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) vs. cool (bluish) lighting. The former color of lighting compared to the latter one was also shown to induce the highest level of pleasantness in game users. According to a regression analysis, 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 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 motor charge of reflex action. The whole game experience is often evaluated with reference to that yet-to-be- fully-defined term "game-play."

In spite of this complexity, much of the design practice of game companies has traditionally been conducted as an intuitive, seat-of-the-pants process, with predictably uneven outcomes and the occasional expensive failure. 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[1]. Play-test consultants have productively addressed issues of player motivation[2], 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. In contrast to other media such as feature films, relatively little work has been done on the emotional response of game players to the game experience[3], which is puzzling. After all, participation in any fictional world has an emotional payoff. Whether the world is mediated by the stage, the movie screen, or the turn of a page, whether we feel suspense, catharsis, or laughter, we willingly enter fictions because we seek full and rich emotional experiences. Interactive media such as digital games create new opportunities for emotional engagement. Some games are punctuated by fist-pumping jubilation, others characterized by muscle-paralyzing tension; still others are marked by the quiet satisfaction of understanding or social participation. The precise complex of emotional effects possible in digital games has yet to be mapped.

What we do know is that light and shadow have always featured in the repertory of those who fashion fictional worlds for particular emotional effects. 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 on our visual system has drawn much research activity in the past, but insights into light's non-visual impact upon our emotions and cognitions has only recently been explored[4]. 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[5].

Circumplex structure of emotional experience

According to Reber[6], 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[7]: "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[8]. Human emotional experience has also been considered as a collection of various independent, monopolar factors such as discrete basic emotions[9,10,11,12]. 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[13,14].

In line with this, Russell[15] proposed a circumplex model of conscious accessible feelings; that is, core affect[16,17]. 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[18,19,20,21,22] 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[16,23,24].

Larsen and Diener[25] suggested a labeling system for the circumplex affect space. As can be seen in Figure 1, and 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).

Insert Figure 1 about here

In line with the Larsen and Diener (1992) labeling system for a circumplex affect space (see also[26] for a similar account), Knez and Hygge[27] developed a Swedish measure for the selfrated current emotional experience, which has been used in, for example, studies on light and noise[28], autobiographical memory[29] and place assessment[30].

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 twentieth century, when the Western world was shifting from a pre-industrial agrarian way of living to a modern one, a 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 on visual perception[31]. 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[32] 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[33], and of emotion on cognition[34]. In line with this and akin to[35,36], Knez[4] proposed a non-visual lighting research assuming that indoor lighting may alter affect in people; an influence that may, in turn, impair/enhance their ongoing intellectual, cognitive performance in that type of physical interior. Knez[4,37] revealed evidence of an influence of indoor lighting on affect. Warm (reddish ca. 3000 K) compared to cool (bluish ca. 4000 K) white lighting was shown to evoke more positive affect in women, while the opposite responses were shown in men. Knez & Kers[38] showed also that cool lighting elicited more positive affect in younger than in older subjects, an impact that reversed in warm lighting. The evidence of an influence of indoor lighting on cognition is complex.

Knez[4] 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[28,39,40].

One general inference to be drawn from this is that an influence of indoor lighting on non-visual, psychological mechanisms is complex[41], 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, reddish vs. cool, bluish) is an emotional source that may evoke different emotional reactions in people.

Present study

As a means of extending the significance of findings in experimental psychology[33,34] and non-visual psychological lighting research[4,27,34,39] to the digital game research[42], the present study was designed to investigate the impact of warm (reddish) and cool (bluish) simulated lighting in digital game world on players' affect and performance. Following the findings shown in previous research[4], the prediction was that warm and cool color of lighting in 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.

Methods

Participants

38 subjects (37% women, 63% men) participated in the study. Their mean age was 22 (Std. = 4.4), ranging from 15 to 32. All participants claimed to be free of vision and motion sickness problems.

Apparatus and experimental room

The stimuli (see below) was displayed through computer monitors which were calibrated for uniform performance. Ambient light in the space was carefully controlled so that 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 have accordingly constructed three maze sequences in the Half Life 2 engine Hammer, through which players will navigate virtual space under three different lighting conditions: warm (reddish), cool (bluish) and neutral (grayish) lighting (see Figures 2-4). Care was taken to ensure that the spatial configuration of each maze is different and yet equivalent in size and complexity (by flipping the model), and we compared histograms (a representation of the distribution of values, from light to dark, in the scene) as a means of lighting for consistent values between the variants.

Insert Figures 2-4 about here

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[43].

Design

Two independent variables: 1) Skill (novice, medium, high) 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 accomplish a game (a maze). Core affect was measured by the circumplex affect instrument. At the end of each game and in line with[21] the participants were asked to rate their core affect, current emotional experience, by rating the forty-eight adjectives representing the eight affect states (see Figure 1) 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, annoying, beautiful. The statistical analyses used were ANOVA (play performance; time) and MANOVAs (affect and lighting evaluations).

Procedure

Participants were brought in the experimental room where they received the instructions for the experiment. Before the start of the experimental session each participant played a test maze game in order to familiarize with the task. Two subjects matched on gender, as long as that was 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 core affect and the lighting in the digital world, the maze. The participants' play performance was measured as the time (minutes and seconds) it took for each maze to accomplish. For each one of the 38 participants, the play order of the three games was altered in line with the latin-square design.

Results

For each dependent variable, as mentioned above, the data were analyzed by an analysis of variance including the two independent variables of skill and lighting. Due to some previous results indicating gender and age differences in lighting-induced affect[4,38], we also tested the effects of gender and age (younger vs. older players) on the three dependent variables. No significant results were however shown. 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-).

Background statistics

As can be seen in Figure 5, 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 low/medium skill players did, $F(2, 34) = 3.49$, $p = .04$. The high skill players were also much more precise in their digital game taste than the low/medium players were (see Table 1), preferring the games of only the FPS (first person shooter) and RPG (role playing game) type.

Insert Figure 5 about here

Insert Table 1 about here

Play performance

A significant main effect of Lighting showed that the participants, independently of their skill, accomplished the maze game as fastest in the warm lighting (see Figure 6), $F(1, 35) = 6.24$, $p = .02$. In addition and as can be seen in Figure 7, a significant main effect of Skill showed that the high skill players accomplished the maze games as fastest, independently of the lighting, $F(2, 35) = 8.18$, $p = .001$.

Insert Figures 6 and 7 about here

Affect

A multivariate significant main effect of Lighting was shown (Wilk's Lambda = .53, $F(16, 134) = 3.11$, $p = .000$) associated with the affect states of HA (Greenhouse-Geisser = 1.65, $F(2, 69) = 4.05$, $p = .02$), LA (Greenhouse-Geisser = 1.99, $F(2, 65) = 4.95$, $p = .01$), P (Greenhouse-Geisser = 2.45, $F(2, 73) = 7.09$, $p = .002$), AP (Greenhouse-Geisser = 2.29, $F(2, 71) = 5.18$, $p = .01$) and UAP (Greenhouse-Geisser = .43, $F(1, 53) = 1.53$, $p = .000$). As can be seen in Figure 8, it was the neutral compared to the cool and warm lighting that generated the highest levels of activated and unactivated pleasantness (P, AP, UAP) and high and low perceived activation (HA, LA). The only significant impact between the two “colored” conditions of cool (bluish) and warm (reddish) lighting on participants’ core affect, was related to the affect states of P and AP. As can be seen in Figure 9, the participants felt happier and gladder (P), $F(1, 37) = 3.11$, $p = .08$ (a strong tendency to a significant effect), and more enthusiastic and peppy (AP), $F(1, 37) = 4.59$, $p = .04$, in the warm than they did in the cool lighting.

Insert Figures 8 and 9 about here

A multivariate significant main effect of Skill (Wilk’s Lambda = .40, $F(16, 56) = 2.04$, $p = .03$) associated with the UAP state ($F(2, 35) = 3.47$, $p = .04$), showed that the medium and high skill players felt calmer and more relaxed than the novice players did, independently of the lighting (see Figure 10).

Insert Figure 10 about here

Lighting evaluation

No influence of Skill was indicated, but a multivariate significant main effect of Lighting (Wilk’s Lambda = .18, $F(20, 130) = 8.74$, $p = .000$) associated with the cold (Greenhouse-Geisser = 84.23, $F(2, 72) = 34.72$, $p = .000$) and warm (Greenhouse-Geisser = 127.16, $F(2, 67) = 77.33$, $p = .000$) dimensions. As can be seen in Figure 11, the participants estimated the bluish (cool) maze lighting as significantly colder than the reddish one (warm) and vice versa on the warmness dimension.

Insert Figure 11 about here

Relation between affect and play performance. According to the results reported above, the participants performed best/fastest in the warm (reddish) vs. cool (bluish) lighting (see Figure 6) and they felt significantly more pleasant in the former vs. latter condition (see Figure 9). 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 (see Figure 1) 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 2), significantly associated with the pleased scale (see Table 3). This implies that the players accomplished the maze game as most fastest 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 7) and feelings of unactivated pleasantness, UAP (see Figure 10); 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 novice players' slower game performance.

Insert Tables 2 and 3 about here

Discussion

The general aim was to extend the experimental psychology findings on influences of physical, real world, surroundings on affect and cognition[33], and on influences of affect on cognition[34], to the digital game world. In line with that and with some results in non-visual lighting research[4,27,34,39] 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 resonance 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) vs. a cool (bluish) lighting (see Figure 6). This is in line with[28,39] who reported similar influences of indoor, general ceiling warm (reddish) vs. cool (bluish) lighting on participants' cognitive performance. It must be noted that we only measured the time it took to accomplish a maze game, not the operations of the underlying processes of spatial vision and cognition; which has as yet to be outlined in future studies. Still, our data show that the psychological processes involved in this type of digital game performance did work fastest in a warm (reddish) vs. 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 shown 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 9). In line with the Knez[4] suggested line of influence: lighting → affect → cognition, it was indicated that the pleasantness induced by a warm (reddish) lighting did improve the players' game performance in that condition (see Tables 2, 3). 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 (see Figure 11). 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 (see Figure 5) and that they most often choose the FPS and RPG types of game compared to the medium/low skill players who have broader preferences (see Table 1). Given their better skill, the high skill players were shown to perform significantly fastest in all three maze games (see Figure 7) and they felt significantly most calm and relaxed in doing that (see Figure 10).

As regards interactive media and game design, and game engine programming, our results suggest that simulated illumination can—in and of itself—influence the emotions of the player. Moreover, we have seen that warm and cool light have specific emotional effects upon emotion and performance. This suggests that players bring a base response with them into their experiences of virtual space, and that game designers can play off of those responses. We wish, however, to avoid simplistic claims about 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 larger patterns of feeling, thought and response that make up the game experience.

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Table 1: Types of digital games played by high, medium and low skilled players.

High skilled players	Medium and low skilled players
FPS (first person shooter) ca 80%	ACTION
RPG (role playing games) ca 20%	SPORTS
	RPG, RTS (real time strategy)
	FPS
	ADVENTURE
	CONSOL
	MUSIC GAME
	HEARTS
	MMORPGH
	SIM
	PUZZLE

Table 2: Influence of P state on player performance in warm (reddish) lighting (Regression/ANOVA).

Dependent variable	SS	df	MS	F	p
Mean-maze-time	68.71	6, 37	11.45	2.02	.09

Table 3: Influence of P state (scale: pleased) on player performance in warm (reddish) lighting (Regression model/Coefficient summary).

Dependent variable	R^2	B	Std. Error	Beta	t	p
Mean-maze time	.28	1.85	.67	.68	2.75	.01

Figure Captions

Figure 1: The affect circumplex space, with eight affect states represented by forty-eight adjectives: HA = High Activation; AP = Activated Pleasant; P = Pleasant; UAP = UnActivated Pleasant; LA = Low Activation; UAUP = UnActivated UnPleasant; UP = UnPleasant; AUP = Activated UnPleasant.

Figure 2: Neutral (grayish) lighting maze condition.

Figure 3: Cool (bluish) lighting maze condition.

Figure 4: Warm (reddish) lighting maze condition.

Figure 5 : Mean game-play-time (hours/week) in high, medium and low skilled players.

Figure 6: Mean maze-game-time in neutral, cool and warm lighting.

Figure 7: Mean maze-game-time in high, medium and low skilled players.

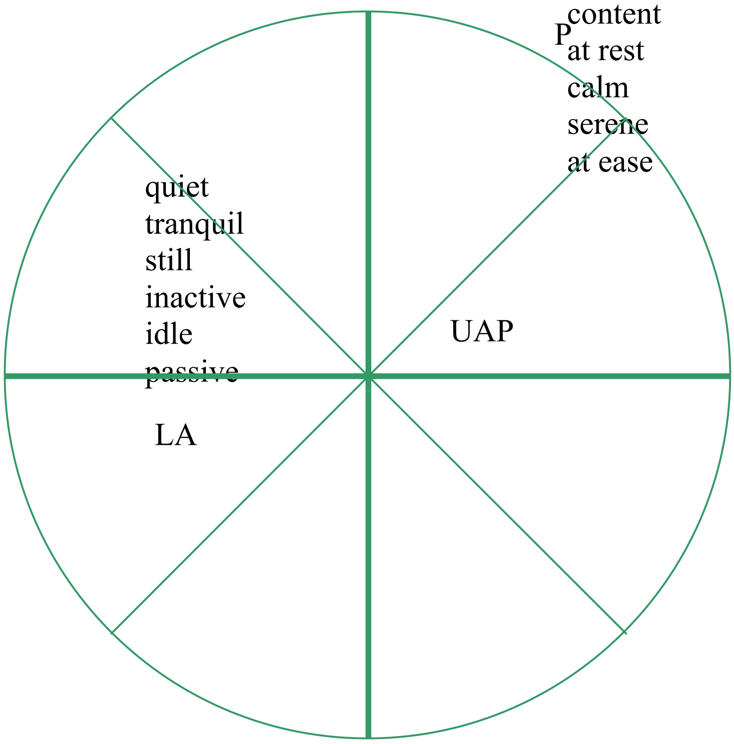
Figure 8: Mean affect (HA, LA, P, AP, UAP) in neutral, cool and warm lighting.

Figure 9: Mean pleasantness (P, AP) in cool and warm lighting.

Figure 10: Mean unactivated pleasantness (UAP) in high, medium and low skilled players.

Figure 11: Mean lighting evaluation (cold and warm) in cool and warm lighting.

Figure 1



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excited
euphoric
lively
peppy
happy
delighted
glad
cheerful
warmhearted
pleased
dull
tired
drowsy
sluggish
bored
droopy
UP
relaxed
content
at rest
calm
serene
at ease
P
quiet
tranquil
still
inactive
idle
passive
UAUP
UAP
LA

Figure 2 (Neutral)

Figure 3 (Cool)

Figure 4 (Warm)

Figure 5

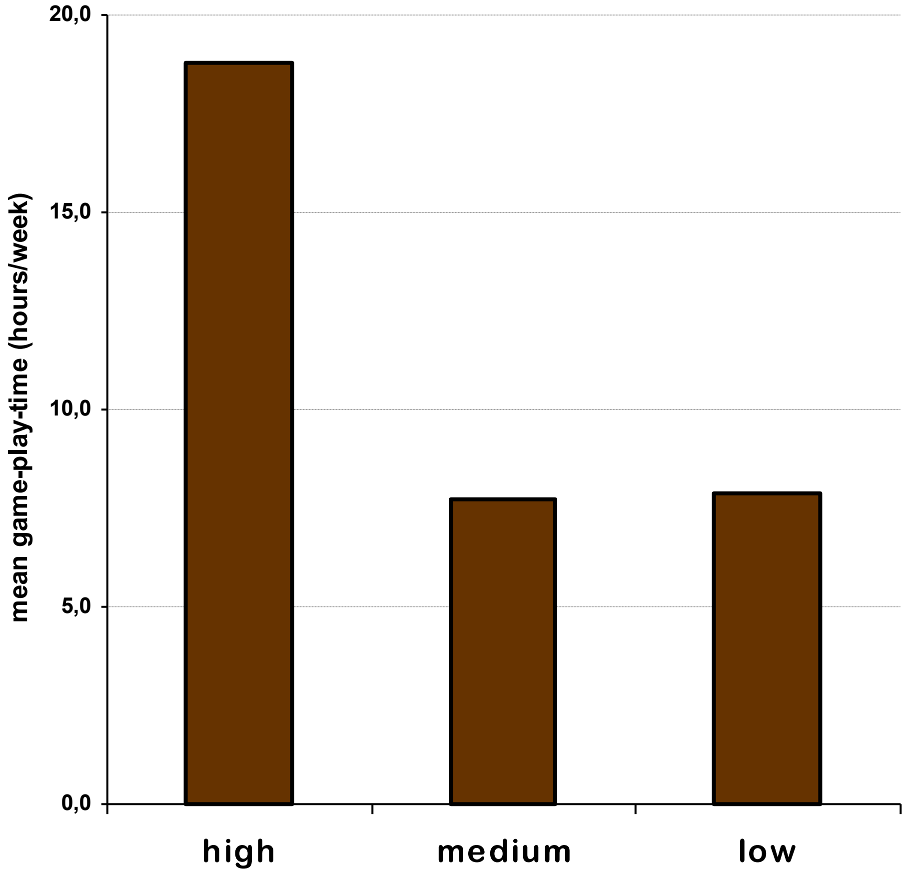

20,0
15,0
10,0
5,0
0,0
mean game-play-time (hours/week)
high
medium
low

Figure 6

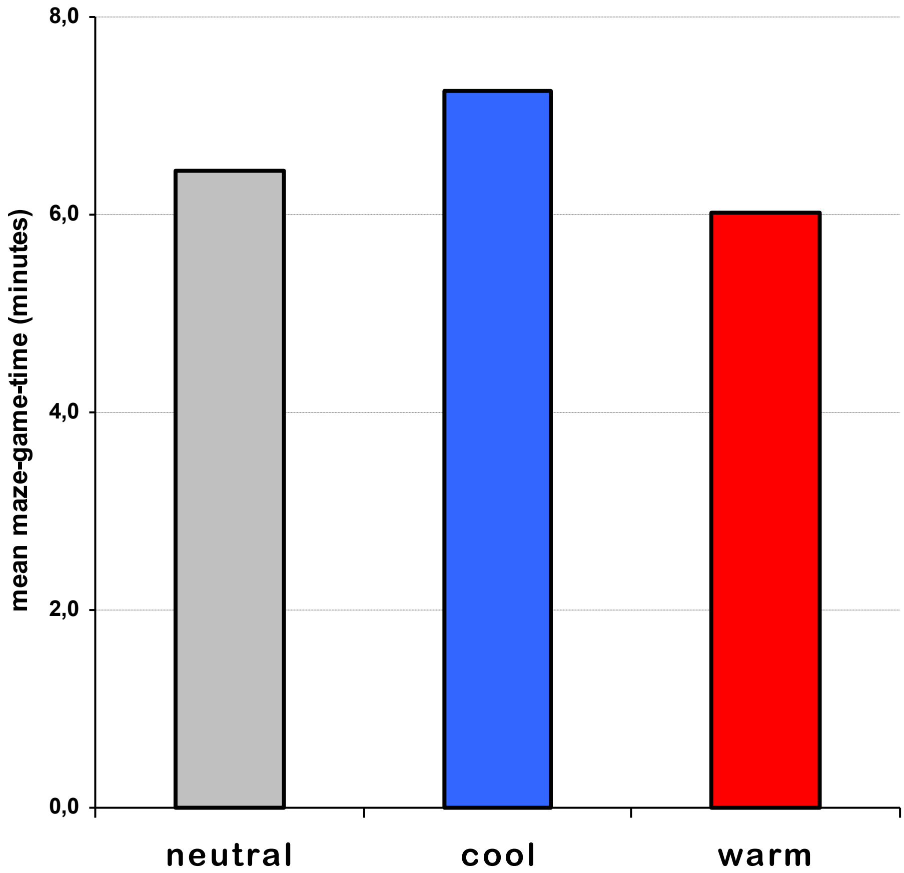


Figure 7

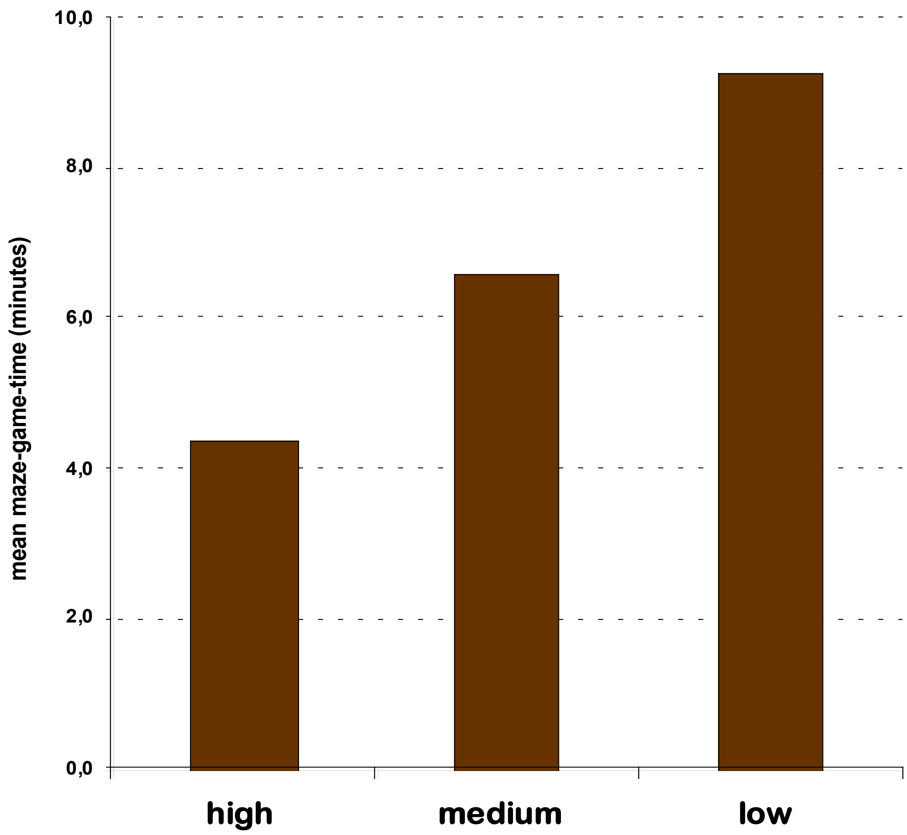


Figure 8

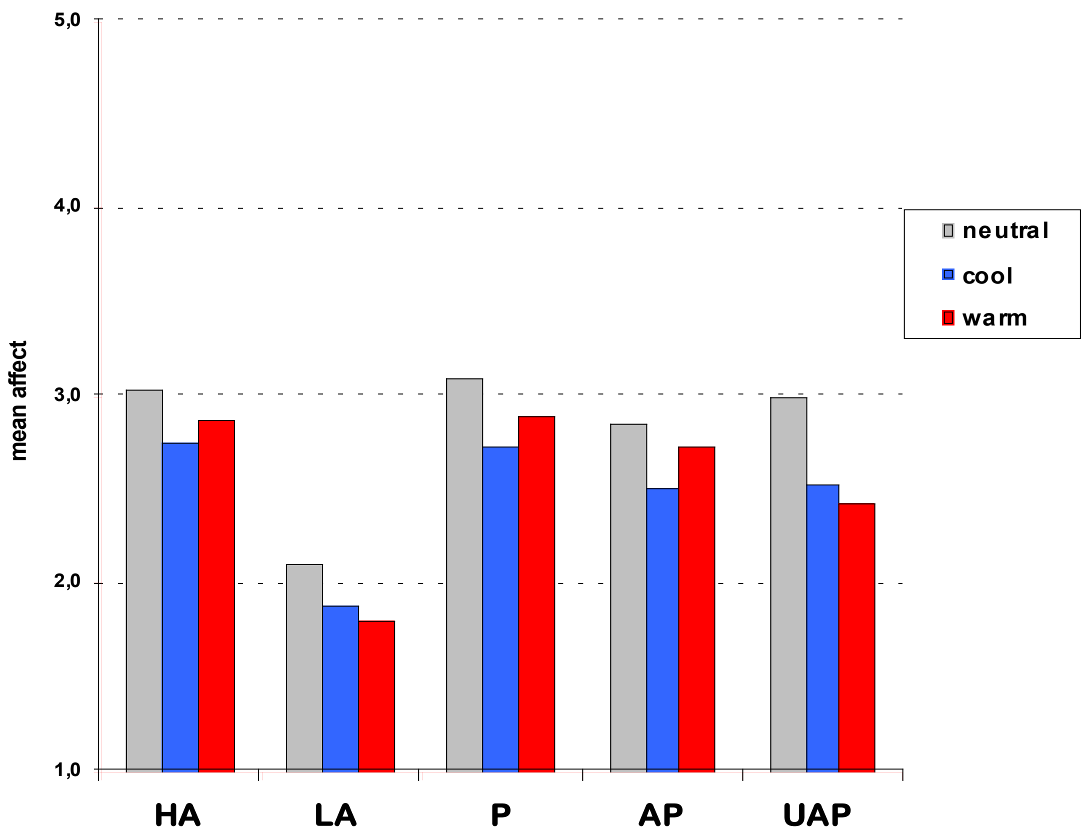


Figure 9

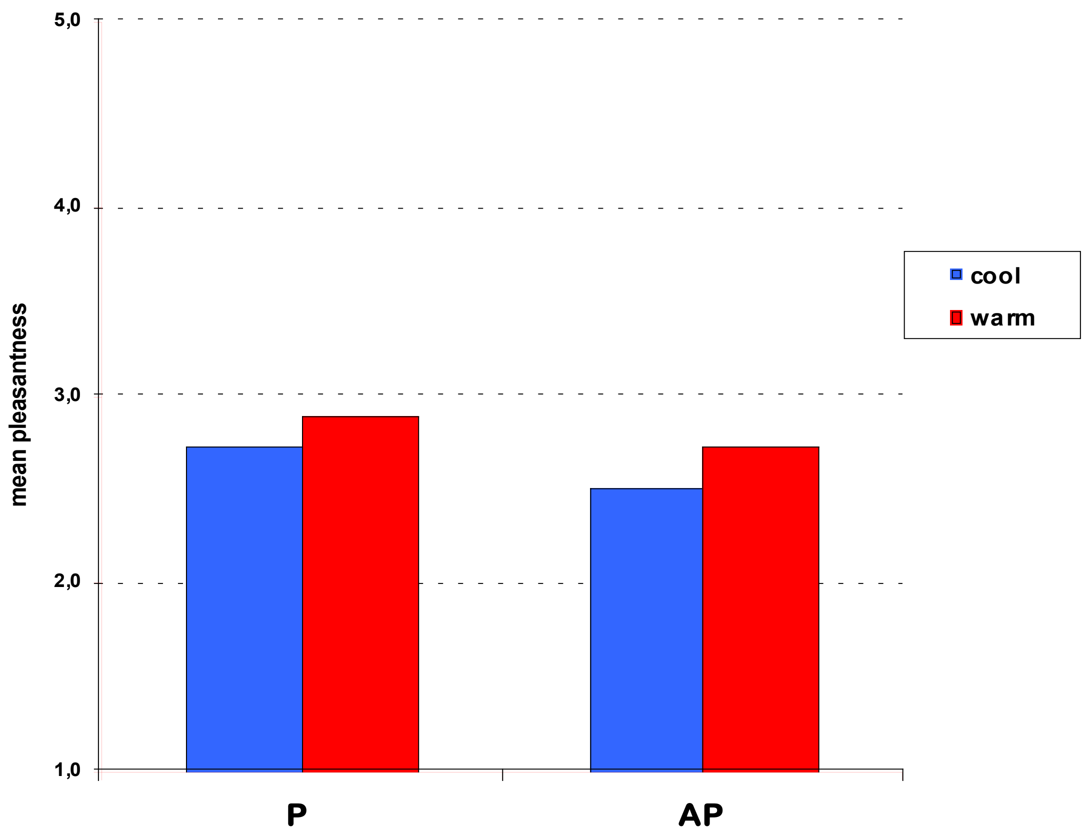


Figure 10

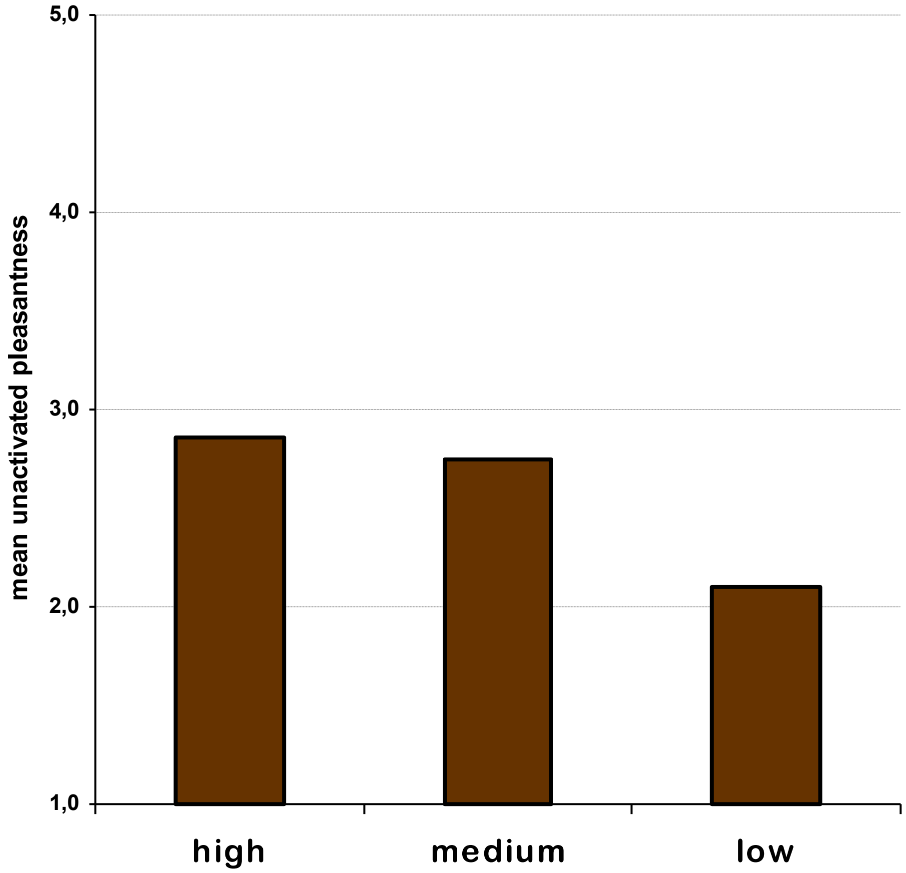
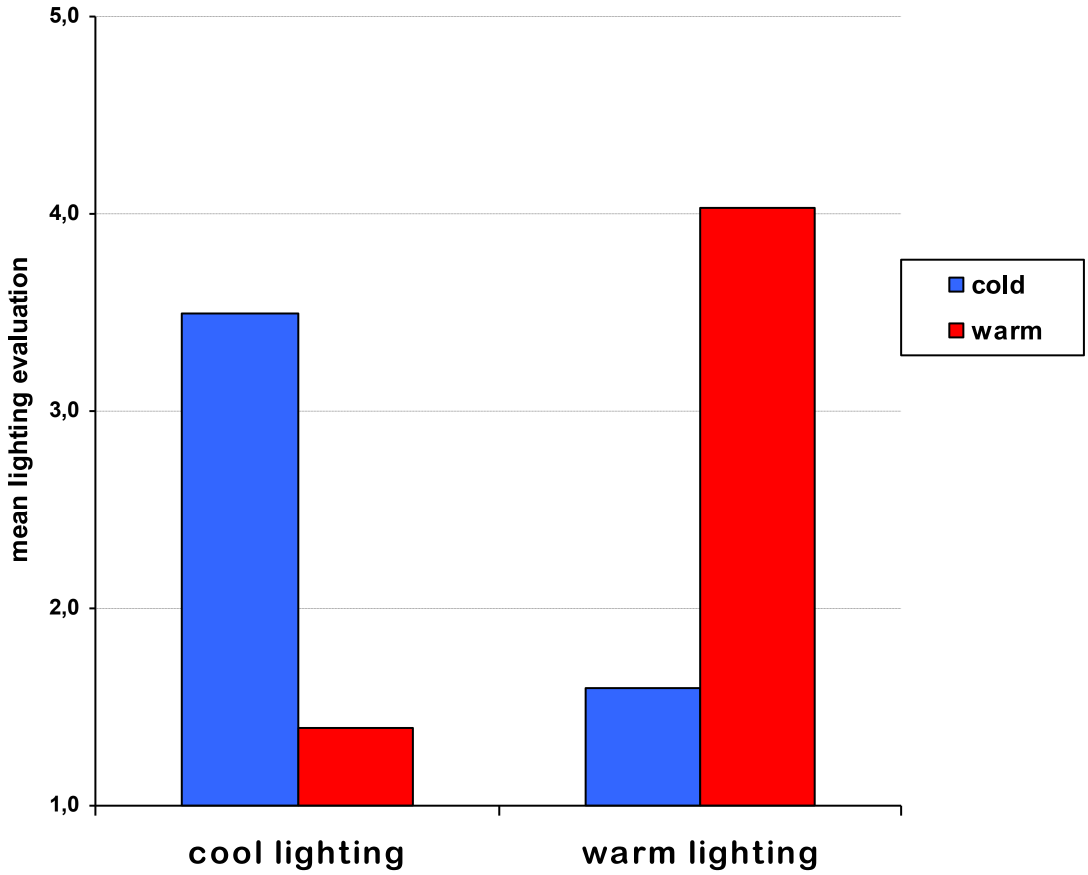

5,0
4,0
3,0
2,0
1,0
mean unactivated pleasantness
high
medium
low

Figure 11


5,0
4,0
3,0
2,0
1,0
mean lighting evaluation
cold
warm
cool lighting
warm lighting