The psycho-social influence of lighting.

an experimental proof of concept

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Lighting design could influence people in their social dimension, having indirect effects that occur through the perceptual pathway. According to cognitive-affective psychology, light influences the brain by sending visual messages which may influence people in affective, cognitive, associative and motivational ways. Through an experimental proof of concept, this research focus on the relationship between lighting variables affecting the psycho-social responses in terms of environmental atmosphere perception, social appraisal, prospect evaluation, and sociality. It emphasises the necessity of appropriate lighting design strategies to support the social dimension in socio-spatial contexts where collaboration and socialisation are essential for overall quality of life.

Keywords: lighting design; social appraisal; social behaviours; social proximity; atmosphere impression; prospect evaluation, territoriality perception.

Introduction

Studies related to lit interiors have already clearly established the relationship between light with visual performance and visual comfort to carry out visual tasks in an efficient, accurate and safe way (Boyce, 2003; Rea and Ouellette, 1991; Veitch and Newsham, 1998). More recently, human psychology has changed the focus of lighting research from visibility to the importance of lighting quality in interiors (Albert and Leung, 1998). In this regards, lighting presents visual indirect effects occurring through the perceptual pathway which are able to influence the human emotional, cognitive and behavioural responses and to affect health, positive mood and well-being (Boyce, 2004). The psychological mechanism of lighting is complex, due to the simultaneous

influence of the visual and non-visual pathway (de Kort, 2019) and is still an unresolved issue which seems to be overlooked in research studies (Kim, 2018; Veitch and Newsham, 1996), lighting has already been proven to add meaning to the space by sending visual messages which can be affective, cognitive, associative and motivational (Steidle & Werth, 2014; de Kort and Veitch, 2014; "Light + Behavior Symposium – Illuminating Engineering Society", 2014; Davis, 2013; de Kort, 2019). Lighting allows the environmental cognition; it influences the impression and the affective evaluation of the atmospheres of a space (Vogel, 2008; Flynn et al. 1973) by stimulating emotions (Tomassoni, Galetta and Treglia, 2015) and, as a contextual cue, it results in cognitive associations which may influence behaviours.

Lighting design and positive affection, social appraisal, social impression

In environmental psychology, social and behavioural processes are strictly linked to the physical setting (environment) and depend on socio-spatial contexts (de Kort, 2015). Research (Butler and Biner, 1987; Biner et al., 1989; Kobayashi, Inui and Nakamura, 2001) suggests that different social situations and environmental contexts require different lighting conditions which have similar trends of subjective preferences: bright uniform lighting for concentration, self-control and reflective regulation activities (e.g. working, studying); bright, non-uniform lighting for active, interpersonal and relaxed, casual behaviours (e.g. dining in a group, talking with family, receiving guests); dim/dark, non-uniform lighting for passive, self-centred and relaxed, casual behaviours (e.g. taking a break, relaxing) and for private/intimate social situations requiring low behavioural control (e.g. listening to music, thinking, talking with a friend, dining with a partner).

A lit environment with warm white and dim lighting levels may influence positive

affective responses which consequently could induce positive interpersonal behaviours in social situations such as evaluating an imaginary employee positively and enhancing collaboration (Baron, Rea and Daniels 1992). Lighting (warm white dim, warm white bright and cold white bright) may influence positive affect in terms of friendliness, helpfulness, trustworthiness and improve social perception and positive judgement of others (Kombeiz, 2017). In particular, the warm tonality of white lighting could limit anti-social and aggressive behaviours, reducing social distance and increasing the propensity for positive, social contacts (being nicer, smiling more, behaving more politely) compared to cold white lighting (Heijboer, 2013).

Lighting may also influence the social appraisal of an environment and the experience of the space regarding motivation, orientation, and mood (Flynn et al., 1973; Flynn et al., 1979). Specifically, luminance distribution and lighting levels send consistent visual messages that define the impression of a space that socially includes or excludes: warm lighting, a non-uniform distribution and up-lighting technique influence the impression of privacy and relaxation whereas a uniform lighting distribution with higher lighting levels defines an impression of publicness and tenseness (Flynn et al., 1973; Flynn and Spencer, 1977; Manav and Yener, 1999).

Lighting influences on social behaviours

Research shows that luminance distribution and lighting arrangements also influence social interactions and behaviours related to the prospect-refuge theory (Appleton, 1975). This theory states that people favour environments with unobstructed views, preferring to stay on the outskirts where they are able to easily observe their surroundings, feel a sense of concealment and retreat without being seen. In the lighting design domain, this theory was explored pivotally by Flynn et al. (1973), which proved

that people opt to face illuminated spaces rather than being under the spotlight. In addition, studies (Barazawa & Hanyu, 2013) suggest that, when two strangers are in a space, an individual could perceive the feature of prospect when the other person is in the light and refuge when in the dark. Otherwise, when conversing, people appreciate uniform lighting, which enhances social connection.

Lighting has also been found to influence interpersonal, verbal communication between individuals: when a person is lit with a direct spotlight technique, attention is driven towards him/her who then becomes less talkative (Magielse, 2014). Some studies reported conflicting results in terms of the relationship between lighting and conversational volume: students talking in a university corridor were quieter under dim and uneven lighting conditions and louder in brighter ones (Sanders, Gustanski and Lawton, 1974). Kobayashi (2013) reported that people spoke louder in a bright environment and quieter in a darker one. Differently, Veitch and Kaye (1988) reported decreased speech volume among students under higher lighting levels. Controversial results were also found in studies exploring the relationship between communication disclosure and lighting. In a study conducted by Gifford (1988), higher illuminance levels and a homelike setting increased both general and personal/intimate written communication with a known friend. Dim lighting conditions did not increase more intimate communication. Contrarily, in other studies (Miwa & Hanyu, 2006; Evensen, 2014), people were more talkative and disclosed more information in a dim lighting condition, as this is considered more pleasant and appropriate. Lighting should alter people's sense of personal space and closeness to others, influencing social spacing between individuals and territorial behaviours (Hall, 1992). An experimental study (Adams and Zuckerman, 1991) has demonstrated that, in lower lighting conditions, the required proxemics distances between individuals increase if compared to brighter

conditions. Research also claims that dark and dim lighting conditions have a positive influence on sociality and cooperation in that they reduce social distance. In private and intimate situations, dimmed lighting atmospheres enhance social proximity and define closer interpersonal distances (Sommer, 1969). In public situations, a completely dark condition was interpreted as an environmental cue of social distance and anonymity, leading to a compensatory, affiliative behaviour (Gergen, Gergen and Barton 1973); dim lighting enhanced prosocial behaviours (Werth, Steidle and Hanke 2012; Steidle, Hanke and Werth 2013), favouring positive interpretation of a social situation which promotes interpersonal closeness and collaboration in conflictual situations (Kombeiz, Steidle and Dietl, 2017). Contrasting results are given in other studies (Zhong et al., 2010; Tane & Takezawa, 2011), where darkness and dimness influence the impression of anonymity, isolation, and disinhibition, by enhancing more self-interested, dishonest and egocentric behaviours; brighter lighting motivates to behave according to socially accepted rules (Steidle and Werth, 2014). If dimness is considered more intimate and preferred in situations requiring a high level of intimacy, it is considered inappropriate and uncomfortable among nonintimates, who consequently show a series of compensatory non-verbal behaviours to re-establish proper psychological distance (Carr and Dabbs, 1974). Kobayashi (2013) noted that darker conditions influence non-verbal communication such as eye contact and social proximity (leaning forward and toward posture) with some differences between sexes: from a wide to a narrow spotlight, men showed the tendency to shorten the distance with the other person, whereas women adjusted the direction of their bodies toward the other person.

Aim and scope

Table 3 summarises the literature review in a schematic fashion, describing the degree of effort that has been undertaken in the study of lighting effects on behavioural

outcomes. Empty cells in the table reveal areas in which there is too little evidence, or none at all, to reach any conclusion. A considerable effort of behavioural research will be necessary in order to identify the best luminous conditions for the broad range of important behavioural outcomes. As yet, only general statements about lighting quality are possible, and there is more disagreement than agreement about many dimensions, within the scientific community and between recommended practice and the scientific literature.

Findings in the literature review state that lighting could play a part in positively influencing both the impression of the luminous atmosphere and social appraisal, along with social impressions, hence driving social behaviours. Particular lighting conditions such as correlated colour temperature (CCT), lighting distribution in the environment (uniform and non-uniform lighting), and lighting levels (dark, dim, bright) have already been tested with different methodologies in relation to the psycho-social effects on individuals. However, controversial and contrasting correlations have been found in many studies, and these results also depend on specific personal, contextual and social factors, other than solely the experimented lighting design conditions. Little is yet established and known concerning the interplay between lighting conditions affecting the psycho-social response of individuals. The majority of research on lighting has looked at interior environments (e.g., offices, classrooms, counsellor rooms, coffee shops and restaurants) by focusing on visual attributes of space to improve productivity and the mood of individuals. Meanwhile, fewer studies have performed experiments exposing subjects to different lighting conditions, analysing specifically the subjective effects on sociality. Moreover, some of the reviewed studies lack a proper characterisation of the luminous environment, which is required to represent reliable luminous conditions to be compared to realistic situations or to be replicated in other

studies (Tiller, 1990). As a consequence, this study attempts to explore, in a real case study and through an experimental subjective evaluation, the influence of different (measured and characterised) lighting conditions in creating a positive social atmosphere which affects sociality. Accordingly, the following research questions were set:

- Could different lighting design conditions influence individuals in terms of environmental atmosphere perception and lighting appearance?
- Could different lighting design conditions influence individuals in terms of social appraisal, prospect evaluation, and sociability?

In this paper, the term sociability refers to the ability to engage in conversation comfortably, by setting a comfortable, luminous environment. Additionally, this study aims to understand the affective, cognitive and behavioural effects of lighting on individuals, by considering the contribution of social factors such as acquaintance and gender.

Methodology

The experimental research was conducted following these sequential phases: (i) design and prototype of an experimental lighting fixture for setting up different lighting design alternatives for the experimental test; (ii) objective characterization of environmental lighting quality by physical measurements of Spectral Power Distribution (SPD), Luminance and Illuminance of the four alternative lighting conditions; (iii) experimental subjective assessment: tests were run with four alternative lighting scenarios different in terms of CCT and lighting distribution; (iv) data collection through the administration of questionnaires for five experimental factors: Environmental Atmosphere, Lighting Appearance, Social Appraisal, Prospect

Evaluation and Sociability (v) statistical analysis of obtained results of questionnaires, (vi) extraction of insights by comparing the results to the qualitative assessment and to the available literature review. Figure 1 represents the flowchart of the research methodology.

Figure 1: Flowchart of the research methodology

Description of the experimental room

The experiment was conducted in a full-scale space, arranged in a laboratory room located in the Design Department of the Politecnico di Milano. The room measurements were 4m x 6m with a height of 2.9m (false ceiling). Walls and ceiling were white, and the 30cm x 30cm ceramic-covered floor tiles were medium grey (20% light reflectance). The room interior reflectance was overall constant, and there was no glare. Environmental conditions such as air temperature, humidity, furniture, and layout were kept almost constant. The windows were obscured in order to prevent the influence of natural light and to ensure standardised artificial lighting conditions during the experiments. As evident from the plan (Figure 2a) and the side elevation layout (Figure 2b) of the experimental room, the room was left intentionally unfurnished with only a pair of office rolling chairs to seat two participants at a time. The lighting was provided by a prototypal LED-based lighting fixture, installed as a suspension in the room.

Figure 2: Plan (a) and side elevation (b) of the experimental room

LED lighting prototype and lighting conditions alternatives

The prototypal lighting fixture was designed, built and set with four modular lighting engines: (i) cold CCT module for direct lighting distribution (calculated luminous flux of 1720 lumen @85°C driven @ 1A); (ii) warm CCT module for direct lighting distribution (calculated luminous flux of 1480 lumen @85°C driven @ 1A); (iii) cold CCT module for indirect lighting (calculated luminous flux of 1064 lumen @85°C

driven @ 700 mA); (iv) warm CCT module for indirect lighting (calculated luminous flux of 760 lumen @85°C driven @ 700 mA). Using rapid prototyping techniques to produce the mechanical parts, the different lighting engines were assembled with their heatsink and secondary optics. The LED lighting engines were hidden inside a white plastic lampshade aimed to prevent direct glare, to provide housing for the lighting modules and to create a familiar luminous shape. Four lighting conditions were set up and tested (Figure 3(a)):

- C1- Direct-indirect Cold CCT;
- C2 - Direct-indirect Warm CCT;
- C3-Direct Warm CCT;
- C4-Direct Cold CCT.

The lighting conditions were manually and remotely set by the researcher, using a platform interface which was prototyped with an Arduino. Measurements of CCT, SPD (Spectral Power Distribution), chromatic rendering index (R_a) and horizontal Illuminance E_h (lux) were taken at a distance of 0.8m from the floor (point A in Figure 2b). Vertical Illuminance (at the eye) E_{eye} (lux), SPD, CCT, R_a were measured in point B and C at a distance of 1.2m from the floor (Figure 2b): these points were 0.8m away which is the distance between two participants in a condition of Personal Space (Hall, 1992). These measurements were performed with a portable Illuminance Spectrophotometer CL-500 by Konica Minolta and are summarised in Table 1. From the measurements, it is evident that the perceived CCT and SPD at the E_{eye} change in every lighting condition and depend not only from the features of the LEDs but also from the inter-reflection of the lighting on the surfaces of the experimental room. This is particularly evident with the divergent CCTs of the cold white lighting conditions: the

direct/indirect lighting condition (C1) presents a neutral CCT of 4487K measured at the eye level; the cold direct lighting (C4) reports a CCT of 5096K. The study of the influence of different luminous atmospheres on sociality was focused on two alternative lighting distributions (direct vs direct/indirect) rather than on assessing different lighting levels (low vs high illuminance values). Therefore, the two direct/indirect lighting conditions (C1 - C2) and the two direct lighting conditions (C3 – C4) were set up to present approximately the same lighting levels between conditions with the same CCT (E_h = 508-536 lux @ cold CCT and E_h = 370-387 lux @ warm CCT). Compared to previous studies which used extreme illuminance values for the experiments (Baron, Rea and Daniels, 1992; Kombeiz, 2016; Steidle, Hanke and Werth, 2013), a narrower and standard range of investigated illuminance levels was selected (300-500 lux measured on the virtual horizontal surface of a table). Similarly, a more realistic range of CCTs was selected and tested: the warmest CCT @E_{eye} was 2917K (C3) and, the coldest CCT @E_{eye} was 5096K (C4) (Table 1). Luminance was evaluated with a Luminance-meter LS-100 by Konica Minolta and a camera Canon Eos 550D equipped with a standard lens (18-55mm) (Inanici, 2006). Image elaboration such as calibration of HDR images and definition of luminance images was performed with Luminance HDR (2019) and HdrScope software (Kumaragurubaran and Inanici, 2013). HDR images (Figure 3a) and Luminance images (Figure 3b) are useful to understand the lighting distribution of the luminous atmosphere for each lighting condition: direct lighting conditions (C3- C4) define a high contrast and focused luminous situation whereas direct/indirect lighting conditions (C1-C2) define a uniform and diffuse luminous atmosphere. In addition, figure 3c shows some frames captured with a hidden video-camera during the experiment.

Figure 3: HDR photographic image (a) luminance image (b) and image taken during the experiment with an hidden video camera (c). The alternative lighting conditions in the experimental room, from left to right C1 – C2 – C3 – C4

Experimental tests – subjective data collection

The experimental study focused on collecting data regarding the psycho-social influence of different lighting conditions. A survey was prepared and administered to each participant for every lighting design condition. The outputs of the experimental analysis were investigated both statistically and qualitatively in terms of five factors: Environmental Atmosphere, Lighting Appearance, Social Appraisal, Prospect Evaluation, and Sociability. Statistical analysis was performed using STATA 15 software.

Participants and procedure of the experimental tests

The experimental test was applied to 20 voluntary participants (5 males and 15 females) which were divided into 10 couples: 5 male/female couples (MF group) and 5 female/female couples (FF group). Furthermore, participants were selected in order to have 5 unacquainted couples and 5 acquainted ones. Ages ranged from 21 to 34 years old ((M = 23.7, SD = 5.57). Nationality was 80% Italian, 10% Pakistani, 5% from Montenegro and 5% Egyptian. Participants were healthy individuals and wore, if needed, visual aids such as glasses or contact lenses to ensure adequate visual performance. The guidelines from the Code of Human Research Ethics by The British Psychological Society (2014) were followed. All experiments were conducted starting at the same time of day, between December 2017 and February 2018: the duration of each experimental session was 60 minutes on average.

The recruited participants were invited, in pairs, to join the experiment and, after administering and completing the informed consent document, they answered a demographic questionnaire (age, gender, acquaintance with the other participant). Subsequently, they entered the experimental room and were asked to sit on the rolling

chairs, to feel at ease, to feel free to move in the space and to engage in a series of non-controversial conversations on four different topics, randomly administered: A: activities to do during the holidays, B: desired country to visit, C: favourite season, D: favourite hobby. The order of the presentation of the four luminous conditions changed for each experimental session to counterbalance sequence and dark/light adaptation effects (Table 2). The length of the presentation of the four luminous conditions depended on the conversation duration and was enough for lighting adaptation. At the end of the conversation for each luminous condition, each participant was given the questionnaire (in English). All participants were given further explanations and details if doubts occurred.

Questionnaire design

The experimental questionnaire consisted of a set of items to quantitatively investigate, for each alternative lighting condition, luminous environmental atmosphere, lighting appearance, social appraisal, prospect evaluation, and sociability. Additionally, a final part focused on exploring evoked social behaviours. Firstly, participants rated, on a five-point Likert scale, the luminous atmosphere impression (Flynn et al.,1979 ; Vogel, 2008) on the following: “pleasant – unpleasant”, “confined – spacious”, “comfortable – uncomfortable”, “lazy – energetic”, “irritating – relaxing”, “hazy – visually clear”, “simple – complex”, “formal – casual”, “quiet – lively”. Participants were also asked to rate the following lighting appearance evaluation on a five-point Likert scale: "dark – bright", "warm – cold". The third part investigated social appraisal, prospect evaluation and sociability (Barazawa and Hanyu, 2013): participants rated, on a five-point Likert scale, the following: "public – private", "unsociable – sociable", "favourable – unfavourable". Prospect and sociability factors included: "I can observe the state of the other person”, “I can observe the eyes of the other person”, “I can get information of the

surroundings", "I can carry on a conversation easily". The final part of the survey included a section which explores whether people consistently think about similar types of activities and behaviours in different lighting conditions: participants were asked to complete a blank space with behaviours and activities which were evoked by the luminous conditions (Butler and Biner,1987; Biner et al.,1989; Kobayashi, Inui and Nakamura, 2001): "Write down the first three activities that come to mind with this lighting atmosphere". An example of the experimental questionnaire is given in Appendix 1.

Statistical analysis methodology

The dataset derived from the survey was preliminarily verified for the normality of data through a Shapiro-Wilk Test to examine the statistical phenomenon of the study correctly. Even though the number of participants was limited, a level of significance of 1% was found, allowing to conduct the parametric analysis (T-test, ANOVA and F-test). Cronbach's alpha was performed to validate the questionnaire and obtained the value of 0.9 which states the high reliability of the study.

Results of statistical analysis of the questionnaire

Statistical analysis results in terms of the psycho-social influence of lighting design

The first elaboration of data extracted from the questionnaire was performed to define how lighting conditions influence the five factors. Lighting conditions were analysed singularly (Table 4) and also paired by CCT (Warm lighting C2 - C3 vs Cold lighting C1 – C4) and lighting distribution (Direct/Indirect lighting C1 - C2 vs Direct lighting C3 – C4) (Table 3).

Warm white lighting (C2 - C3) vs Cold white lighting (C1 – C4)

The impression of the tonality of lighting being warm or cold in relation to the different CCTs was found statistically significant: C2-C3 lighting conditions were perceived as warmer (μ =1.93) than C1-C4 which were perceived as colder (μ =4.23, t = -11.2032, p = 0.0000). Cold lighting was perceived as unpleasant (t = -3.2704, p = 0.0016) and more energetic compared to warm lighting which defined the environmental atmosphere as lazier (t = 2.6716, p = 0.0092), more relaxing (t = -3.9262, p = 0.0002) and more casual (t = -3.0627, p = 0.0030). As for the social appraisal assessment, the environment with warm lighting was evaluated more sociable (μ = 2.53, t = -2.5205, p = 0.0138) and more favourable in inducing socialization (μ = 2.63) versus the cold lighting atmosphere (t = -2.4241, p = 0.0177) (Table 3).

Direct/Indirect Lighting (C1 - C2) vs Direct Lighting (C3 – C4)

The impression of darkness or brightness in relation to the different lighting distributions was found statistically significant: direct /indirect lighting conditions were perceived as brighter ($\mu = 3.35$) than direct lighting conditions ($\mu = 2.4$, $t = 3.3874$, $p= 0.0011$). The direct lighting conditions were associated with the impression of an unpleasant ($\mu = 3.3$, $t = -2.6171$, $p = 0.0106$), confined ($\mu = 4.15$, $t = -8.1015$, $p = 0.0000$) and uncomfortable atmosphere ($\mu = 3.38$, $t = -2.4551$, $p = 0.0163$). Conversely, the brighter lighting appearance of the direct/ indirect lighting conditions was associated to a visually clean impression ($t = -5.6019$, $p = 0.0000$) and a more lively atmosphere ($t = 2.2916$, $p = 0.0246$). The environment was considered more formal ($t = -2.1860$, $p = 0.0318$) and more private with direct lighting ($t = -6.1369$, $p = 0.0000$). The direct/indirect lighting distribution was considered more sociable ($t = -2.3127$, $p = 0.0234$), giving the participants a higher prospect (Stamps, 2006) and sense of

cohesiveness: it increased the opportunity to watch both the other person's eyes and the surroundings ($p \leq 0.001$). The direct/indirect lighting distribution increased sociability, by supporting and easing the conversation between participants ($t = 2.3291, p = 0.0224$) (Table 3).

Comparison between the four lighting conditions C1 – C2 - C3 – C4

The analysis of the impact of lighting on the perception of the environment and sociality was performed considering the four lighting conditions individually. Table 4 shows that some differences on average (Test F) are characterised by statistical significance. Participants found that lighting condition C1 (cold CCT - direct / indirect) defined the most spacious *($p \leq 0.001$)*, visually clean *($p \leq 0.001$)*, energetic *($p \leq 0.05$)* and public *($p \leq 0.001$)* environmental atmosphere, with the brightest *($p \leq 0.001$)* lighting appearance and highest achieved prospect of the surroundings *($p \leq 0.001$).* In lighting setting C2 (warm CCT - direct/indirect), environmental atmosphere was perceived as the most pleasant *($p \leq 0.001$)*, comfortable *($p \leq 0.001$)*, relaxing *($p \leq 0.001$)* and casual *($p \leq 0.001$)*. Therefore, C2 was also the most sociable ($p \leq 0.001$) and most favourable ($p \leq 0.05$) in terms of social appraisal: it was the condition where participants found the highest prospect by observing each other's states and eyes ($p \leq 0.001$). Lighting setting C3 (warm CCT - direct) determined an environmental impression of highest confinement *($p \leq 0.001$)* with an atmosphere perceived as relaxing ($p \leq 0.001$), lazy *($p \leq 0.05$)* and private *($p \leq 0.001$)*. The luminous appearance of C3 was also found as the darkest *($p \leq 0.001$)* and the warmest *($p \leq 0.001$)* compared to the other ones. Participants found lighting condition C4 (cold CCT - direct) as the most unpleasant *($p \leq 0.001$)*, uncomfortable ($p \leq 0.001$), irritating *($p \leq 0.001$)*, hazy *($p \leq 0.001$)* and formal ($p \leq 0.001$) with regards to environmental atmosphere impression. The luminous appearance was also found as the coldest *($p \leq 0.001$)*. Therefore, C4 was perceived as

the most unsociable *($p \leq 0.001$)* and unfavourable *($p \leq 0.001$)* for social appraisal, by also giving the least prospect in terms of people's face and eye observation *($p \leq 0.001$)* and in terms of gathering information from the surroundings *($p \leq 0.001$)*.

Statistical analysis results in terms of the psycho-social influence of personal factors: gender and acquaintance

Gender: FF groups and MF groups

As a personal factor, gender may affect social appraisal and socialisation. An a priori comparison between the FF and MF group in relation to gender composition was performed: the only difference between the two groups was greater prospect perception in watching the state and eyes of the other person in the FF group. Accordingly, data were analysed to understand if people of the same gender (FF group) or mixed gender (MF group) reported a different perception of the five factors concerning CCT and lighting distribution. The elaboration from the T-test (Table 5) shows that participants in the FF group perceived a greater sense of unpleasantness *($p \leq 0.001$)*, discomfort *($p \leq 0.001$)*, irritation *($p \leq 0.001$)*, haziness *($p \leq 0.05$)* and formality *($p \leq 0.001$)* under cold CCT, which was also perceived as unsociable *($p \leq 0.001$)* and unfavourable for socialization *($p \leq 0.001$)*. Differently, participants in the MF group found that cold lighting defined a more lively *($p \leq 0.001$)* and brighter *($p \leq 0.05$)* atmosphere versus warm lighting which determined a greater sense of confinement *($p \leq 0.05$)* and privacy *($p \leq 0.001$)*. Elaboration from the T-test (Table 6) shows that direct lighting conditions further increased the perception of unpleasantness *($p \leq 0.001$)*, discomfort *($p \leq 0.05$)* and formality *($p \leq 0.05$)* for the MF group. Mixed couples perceived a greater sense of social appraisal *($p \leq 0.05$)*, sociability *($p \leq 0.05$)* and brightness *($p \leq 0.001$)* under the Direct / Indirect lighting mode. Both MF and FF groups perceived the Direct / Indirect lighting

with a higher prospect factor (*p≤0.001*), defining the environmental atmosphere as more spacious, visually clear and less private (*p≤0.001*), in contrast to direct lighting conditions.

Closeness and acquaintance

Through an a priori comparison between acquainted and unacquainted couples, the study investigated if the level of familiarity between the participants in the couple could influence the perception of the five factors. Participants in the acquainted pairs reported the highest perception of brightness *(μ = 3.23; p≤0.05)* and a better view of the other's state and eyes *(p≤0.05)* compared to the unacquainted ones. Moreover, as expected, with reference to sociability, people in the acquainted couples were more easily conversational *(p≤0.05)*. The elaboration from the T-test (Table 7) shows that cold lighting was perceived as unpleasant and irritating by both acquainted and unacquainted couples, but was evaluated more uncomfortable and unfavourable in terms of socialisation, only by the acquainted ones. Direct lighting increased the perception of unpleasantness *(p≤0.001)*, discomfort *(p≤0.05)* and formality *(p≤0.05)* for the acquainted couples who also found the Direct/Indirect lighting conditions quieter *(p≤0.05)* (Table 8). In relation to direct lighting conditions, the two groups showed the same perception of confinement *(p≤0.001)*, haziness *(p≤0.001)* and privacy *(p≤0.001)*; whereas, in relation to direct/indirect lighting conditions, they shared the same perception of brightness and a greater sense of general prospect (ability to see people's state, eyes, and surroundings) *(p≤0.001)*. Conversely, no statistically relevant difference was found for social appraisal and sociability.

Results of qualitative analysis: described activities and social appraisal

For each lighting condition, all participants were asked to mention the activities that

could be associated, based on previous experiences and cultural background, to the lighting atmosphere they were exposed to. Their answers were categorized in semantic groups to explore the activities and behaviours associated with specific lighting features: mental (e.g. working and studying), tense (frightening and activities which create anxiety), socialization (e.g. being with friend, conversing), relaxing (e.g. sleeping, meditating), leisure (e.g. eating and dancing) and sport activities (e.g. walking and practicing sports).

The majority of mental activities were reported with cold direct/indirect (29%) and with warm direct/indirect lighting conditions (33%), presumably indicating a preference for perceived higher brightness for visual performances. Differently, tension and anxiety-provoking activities were evoked prevalently (35%) under cold lighting conditions (C1-C4). Cold CCT evoked high-level visual task activities (31% with C1 and 28% with C4) and inspired ones linked both to concentration (positive mood) and tenseness (negative mood). The lighting condition of warm direct/indirect lighting (C2) evoked more leisure activities (45%), insomuch as warm, direct lighting (C3) evoked more relaxing activities (56%), which were both low-level visual tasks (41%). Warm CCT elicited socialisation activities: 29% with the direct/indirect lighting condition C2 and 35% with the direct lighting condition C3 (Table 9).

Conclusions

This study aims to underline the importance and influence of lighting parameters on the perception of the luminous environmental atmosphere as well as on social appraisal, prospect evaluation, and sociability. More than a solely stimulus-response for vision, lighting may send visual messages which may involve thinking (cognitive process), emotions (affective process) in addition to motivation and purposeful behaviours. The

research focuses primarily on the influence of lighting design on human psychology in terms of social-affective, cognitive and psycho-social behavioural effects. Guided by a cognitive-affective, socio-cultural and environmental perspective, the purpose of the study was to investigate the influence of two lighting parameters, CCT, and lighting distribution, on the sociability of couples engaged in conversations. Besides the lighting parameters, it demonstrates that social factors also positively affect the sociability of people, particularly when close and already acquainted. The gathered insights are useful to support lighting practitioners in design decisions within socio-spatial contexts where collaboration and socialisation are essential for overall quality of life and where the co-presence of multiple people performing mental and relaxing activities is an important issue. The social influence of lighting should be considered both in the research and design of lighting conditions which foster social appraisal, socialisation, and social behaviours.

This experimental study based on subjective assessment found that lighting may be adjusted to support different social relationships (at least between two individuals) to negotiate the impression of space and improve sociability during the conversation. These results emerged from the statistical elaboration of data derived from the questionnaires and the qualitative analysis of the open answers. Through the qualitative and quantitative elaborations of data, results showed high deviations and interesting statistical relevance of 1% and 5% concerning environmental atmosphere, social appraisal, lighting appearance, prospect evaluation, and sociability.

Specific lighting parameters were found able to foster social atmospheres: as to CCT, warm white lighting was perceived as defining a more relaxing atmosphere, and creating a more sociable and favourable impression for socialization compared to cold white lighting, which was considered unsociable and unfavourable for socialization,

particularly within the homogeneous (FF) group and the acquainted couples. These findings complement and confirm previous studies with reference to the effects of warm white lighting on sociality (Baron, Rea and Daniels 1992; Heijboer,2013; Kombeiz et al., 2017). By extending the literature review as to the subjective preferences of lighting in specific social-spatial contexts, and with specific activities (Butler and Biner, 1987; Biner et al., 1989; Kobayashi, Inui and Nakamura, 2001), the qualitative results of this study confirm that cold white lighting evokes activities connected to concentration (positive mood), tenseness (negative mood) and high-level visual tasks. Warm, white lighting (2900K-3000K), evokes casual activities, either practiced individually (relaxing activities) or with others (leisure activities), supports socialisation and sociability and is also associated with low-level visual tasks. A different luminous, atmospheric impression between genders was evidenced with different CCTs: people in the MF group found that cold lighting defined a livelier and brighter atmosphere in contrast to warm lighting which determined a greater sense of confinement and privacy while the FF group found cold CCT as unpleasant, uncomfortable, irritating, hazy and formal.

In relation to lighting distribution, direct/indirect lighting contributed to define a positive impression of the luminous atmosphere of a space, providing a visually clean, brighter and livelier environment, which is also preferred to direct lighting distribution as reported in previous studies in office settings (Houser et al., 2002; Boyce et al., 2006; Veitch and Newsham, 2000). Other than having a substantial impact on the impression of social appraisal, prospect evaluation and sociability, a direct/indirect lighting condition defined a more sociable atmosphere, giving the participants a higher prospect and a sense of cohesiveness. Direct/indirect lighting allows watching the other person's state and eyes as well as the surroundings, regardless of social factors of gender and acquaintance. This findings agree with the ones reported in the studies of Barazawa and

Hanyu (2013). The uniform, luminous atmosphere achieved with direct/indirect lighting serves to create an evenly lighting distribution, without harsh shadows, on people conversing together in a space and is preferred for enhancing conversation and achieving a sense of inclusion, unity, and connection while performing interpersonal activities (leisure and socialisation). Conversely, direct lighting conditions isolate individuals in the conversation by setting a focused lighting distribution and create a more private and confined environment which best suits relaxing and solitary activities.

The participants showed a strong preference for warm CCT and direct and indirect lighting distribution (C2) perceived as the most pleasant, comfortable, relaxing and casual lighting strategy. Therefore, this lighting condition was perceived as the most sociable and favourable in terms of social appraisal, achieving the highest prospect by observing each other's states and eyes. On the contrary, cold CCT and direct lighting distribution (C4) was perceived as the most unpleasant, uncomfortable, irritating, hazy, formal, and coldest condition with regards to environmental atmosphere perception. Hence, it was discerned as the most unsociable and unfavourable for socialisation and gave the least prospect in terms of people's state and eye observation in addition to information gathering of surroundings. Accordingly, by using an appropriate lighting design strategy, it is possible to increase the positive impact of an illuminated environment to enhance sociality among people. The obtained data present practical implications for architecture and design of social atmospheres inside public areas such as workspaces in offices, schools, and universities (e.g., public library, open space office, workshop classroom). The results of this study could provide practical design guidance for architects, interior and lighting designers which will help them develop new lighting design solutions that take into account the psycho-social effects of lighting. Non-uniform lighting conditions such as direct lighting may be used to virtually

separate individuals in the same space, to perform individual, mental and concentrated activities and to enhance territorialization. Diversely, uniform lighting, through the use of direct/indirect lighting conditions, may be employed to increase prospect, enhance cohesion between interacting individuals and improve collaboration and socialisation. Warm CCT may support relaxing and casual exchanges between people whereas cold CCT, mental concentration.

These conclusions are limited by the fact that the study was performed in a controlled laboratory setting and not in a real-life context: this research could further be extended to consider an installation in a real socio-spatial context for future investigation. Moreover, the study does not allow to generalise the gathered insights onto the overall population in different age ranges: the results only refer to a population between the ages of 21 and 34 years old. In addition, the majority of the participants were Italian, and the rest had mixed cultural backgrounds. This unbalanced distribution did not permit to analyse the phenomenon of the social influence of lighting among different cultures. As a future study, participants from a broader age sample and different cultures should be analysed to understand if personal and cultural factors affect the impression of social appraisal and sociability.

Acknowledgments

I'm expressing my gratitude to all the voluntary participants that were involved in the experimental phase. A special thanks goes to the Eng. Fulvio Musante for his smart conversations and assistance in the lighting set-up. Finally, I would like to thank the panel of the SSL for their involvement during the research and their valuable feedbacks.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was performed with the support of “2017 Jean Heap Research Bursary” given by CIBSE-Chartered Institution of Building Services Engineers, Society of Light and Lighting (SLL). The web link is as follows: https://www.cibse.org/society-of-light-and-lighting-sll/education/the-jean-heap-bursary

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Table 1 - Quantitative assessment of the lighting conditions of the experiment: illuminance on Horizontal plane (E_h), illuminance at eyes level E_{eye}, CCT, $R_{a,}$ SPD

Lighting Conditions	**Lighting Parameters**	**Measured Horizontal Illuminance E_H (lux) – (point A)**	**CCT (measured at E_H)**	**Measured Vertical Illuminance (at the eye) E_{eye} (lux) – (average points B and C)**	**CCT (measured at B and C points) (average)**
C1	**Direct-indirect Cold CCT**	536	5400K	35	4487K
C2	**Direct-indirect Warm CCT**	387	2960K	24	2927K
C3	**Direct Warm CCT**	370	2958K	16	2917K
C4	**Direct Cold CCT**	508	5523K	21	5096K

Table 2 - Lighting conditions and topics of conversation sequence for each group of participants

Groups	**Participants**	**Lighting conditions sequence**	**Conversation topics sequence**
G1	P1; P2	C1-C4-C3-C2	A-B-C-D
G2	P3; P4	C2-C3-C4-C1	C-A-B-D
G3	P5; P6	C1-C4-C2-C3	A-B-C-D
G4	P7; P8	C2-C3-C1-C4	B-C-A-D
G5	P9; P10	C1-C4-C2-C3	D-C-B-A
G6	P11; P12	C1-C4-C3-C2	A-B-C-D
G7	P13; P14	C2-C3-C4-C1	A-C-D-B
G8	P15; P16	C3-C2-C1-C4	C-D-B-A
G9	P17; P18	C4-C2-C1-C3	A-B-C-D
G10	P19; P20	C3-C1-C2-C4	D-C-B-A

Table 3 - T-test: Warm lighting vs Cold lighting and Direct/Indirect lighting vs Direct lighting – with p-value ***≤ 0.001 and **≤ 0.05

Factors	Variables	Warm	Cold	T-test	Direct/ Indirect	Direct	T-test
Environmental atmosphere	Pleasant/Unpleasant	2.55	3.38	-3.2704***	2.63	3.3	-2.6171**
	Spacious/Confined	3.33	3.05	0.8569	2.23	4.15	-8.1015***
	Comfortable/Uncomfortable	2.63	3.48	-3.3024	2.73	3.38	-2.4551**
	Energetic/Lazy	3.63	3.00	2.6716***	3.13	3.5	-1.5580
	Relaxing/Irritating	2.4	3.4	-3.9262***	2.7	3.1	-1.4544
	Visually Clean/Hazy	3.05	3.13	-0.2679	2.43	3.75	-5.6019***
	Interesting/Boring	2.78	2.68	0.4169	2.78	2.68	0.4169
	Simple/Complex	2.15	2.58	-1.4903	2.1	2.63	-1.8549
	Quiet/Lively	2.03	2.4	-1.6105	2.48	1.95	2.2916**
	Casual/Formal	2.33	3.08	-3.0627***	2.43	2.98	-2.1860**
	Public/Private	3.8	3.5	1.0146	2.9	4.4	-6.1369***
Lighting appearance	Dark/Bright	2.73	3.03	-1.0052	3.35	2.4	3.3874***
	Warm/Cold	1.93	4.23	-11.2032***	2.95	3.2	-0.7566
Social appraisal	Sociable/Unsociable	2.53	3.18	-2.5205**	2.55	3.15	-2.3127**
	Favourable/Unfavourable	2.63	3.2	-2.4241**	2.73	3.1	-1.5478
Prospect Evaluation	I can observe the state of the other person	3.5	3.15	1.1806	4.00	2.65	5.2513***
	I can observe the eyes of the other person	3.00	2.88	0.3851	3.73	2.15	5.7990***
	I can get information from the surroundings	2.55	2.55	0.0000	3.23	1.88	5.0082***
Sociability	I can carry the conversation easily	3.38	3.08	1.0467	3.55	2.9	2.3291**

Table 4 - Comparison between the four lighting conditions with p-value ***≥ 0.001 and **≥0.05

Factors	Variables	C1	C2	C3	C4	F-Test
Environmental atmosphere	Pleasant/Unpleasant	2.95	**2.3**	2.8	**3.8**	6.60***
	Spacious/Confined	**2.15**	2.3	**4.35**	3.95	22.30***
	Comfortable/Uncomfortable	3.05	**2.4**	2.85	**3.9**	6.38***
	Energetic/Lazy	**2.8**	3.45	**3.8**	3.2	3.26**
	Relaxing/Irritating	3.0	**2.4**	**2.4**	**3.8**	7.05***
	Visually Clean/Hazy	**2.35**	2.5	3.6	**3.9**	10.66***
	Interesting/Boring	2.8	2.75	2.8	2.55	0.24
	Simple/Complex	2.1	2.1	2.2	3.05	2.74
	Quiet/Lively	2.7	2.25	1.8	2.1	2.71
	Casual/Formal	2.7	**2.15**	2.5	**3.45**	5.29***
	Public/Private	**2.65**	3.15	**4.45**	4.35	13.31***
Lighting appearance	Dark/Bright	**3.4**	3.3	**2.15**	2.65	4.36***
	Warm/Cold	3.9	2	**1.85**	**4.55**	45.56***
Social appraisal	Sociable/Unsociable	2.6	**2.5**	2.55	**3.75**	6.07***
	Favourable/Unfavourable	3.05	**2.4**	2.85	**3.35**	2.85**
Prospect Evaluation	I can observe the state of the other person	3.85	**4.15**	2.85	**2.45**	9.81***
	I can observe the eyes of the other person	3.65	**3.8**	2.2	**2.1**	11.02***
	I can get information from the surroundings	**3.25**	3.2	1.9	**1.85**	8.16***
Sociability	I can carry the conversation easily	3.35	3.75	3	2.8	2.22

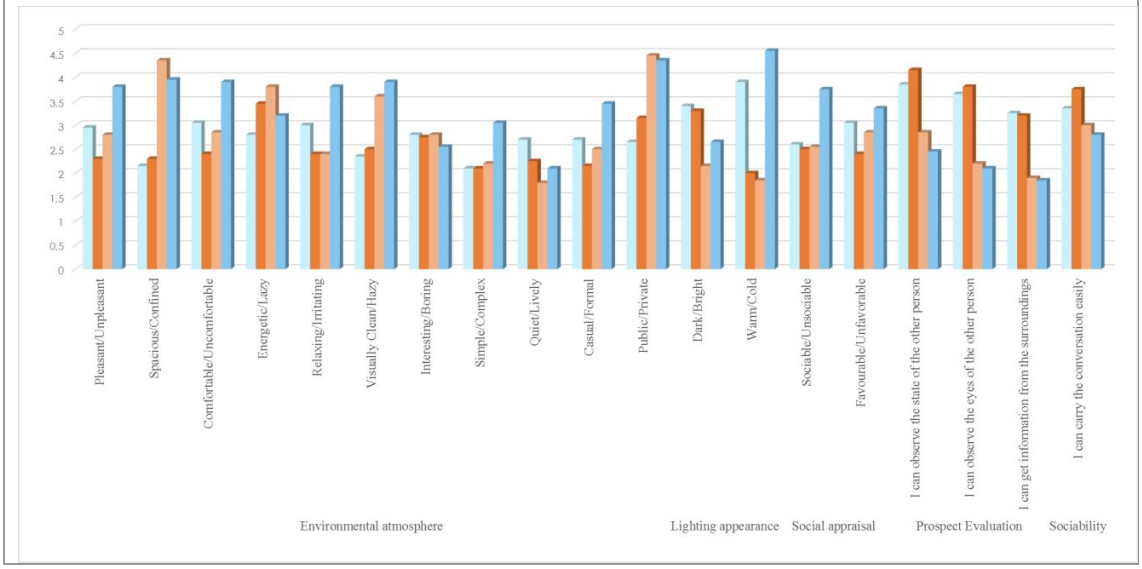

Table 5 - T-test: Warm Lighting vs. Cold Lighting for MF Groups and FF Groups - p-value ***≤ 0.001 and **≤0.05. The "-" sign of the T-test indicates a higher average for the Cold Lighting conditions, meanwhile the "+" sign indicates a higher average for the Warm Lighting conditions

Factors	Variables	Warm	Cold	MF Groups	Warm	Cold	FF Groups
Environmental atmosphere	Pleasant/Unpleasant	2.9	3	-0.2610	2.2	3.75	-5.2638***
	Spacious/Confined	3.8	2.8	2.1740**	2.85	3.3	-1.05800
	Comfortable/Uncomfortable	2.9	3.05	-0.3882	2.35	3.9	-5.0115***
	Energetic/Lazy	3.6	2.9	1.9183	3.65	3.10	1.82930
	Relaxing/Irritating	2.6	3.3	-1.7765	2.20	3.50	-3.9969***
	Visually Clean/Hazy	3.4	2.8	1.4854	2.70	3.45	-2.0442**
	Interesting/Boring	2.65	2.65	0.0000	2.90	2.70	0.61640
	Simple/Complex	2.2	2.55	-0.8389	2.10	2.60	-1.25210
	Quiet/Lively	1.8	2.95	-4.0827***	2.25	1.85	1.22830
	Casual/Formal	2.65	2.95	-0.8670	2.00	3.20	-3.5590***
	Public/Private	4.2	3	3.6444***	3.40	4.00	-1.31760
Lighting appearance	Dark/Bright	2.45	3.3	-2.1544**	3.00	2.75	0.56750
	Warm/Cold	2	4	-6.3246***	1.85	4.45	-10.0368***
Social appraisal	Sociable/Unsociable	2.95	3.05	-0.2607	2.10	3.30	-3.6986***
	Favourable/Unfavourable	2.95	2.95	0.0000	2.30	3.45	-3.6780***
Prospect Evaluation	I can observe the state of the other person	3.05	2.95	0.2519	3.95	3.35	1.42360
	I can observe the eyes of the other person	2.3	2.85	-1.3988	3.70	2.90	1.68160
	I can get information from the surroundings	2.1	2.85	-1.9476	3.00	2.25	1.61700
Sociability	I can carry the conversation easily	3	2.95	0.1269	3.75	3.20	1.35130

Table 6 - T-test: Direct/Indirect Lighting vs. Direct Lighting for MF Groups and FF Groups - p-value ***≤ 0.001 and **≤0.05. The "-" sign of the T-test indicates a higher average for the Direct Lighting conditions, meanwhile the "+" sign indicates a higher average for the Direct/Indirect Lighting conditions

Factors	Variables	Direct/ Indirect Lighting	Direct Lighting	MF Groups	Direct /Indirect Lighting	Direct Lighting	FF Groups
Environmental atmosphere	Pleasant/Unpleasant	2.45	3.45	-2.8773***	2.8	3.15	-0.9138
	Spacious/Confined	2.25	4.35	-6.0162***	2.2	3.95	-5.3838***
	Comfortable/Uncomfortable	2.55	3.4	-2.3492**	2.9	3.35	-1.1484
	Energetic/Lazy	3.05	3.45	-1.0621	3.20	3.55	-1.1348
	Relaxing/Irritating	2.6	3.3	-1.7765	2.80	2.90	-0.2582
	Visually Clean/Hazy	2.3	3.9	-4.9315***	2.55	3.60	-3.0261***
	Interesting/Boring	2.6	2.7	-0.2785	2.95	2.65	-0.9305
	Simple/Complex	1.95	2.8	-2,1365**	2.25	2.45	-0.4924
	Quiet/Lively	2.7	2.05	2.0251	2.25	1.85	1.2283
	Casual/Formal	2.4	3.2	-2.4658**	2.45	2.75	-0.7766
	Public/Private	2.9	4.3	-4.5485***	2.95	4.50	-4.1384***
Lighting appearance	Dark/Bright	3.4	2.35	2.7512***	3.30	2.45	2.0220
	Warm/Cold	2.75	3.25	-1.1217	3.15	3.15	0
Social appraisal	Sociable/Unsociable	2.6	3.4	-2.2143**	2.50	2.90	-1
	Favourable/ Unfavourable	2.65	3.25	-1.8424	2.80	2.95	-0.4129
Prospect Evaluation	I can observe the state of the other person	3.55	2.45	3.0983***	4.45	2.85	4.6239***
	I can observe the eyes of the other person	3.3	1.85	4.4279***	4.15	2.45	4.1587***
	I can get information from the surroundings	3.2	1.75	4.4171***	3.25	2.00	2.8767***
Sociability	I can carry the conversation easily	3.45	2.5	2.6203**	3.65	3.30	0.8479

Table 7 - Warm Lighting vs Cold Lighting for Acquainted Couples and Unacquainted Couples - p-value ***≤ 0.001 and **≤0.05 The "-" sign of the T-test indicates a higher average for the Cold Lighting conditions, meanwhile the "+" sign indicates a higher average for the Warm Lighting conditions

Factors	Variables	Warm	Cold	Acquainted Couples	Warm	Cold	Unacquainted Couples
Environmental atmosphere	Pleasant/Unpleasant	2.45	3.3	-2.2312**	2.65	3.45	-2.3645**
	Spacious/Confined	3.35	2.85	1.1100	3	3	0.1077
	Comfortable/Uncomfortable	2.45	3.45	-2.7059**	2.8	3.5	-1.9259
	Energetic/Lazy	3.45	2.90	1.6398	3.80	3.10	2.1311**
	Relaxing/Irritating	2.15	3.35	-3.3384***	2.65	3.45	-2.2166**
	Visually Clean/Hazy	2.95	2.95	0.0000	3.15	3.30	-0.4105
	Interesting/Boring	2.75	2.50	0.6980	2.80	2.85	-0.1546
	Simple/Complex	2.05	2.40	-0.8827	2.25	2.75	-1.2043
	Quiet/Lively	2.10	2.50	-1.1162	1.95	2.30	-1.1508
	Casual/Formal	2.25	2.90	-1.7648	2.40	3.25	-2.6020**
	Public/Private	3.95	3.20	1.7976	3.65	3.80	-0.3606
Lighting appearance	Dark/Bright	2.95	3.50	-1.2468	2.50	2.55	-0.1327
	Warm/Cold	2.00	4.35	-7.7936***	1.85	4.10	-7.9615***
Social appraisal	Sociable/Unsociable	2.40	2.85	-1.1791	2.65	3.50	-2.5108**
	Favourable/Unfavourable	2.35	3.20	-2.3033**	2.90	3.20	-1.0180
Prospect Evaluation	I can observe the state of the other person	3.90	3.35	1.5419	3.10	2.95	0.3254
	I can observe the eyes of the other person	3.45	3.10	0.7688	2.55	2.65	-0.2243
	I can get information from the surroundings	2.80	2.80	0.0000	2.30	2.30	0.0000
Sociability	I can carry the conversation easily	3.80	3.35	1.2194	2.95	1.80	0.3595

Table 8 - Direct Lighting vs. Direct/Indirect Lighting for Acquainted Couples and Unacquainted Couples - p-value ***≤ 0.001 and **≤0.05 The "-" sign of the T-test indicates a higher average for the Direct Lighting conditions, meanwhile the "+" sign indicates a higher average for the Direct/Indirect Lighting conditions

Factors	Variables	Direct /Indirect Lighting	Direct Lighting	Acquainted Couples	Direct /Indirect Lighting	Direct Lighting	Unacquainted Couples
Environmental atmosphere	Pleasant/Unpleasant	2.35	3.4	-2.8563***	2.90	3.20	-0.8354
	Spacious/Confined	2.15	4.05	-5.6157***	2.30	4.25	-5.7339***
	Comfortable/Uncomfortable	2.45	3.45	-2.7059**	3.00	3.30	-0.7944
	Energetic/Lazy	2.9	3.45	-1.6398	3.35	3.55	-0.5780
	Relaxing/Irritating	2.4	3.1	-1.7825	3.00	3.10	-0.2610
	Visually Clean/Hazy	2.15	3.75	-4.6861***	2.70	3.75	-3.2383***
	Interesting/Boring	2.55	2.7	-0.4171	3.00	2.65	1.0989
	Simple/Complex	1.85	2.6	-1.9651	2.35	2.65	-0.7139
	Quiet/Lively	2.75	1.85	2.6975**	2.20	2.05	0.4863
	Casual/Formal	2.1	3.05	-2.7085**	2.75	2.90	-0.4240
	Public/Private	2.8	4.35	-4.3726***	3.00	4.45	-4.2159***
Lighting appearance	Dark/Bright	3.8	2.65	2.8077***	2.90	2.15	2.1026**
	Warm/Cold	2.9	3.45	-1.1511	3.00	2.95	0.1083
Social appraisal	Sociable/Unsociable	2.35	2.9	-1.4543	2.75	3.40	-1.8571
	Favourable/Unfavourable	2.45	3.1	-1.7124	3.00	3.10	-0.3353
Prospect Evaluation	I can observe the state of the other person	4.05	3.2	2.4937**	3.95	2.10	5.2744***
	I can observe the eyes of the other person	3.85	2.7	2.7439***	3.60	1.60	6.5343***
	I can get information from the surroundings	3.6	2	4.0000***	2.85	1.75	3.1513***
Sociability	I can carry the conversation easily	3.85	3.3	1.5050	3.25	2.50	1.8758

Table 9 - Categorization of activities in semantic groups

Activities	C1 – Cold Direct/Indirect	C2 - Warm Direct/Indirect	C3 - Warm Direct	C4 - Cold Direct
Mental activities	**29%**	**33%**	13%	24%
Tense activities	**35%**	5%	25%	**35%**
Socialization activities	18%	**29%**	**35%**	18%
Relaxing activities	11%	19%	**56%**	14%
Leisure activities	14%	**45%**	32%	9%
Sport activities	**83**%	0%	0%	17%
High-level Visual Tasks	**31%**	25%	17%	**28%**
Low-level Visual Tasks	19%	27%	**41%**	14%

Appendix 1. Experimental questionnaire

Participant Code _____Condition _____Date_____
(for anonimity)

ATMOSPHERE IMPRESSION QUESTIONNAIRE
How would you describe the room on the following scale:
(Put a cross on each line closest to the most appropriate answer)

PLEASANT ____|____|____|____|____ UNPLEASANT
CONFINED____|____|____|____|____ SPACIOUS
COMFORTABLE____|____|____|____|____ UNCOMFORTABLE
LAZY ____|____|____|____|____ ENERGETIC
PUBLIC ____|____|____|____|____ PRIVATE
IRRITATING____|____|____|____|____ RELAXING
HAZY ____|____|____|____|____ VISUALLY CLEAR
BORING____|____|____|____|____ INTERESTING
SIMPLE____|____|____|____|____ COMPLEX
DARK ____|____|____|____|____ BRIGHT
FORMAL____|____|____|____|____ CASUAL
QUIET____|____|____|____|____ LIVELY
WARM____|____|____|____|____ COLD
UNSOCIABLE____|____|____|____|____ SOCIABLE
FAVORABLE ____|____|____|____|____ UNFAVORABLE

Rate (Put a Cross) on each of the following statement on the following scale.

[1] not at all – [2] a little/very low – [3] moderate – [4] quite a bit – [5] very high

I CAN OBSERVE THE STATE OF THE OTHER PERSON
_____1_____2_____3_____4_____5_____
I CAN OBSERVE THE EYES OF THE OTHER PERSON
_____1_____2_____3_____4_____5_____
I CAN GET INFORMATION FROM THE SORROUNDINGS
_____1_____2_____3_____4_____5_____
I CAN CARRY ON A CONVERSATION EASILY
_____1_____2_____3_____4_____5_____

Write down the first three activities that come to mind with this lighting atmosphere
_____
_____
_____