magnified by this sort of opponent.

In the end, survival is its own reward. Our journey through the labyrinths, caverns, castles and haunted houses of survival horror games is a compelling experience in which we can taste can the emotion of fear most fully, because we can (eventually) act in the face of our fears. It is the process of perception and action—scanning, anticipating, feeling and doing—that is exercised by these games. The magnificent gothic spaces of *Resident Evil 4*, and the uncanny, fogbound and surreal ambiance of *Silent Hill 2* offer two quite different explorations of gothic themes in interactive media. They provide a new media playground for an established genre.

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COMPENDIUM TEXT 6:

LIGHTING IN DIGITAL GAME WORLDS: EFFECTS ON AFFECT AND PLAY PERFORMANCE

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Abstract

As a means of extending the significance of findings in experimental psychology and non-visual psychological lighting research to the digital game research, the present study was designed to investigate the impact of warm (reddish) and cool (bluish) simulated illumination in digital game world on game users' affect and play performance. In line with some previous findings, we predicted that lighting in a digital game world might, as in the real world, differently influence the non-visual psychological mechanisms of affect, which in turn might enhance/impair the players' performance. It was shown that the players performed best/fastest in a game world lit with a warm (reddish) as compared to cool (bluish) lighting. The former color of lighting also induced the highest level of pleasantness in game users. A regression analysis indicated tentatively that it was the level of pleasantness induced by the warm lighting that enhanced the players' better performance in that digital game world. It was also shown that high as opposed to medium/low skill players engage almost 2.5 times more per week in game-playing. Given their skill, they performed significantly fastest and they felt significantly most calm and relaxed in doing that.

Introduction

Digital games are among the most complex of interactive media. Not only do games simulate many of the components of traditional filmic media, such as plot, characters, sound and music, lighting, sets and pre-rendered animations, they are also digital artifacts played through graphic interfaces and controllers. As interactive experiences, moreover, games are the site for 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 perceptual, cognitive and motor resources, contributing to what Lindley refers to as the "gameplay gestalt" [1].

In spite of the complexity of game artifacts and player experience, much of the design activity at game companies has traditionally been conducted as an intuitive process, an "unselfconscious design culture" [2]. Although companies have begun to integrate usability studies and play-testing into their design processes, as a means of increasing the chances of developing a successful game, much of the scrutiny is directed at the interface, with the intention of reducing player frustration[3]. Play-test consultants have productively addressed issues of player motivation[4], though their efforts are often driven by research questions framed by, and immediately meaningful to their clients.

In this climate, independent research into deeper sources of player behavior is crucial. One promising area of digital game research is the impact of game aesthetics upon the emotional response of players. Within the area of game studies research, there are currently three main understandings of the term "game aesthetics:" 1) Sensory phenomena that the player encounters in the game[5]; 2) Aspects of digital games that are shared with other art forms[6]; 3) Expression of the game experienced as pleasure, emotion, or sociability, with focus on the aesthetic experience[7,8]. All of these understandings mirror the larger history of aesthetics discourse[9]. But whether one considers game aesthetics from the point of view of sensory phenomena, generalizing about art, or the aesthetic experience, it is clear that game aesthetics as a field of research is capacious enough to meaningfully inform the design of rich and complex interactive experiences that have a particular emotional effect upon the player.

One way of approaching game aesthetics research in an empirical manner is to cut a thin slice through a complex system. Light and shadow have always featured in the repertory of those who fashion fictional worlds for particular emotional effects. Cinematographer autobiographies and handbooks, for example, testify to the skills of creative practitioners who have mastered the close coupling between light effects and emotional response[10,11]. Light and shade can be manipulated as emotional bass-line, subtly modulating our response to events; light and shadow are capable of shaping the bravura moment, the brilliant effect. The effects of real-world lighting upon our visual system have attracted research activity in the past[12], but insights into light's non-visual impact upon emotion and cognition has only recently been explored[13]. This research confirms what lighting practitioners in architecture, theatre, film and digital animation have long intuited: that light in and of itself "matters" in our emotional experience[14].

Emotional experience – a circumplex structure

According to Reber[15], affect is a:"... general term used more-or-less interchangeably with various others such as emotion, emotionality, feeling, mood, etc.". Other definitions have proposed that affect is a broad term comprising emotion (a brief intense experience such as anger) and mood (a prolonged and low-intensity experience such as melancholy). In the words of Simon[16]: "emotion ... refers to affect that interrupts and redirects (usually with accompanying arousal), mood ... refers to affect that provides a context for ongoing thought processes without noticeably interrupting them." Within these categories an additional distinction is made, that of positive and negative emotionality and mood[17]. Human emotional experience has also been considered as a collection of various independent, monopolar factors such as discrete basic emotions[18,19,20,21]. Others have argued for an arrangement of human emotional experience around two bipolar dimensions of perceived activity (activation-deactivation) and hedonic tones of pleasantness-unpleasantness[22,23].

In line with this, Russell[24] proposed a circumplex model of conscious accessible feelings; that is, core affect[25,26]. He showed that human emotional experience could be accounted for by a two-dimensional circular structure with eight affect states. In a series of studies, Russell and his colleagues demonstrated evidence for this view[27,28,29,30,31] and concluded that there is an emerging convergent view among researchers in emotional psychology for a two-dimensional structure of core affect, meaning that these affective states are in the center of human emotional experience[25,32,33].

Larsen and Diener[34] suggested a labeling system for the circumplex affect space analogous to a compass. The states are organized according to the bipolar axes of pleasure-displeasure and perceived high-low activation. They mark the two north-south (High Activation - Low Activation) and east-west (Pleasant - UnPleasant) sides and so define four quadrants; hence, interrelated like points on a compass. Each of the quadrants is bisected, giving the eight octants that fix the circumplex structure. The remaining points on the circumplex are: north-east (Activated Pleasant), north-west (Activated UnPleasant), south-east (UnActivated Pleasant) and south-west (UnActivated UnPleasant). All this suggests that the affect states with: (1) Unpleasant valences are placed at the left side; (2) Pleasant valences are placed at the right side; (3) High activation levels are placed above; (4) Low activation levels are placed below. In addition and according to the circumplex structure, a single attribute defines an octant and two single attributes placed 180° from each other define a dimension (an axis pair). Formally, the octants correlate highly, when located nearby (e.g., HA-AP), near zero when fixed 90° from each other (e.g., HA-P) and inversely when placed 180° from each other (e.g., HA-LA). In line with the Larsen and Diener[34] labeling system for a circumplex affect space (see also[35] for a similar account), Knez and Hygge[36] developed a Swedish measure for the self-rated current emotional experience, which has been used in, for example, studies on light and noise[37], autobiographical memory[38] and place assessment[39].

Psychology of lighting

The link between light and eye has been a subject for scientific inquiry for a long time. Interest in this topic can be traced back to the developments of physics, biology and medicine. Since the beginning of the twentieth century, when the Western world was shifting from a pre-industrial agrarian way of living to a modern one, the need for electrical power and light has increased considerably. The pioneering technical and human factors work on lighting laid down the fundamentals for contemporary lighting research. Measuring the human eye's reactions to light was initiated. Much has been learned since then about the effects of light characteristics on visual perception[12]. Two perceptual phenomena have been intensely examined; namely, visual task performance and visual comfort related to the parameters and features of light and lighting such as illuminance, color, glare and flicker. Current international recommendations and standards concerning the human factors in lighting[40] are in general based on the visual lighting research results.

A number of findings in experimental psychology have demonstrated effects of environmental variables on emotion and cognition[41], and of emotion on cognition[42]. In line with this and akin to[43,44], Knez[13] proposed a non-visual lighting research assuming that indoor lighting may alter affect in people; an influence that may, in turn, impair or enhance their ongoing intellectual, cognitive performance in that type of physical interior. Knez[13,45] revealed evidence of an influence of indoor lighting on affect. Warm (<u>reddish</u> ca. 3000 K) compared to cool (<u>bluish</u> ca. 4000 K) white lighting was shown to evoke more positive affect in women, while the opposite responses were shown in men. Knez & Kers[46] showed also that cool (<u>bluish</u>) lighting elicited more positive affect in younger than in older subjects, an impact that reversed in warm (<u>reddish</u>) lighting. The evidence of an influence of indoor lighting on cognition is complex. Knez[13] has shown interaction effects between the color of lighting and gender on cognitive performance. However, most recent findings indicate main effects of the color of lighting on cognitive performance[37,47,48].

One general inference to be drawn from this is that an influence of indoor lighting on non-visual, psychological mechanisms is complex[49], meaning that empirical evidence diverge in several aspects. Nevertheless, and generally speaking, an influence of lighting on affect has been indicated, suggesting that indoor lighting and especially its color character (warm, <u>reddish</u> and cool, <u>bluish</u>) is an affective source that may evoke different affective reactions in people.

Present study

As a means of extending the significance of findings in experimental psychology[41,42] and non-visual psychological lighting research[13,35,47] to digital game research[50], the present study was designed to investigate the impact of warm (reddish) and cool (bluish) simulated lighting in digital game worlds on players' affect and performance. Following the findings shown in previous research[13], the prediction was that warm and cool color of lighting in digital game worlds might, as in the real world, influence the non-visual psychological mechanisms of affect in different ways, which in turn might enhance/impair the players' performance. Finally and in order to address the importance of practice in building a knowledge and skill base[51], the level of participants' game skill (low, medium, high) was included as an independent variable.

Methods

Participants:

38 subjects (14 women, 24 men) participated in the study. They were recruited from our student body (Schools of Arts and Communication, Malmö University, Sweden) and from a local console gaming club. Participants were paid 100 Swedish crowns (ca. 15 U.S. dollars) to participate. Their mean age was 22 (Std. = 4.4), ranging from 15 to 32. Participants play skill was categorized (see Procedure section below) as low (9 participants), medium (22 participants) and high (7 participants). All participants claimed to be free of vision and motion sickness problems.

Apparatus and experimental room:

The stimuli (see below) were displayed through computer monitors which were calibrated for uniform performance. The experimental room was dim so that other sources of light would not affect perception of the screen.

Stimuli:

In order to produce results that are meaningful within the world of game design, it is necessary to explore player response to simulated lighting while engaged in a genuine game task. We accordingly constructed three maze sequences in the Half Life

2 engine Hammer, through which players navigated in virtual space under three different lighting conditions: neutral (grayish), cool (bluish) and warm (reddish) lighting (see Figures1-3). Care was taken to ensure that the spatial configuration of each maze was different and yet equivalent in size and complexity (by flipping the model), and histograms (a representation of the distribution of values, from light to dark, in the scene) were compared as a means of lighting for consistent values between the variants.

The maze form was chosen because spatial navigation is a feature of almost all games that are experienced as 3D simulations; indeed, the experience of navigable space has been acknowledged as one of the hallmarks of new media artifacts[52]. Gray color was used as a neutral condition rather than normal game colors in order to sharpen the contrast between the different lighting conditions, which is easier to do if object color does not come into play.

Design:

Two independent variables: 1) Skill (low, medium, high; see Procedure section below) as a between-subject variable; 2) Lighting (neutral -grayish-, cool -bluish-, warm -reddish-) as a within-subject variable.

Dependent variables and statistical analyses:

Play performance was measured by the time (minutes and seconds) it took to complete a game (a maze). Affect was measured by the circumplex affect instrument. At the end of each game and in line with[36] the participants were asked to rate their affect by rating forty-eight adjectives representing the eight affect states on 5-point scales from ”little or not at all” to ”very much”, in reply to the question: ”How do you feel right now?” Also at the end of each game the participants were asked to evaluate the maze lighting (“How would you describe the lighting?”) on a five point scale ranging from 1 (little or not at all) to 5 (very much), comprising the following 10 scales: ugly, glaring, cold, dim, intense, warm, bright, soft, annoying, beautiful. The statistical analyses used were ANOVA (play performance; time) and MANOVAs (affect and lighting evaluations).

Procedure:

Participants were brought into the experimental room where they received the instructions for the experiment. Before the start of the experimental session, each participant played a tutorial level in order to familiarize themselves with the task. They filled out a questionnaire in which they were asked to categorize themselves as low, medium or skilled players, as well as to estimate how many hours they played per week and what kind of games they prefer to play. Two subjects of the same gender (where possible) were run at each experimental session. At the end of each of the three game sessions the participants were asked to evaluate their momentary affect and the lighting in the maze. The participants' play performance was measured as the time (minutes and seconds) it took to clear each maze. The play order of the three games was counterbalanced according to a latin-square.

Results

For each dependent variable, as mentioned above, the data were analyzed by a two-way analysis of variance (3 skill levels X 2 lighting conditions). Due to some previous results indicating gender and age differences in lighting-induced affect[13,46], we also tested the effects of gender and age (younger vs. older players) on the three dependent variables. No significant results were shown, however. In consequence, all findings reported below are related to the independent variables of skill (low, medium, high) and lighting (neutral -grayish-, cool -bluish-, warm -reddish-). Due to our aims and prediction, it must be noted that the impact of warm (reddish) and cool (bluish) lighting on the three dependent variables will primarily be considered. Thus, and also as mentioned in the Stimuli section, the grayish lighting condition was treated as a neutral, reference one.

Background statistics:

The high skill players' mean digital-game-play-time was ca. 19 hours per week compared to the low and medium skill players' ca. 8 hours. Thus, the high skill players were shown to play almost 2.5 times more per week than the medium/low skill players did ($M = 18.8$ vs. $M = 7.7/7.8$ hours per week), $F(2, 34) = 3.49$, $p = .04$. It must be noted, however, that they do not necessarily play more often, but probably play for longer in each game session. The high skill players were also much more precise in their digital game taste than the low/medium players were. They played only the FPS (first person shooter) and RPG (role playing game) types of games (80% vs. 20%) compared to the medium/low skill players who played FPS, RPG, RTS (real time strategy) Action, Sports, Adventure, Consol, Music, Hearts, Mmorpg, Sim and Puzzle types of games

Play performance

A significant main effect of Lighting showed that the participants, independently of their skill, completed the maze game fastest in the warm lighting (see Figure 4), $\underline{F}(1, 35) = 6.24$, $\underline{p} = .02$. In addition and as can be seen in Figure 5, a significant main effect of Skill showed that the high skill players accomplished the maze games as fastest, independently of the lighting, $\underline{F}(2, 35) = 8.18$, $\underline{p} = .001$.

Affect:

A multivariate significant main effect of Lighting was shown (Wilk's Lambda = .53, $\underline{F}(16, 134) = 3.11$, $\underline{p} = .000$) associated with the affect states of HA (Greenhouse-Geisser = 1.65, $\underline{F}(2, 69) = 4.05$, $\underline{p} = .02$), LA (Greenhouse-Geisser = 1.99, $\underline{F}(2, 65) = 4.95$, $\underline{p} = .01$), P (Greenhouse-Geisser = 2.45, $\underline{F}(2, 73) = 7.09$, $\underline{p} = .002$), AP (Greenhouse-Geisser = 2.29, $\underline{F}(2, 71) = 5.18$, $\underline{p} = .01$) and UAP (Greenhouse-Geisser = .43, $\underline{F}(1, 53) = 1.53$, $\underline{p} = .000$). The only significant impact between the two "colored" conditions of cool (<u>bluish</u>) and warm (<u>reddish</u>) lighting on participants' affect was related to the affect states of P and AP. As can be seen in Figure 6, the participants felt happier and gladder (P), $\underline{F}(1, 37) = 3.11$, $\underline{p} = .08$ (a tendency to a significant effect), and more enthusiastic and peppy (AP), $\underline{F}(1, 37) = 4.59$, $\underline{p} = .04$, in the warm than they did in the cool lighting.

A multivariate significant main effect of Skill (Wilk's Lambda = .40, $\underline{F}(16, 56) = 2.04$, $\underline{p} = .03$) associated with the UAP state ($\underline{F}(2, 35) = 3.47$, $\underline{p} = .04$), showed that the medium and high skill players felt calmer and more relaxed than the low skill players did, independently of the lighting (see Figure 7).

Lighting evaluation:

No influence of Skill was indicated, but a multivariate significant main effect of Lighting (Wilk's Lambda = .18, $\underline{F}(20, 130) = 8.74$, $\underline{p} = .000$) associated with the cold (Greenhouse-Geisser = 84.23, $\underline{F}(2, 72) = 34.72$, $\underline{p} = .000$) and warm (Greenhouse-Geisser = 127.16, $\underline{F}(2, 67) = 77.33$, $\underline{p} = .000$) dimensions showing that the participants estimated the <u>bluish</u> maze lighting as significantly colder than the <u>reddish</u> one ($\underline{M} = 3.5$ vs. 1.4) and vice versa on the warmness dimension ($\underline{M} = 1.6$ vs. 4.0).

Relation between affect and play performance:

According to the results reported above, the participants performed best/fastest in the warm (reddish) lighting (see Figure 4) and they felt significantly more pleasant in that condition (see Figure 6). Regression analyses were performed to test the associations between player performance and the two states of P and AP in warm and cool lighting respectively; with the 6 adjectives/scales (P = happy, delighted, glad cheerful, warmhearted, pleased; AP = enthusiastic, elated, excited, euphoric, lively, peppy) as the independent variables for each affect state. A tendency to a significant relation between P state and player performance in warm lighting was indicated (see Table 1), significantly associated with the pleased scale (see Table 2). This implies tentatively that the players cleared the maze faster when they felt relatively most satisfied (P state), which they did in the warm (reddish) lighting. It must be noted that no significant relation was found between players' skill level, their performance (see Figure 5) and feelings of unactivated pleasantness, UAP (see Figure 7); meaning that the medium/high skill players' feelings of calmness and relaxation did not significantly account for their fast game performance and, vice versa, for the low skill players' slower game performance.

Discussion

The general aim was to extend the experimental psychology findings on influences of physical, real world, surroundings on affect and cognition[41], and on influences of affect on cognition[42], to the digital game world. In line with that and with some results in non-visual lighting research[13,35,42,47] we predicted that simulated warm (reddish) and cool (bluish) lighting in digital game world would affect the players' feelings and game performance. Generally speaking, and in keeping with our aim and prediction, we obtained data that point toward a similar influence of the color of light in a digital game world as in the real world on the psychological processes of affect and cognition.

More precisely, it was shown that the players performed best/fastest in a game world lit with a warm (reddish) as compared to a cool (bluish) lighting (see Figure 4). This is in line with[37,47] who reported similar influences of indoor, general ceiling warm (reddish) and cool (bluish) lighting on participants' cognitive performance. It must be noted that we only measured the time it took to complete a maze game, not the operations of the underlying processes of spatial vision and cognition; which has as yet to be outlined in future game studies, but which has previously been addressed in the, for example, video game research as related to the developmental psychology issues[53,54,55,56]. Still, our data show that the psychological processes involved in this type of digital game performance did work faster in a warm (reddish) than in a cool (bluish) lighting; thus, indicating an enhancement/ impairment of the psychological processes at hand as a result of the type of lighting installed.

Concerning the players' affect, it was indicated that they felt better playing in a warm (reddish) than in cool (bluish) digital world. That is, they felt happier and gladder and more enthusiastic and peppy in the former compared to the latter color lighting condition (see Figure 6). In line with the Knez[13] suggested line of influence: lighting ® affect ® cognition, it was tentatively indicated that the pleasantness induced by a warm (reddish) lighting might have improved the players' game performance in that condition (see Tables 1, 2). It must be noted however that a definitive direction of the affect and cognition link remains unclear due to the correlation analysis (simple regression) used, which do not permit a strict interpretation of causality. In addition, the participants were shown to evaluate warm (reddish) compared to cool (bluish) lighting as significantly warmer and cool (bluish) compared to warm (reddish) lighting as significantly colder. This implies a consistency in the participants' color discrimination of the two digital game worlds.

Our results have also shown that high as opposed to medium/low skill players engage almost 2.5 times more per week in game-playing and that they most often choose the FPS and RPG types of game compared to the medium/low skill players who have broader game preferences. The high skill players were shown to perform significantly faster than players at lower skill levels in all three maze games (see Figure 5) and they also felt significantly calmer and more relaxed in doing that (see Figure 7).

As regards interactive media and game design, and game engine programming, our results suggest that simulated illumination can, in and of itself, influence the feelings of the player. This is significant for game developers, as well as for those who design virtual worlds. We wish, however, to avoid simplistic claims about the influence of simulated illumination in game worlds. A digital game is a complex artifact composed of discrete elements that are experienced as a whole. Simulated illumination constitutes just one of the aesthetic components of a game; obviously, narrative structure, genre and player tasks and activities also shape player expectation and response when it comes to simulated illumination. What we do claim is that we have made a first step towards better understanding the contribution of a specific aesthetic quality of game worlds to the patterns of feeling and response that make up the game experience.

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COMPENDIUM TEXT 7:

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, accessed June 2007).

Game Aesthetics

Comprehending such a complex interactive experience is difficult, but can be approached using aesthetics discourse. 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 game-play (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). 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 game-play 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 game-play and "flow."

Simulated Illumination in Games

Simulated illumination is defined as the method by which virtual 3D game environment 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 color representation, e.g. "Rez" (United Game Artists, 2002), through cel-shaded[1] games, to those that approach photorealism (which incorporate a range of lighting that approximates the visual experience of real space). 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 modeling 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 modeling 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 color.

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 have demonstrated that warm and cool simulated illumination conditions have differing emotional and performance

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.

effects upon players navigating a virtual maze created in the "Half Life 2.0" game engine (Knez and Niedenthal, forthcoming).

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 game-play 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 game world—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; specifically, (1) 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, and (2) 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. 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 argument of the article, where we 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.)
- color (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 color 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 artifacts, 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 (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 have 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 color 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 color patterns in time, where the variation in a specific order or pattern causes rise or fall of projected tension.

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), e.g., "Citizen Kane", "The Shanghai Gesture", and "This Gun For Hire". Another form of contrast used in movies is the contrast between warm and cool colors (Block, 2001). This composition appeared in several movies, including "The Shining" which used a high warm/cool color contrast composition, where contrast is defined as the difference between warm colored lights lighting the character and cool colored 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.

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.

In addition to color and brightness contrast, lighting designers also use affinity of color, e.g., affinity of high saturated warm colors or unsaturated cold colors 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", sustained affinity of highly saturated warm colors 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 color to achieve white color. Hence, when projected with red color, the eye will try to compensate the red with cyan to achieve white color. 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 colors in one shot then cool saturated colors in the other, thus forming a warm/cool color contrast between shots to reflect a decrease in dramatic intensity. Some designers use saturated colored shots then de-saturated colored 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 color contrast, increases projected tension
(2) patterns that subject an audience to low affinity of color, in terms of saturation/brightness/warmth, followed by high affinity of color, in terms of saturation/brightness/warmth, increases 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 colors releases projected tension
(4) patterns that subject an audience to high affinity of color, in terms of saturation/brightness/warmth, followed by low affinity of color, 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 color 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 colors can cause increased arousal as discussed in (Handprint-Media, 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 game-play 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 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 game-play, most game environments are 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 colors, positions, angles of lighting in relation to objects, materials, and colors, angles of lights used on other surfaces within the frame. Moving or changing one color 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 colors 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).

ELE, 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, colors, 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.

ELE 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. ELE then emits the number of lights used, and properties for each light, including color, 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 color of lights in different areas, or increase contrast (determined by colors of lights lighting focus and non-focus areas). ELE 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 colors 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. ELE calculates contrast and depth according to the difference between colors assigned to each area. Using the supplied lighting constraints, ELE uses constrained nonlinear optimization to select an appropriate color 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 color 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, 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 of '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 game-play 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 game-play. While "Rez" was the first to create a dynamic environment that changes and adapts to game-play, 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' colors 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 color 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

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

lighting itself gave the player the information he/she needed through the patterns used.

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, where participants were given flyers explaining the game, and were then asked to play the two games and share their experience with us, if they so desire. We explained to all participants that the two laptops ran the same game, which is our own mod of the "Unreal Tournament 2004" (Epic Games, 2004) game. They were notified that one used enhanced temporal light and the other used static lighting. Each participant was urged 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 a hundred participants who played the game, judging by the number of flyers we handed out, we collected several interesting responses. Many expressed an interest in the system and voluntarily discussed their experiences with us after their play session. An interesting outcome was that many non-first person shooter 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 had several experienced first person shooter 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 first person shooter 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 emotionally attached them to the game. Some commented that this effect made them feel as if they are not in control.

Conclusion

This article 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 game-play 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 dependant 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.

Biographies

Magy Seif El-Nasr earned her Ph.D. degree from Northwestern University, her master's degree in Computer Science from Texas A&M University and her B. S. degree in Computer Science from the American University in Cairo. Dr. Seif El-Nasr received several awards, including 2nd best paper award at the International Conference of Virtual Storytelling, and Leadership Excellence Award from Texas A&M University. She is on the editorial board of the International Journal of Intelligent Games and Simulation, and ACM Computers in Entertainment. She is the co-director of the RAEL (Real-time Aesthetic and Experience Lab). Her research work includes designing and developing tools that enhance the engagement of interactive environments used for training, education, and/or games.

Simon Niedenthal is an associate professor of interaction design at Malmö University in the School of Arts and Communication (K3). His areas of research interest include digital game aesthetics, simulated illumination, and design process for games and interaction, and he has been published in scholarly periodicals including Leonardo, Digital Creativity, Afterimage and the Journal of Architectural Education. He was leader of a recently completed Knowledge Foundation-sponsored project on game aesthetics and emotion, "Shadowplay: Simulated illumination in game worlds," and his paper of the same title was selected "Best Paper" at the 2005 Digital Game Researchers Association (DiGRA) conference in Vancouver.

Igor Knez is an associate professor of psychology at the department of Technology and Built Environment at University of Gävle. He has a Ph.D. in cognitive psychology from Uppsala University. Igor's present research concerns the effects of illumination upon emotion and cognition and place-related identity and memory, and has been published in journals including Journal of Environmental Psychology, Environment and Behavior, Applied Cognitive Psychology and Memory.

Priya Almeida is currently a Project Engineer at Impact Technologies, Rochester, NY with the Electronic Systems PHM Group. She received her Master of Science Degree in Electrical Engineering from The Pennsylvania State University in 2005 and is a member of IEEE and IEEE Aerospace & Electronic Systems Society. Her thesis 'Identifying low level patterns in movies and video games that influence emotions and moods' has contributed to this article. She has two years of experience in embedded systems and software programming. At Impact, she works on research and development of diagnostic and prognostic reasoners and strategies for aircraft electronic systems such as mixed mode radio frequency/ digital systems.

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ABSTRACT

A common feature of many digital games is that they are played in a simulated 3D environment, a game world. Simulated illumination is the lighting designed into a game world. This thesis explores the influence of simulated illumination in digital games upon the emotion and behavior of the player. It does so within the context of game aesthetics, building upon an understanding of games as having the potential to evoke an aesthetic experience that is deeply absorbing, is experienced as whole and coherent, evokes intense feelings or emotions, and engages a sense of "make believe." A full account of how simulated illumination affects people is gained by tracing the contributions from media practice and real-space lighting, as well as taking into account the unique possibilities of interactive media. Based upon the rich set of lighting references and possibilities that are present in digital games, this thesis offers a taxonomy of influence of simulated illumination, which is organized such that it moves from progressively simple patterns and mechanisms that work without much player awareness, towards progressively greater complexity and consciousness of light qualities.

The study of simulated illumination is complex, and best conducted within a transdisciplinary framework that includes three perspectives: empirical emotion research, investigation of the lighting attitudes of creative practitioners, and formal analysis of games with the aim of articulating their use qualities related to simulated illumination. The way in which a "triangulation" study could be structured is presented through the results of the two-year Shadowplay project, with specific reference to the effects of warm (reddish) and cool (bluish) simulated illumination upon the experience of gameplay. We learned that exposure to warm light in a game prototype created more positive affect and led to better performance, and uncovered an interesting correspondence in the lighting attitudes of creative practitioners, regarding the relatively attractive versus repulsive qualities of warm and cool illumination in game environments.

The (sometimes inconsistent) results of the Shadowplay project are discussed with reference to the conception of "pleasure" as it is developed within phenomenological philosophy and hedonic psychology. Considered this way, simulated illumination can create "eliciting conditions" for more complex sequences of emotions that constitute game pleasures. Within a game, we respond emotionally to exposure to qualities of simulated illumination, based upon what we bring with us into the game (whether based upon tastes, attitudes related to genre, memories or more "hard-wired" responses to light). At the same time, we implicitly learn the significance of the illumination that we encounter through our activity in the game. This means that there is no simple mapping of illumination quality to emotional outcome. Rather, designers need to learn to manipulate the unique potentials of simulated illumination in relation to the other elements of the gameplay experience.

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