International Journal of Architectural Engineering & Urban Planning, Volume 35, Number 1, 2025
DOI: 10.22068/ijaup.872

Review Paper

The Impact of Lighting on Emotions in Architectural Interior Spaces: A Systematic Review

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Received: September 2024, **Revised:** January 2025, **Accepted:** March 2025, **Publish Online:** March 2025

Abstract

Light significantly affects human physiological and psychological dimensions, particularly emotions, which play a key role in mental health. Exploring the relationship between the quantitative and qualitative characteristics of light and emotional or affective states in indoor architectural spaces is essential due to the substantial time people spend in such environments. However, a comprehensive study that integrates and summarizes existing knowledge in this field is still lacking. This systematic review aims to synthesize current evidence and identify research gaps. A total of 4,897 records were identified using relevant keywords from five databases: Scopus, Web of Science, ScienceDirect, PubMed, and APA PsycINFO. The review followed the Prisma 2020 guidelines. After screening (kappa = 0.784) and assessing eligibility based on PICOS criteria, 14 articles were selected according to the inclusion criteria and authors' consensus. Reviewing references led to the inclusion of one additional article. All 15 studies were rated as of acceptable quality, and their data were extracted. The findings reveal that most prior studies have evaluated the effects of Illuminance, Correlated Color Temperature (CCT), Lighting Color, and Lighting Distribution or Direction on Pleasure, Arousal, and Dominance (PAD) in predominantly administrative, commercial, or educational indoor spaces. Generally, all PAD dimensions are directly correlated with Illuminance level, and Arousal is directly related to CCT. Furthermore, the combination of direct and indirect Lighting and relatively complex lighting Distribution increase Pleasure, and Colored light heightens Arousal while reducing Dominance. Identified research gaps underscore the need for future studies focusing on artificial lighting dependent on interior architectural form, indoor natural light, residential environments, and the use of behavioral and neurophysiological indicators for emotion evaluation.

Keywords: *Emotion, Affective state, Lighting, Architectural space, Interior environment.*

Notation List

A	Arousal / Activation	**D**	Dominance	**SCS**	Subjective Coordinate Scale
CATA	Check-all-that-apply	**EEG**	Electroencephalogram	**V**	Valence
CCT	Correlated Color Temperature	**P**	Pleasure	**VAS**	visual analog scales
CRI	Color Rendering Index	**SAM**	Self-Assessment Manikin	**VR**	virtual reality

INTRODUCTION

Studies indicate that individuals spend around 90% of their time in indoor environments, including residential, educational, commercial, and office spaces (Allen & Macomber, 2020; Klepeis et al., 2001). Therefore, considering the limited access to natural light, providing adequate and high-quality lighting in interior spaces is essential. Given that the human body receives 87% of external information through vision (Yang, 2002), the essential role of light in processing this information is undeniable. Both artificial and natural light are well-established to impact psychological and physiological aspects of life, including emotions (Zhang et al., 2022), as well as other mental and physical dimensions (Shishegar & Boubekri, 2022). Furthermore, individuals' health and

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well-being are affected by lighting (Osibona et al., 2021). Beyond these impacts, light has a therapeutic role in alleviating depression (Obayashi et al., 2018; Perera et al., 2016), reducing symptoms of seasonal affective disorders (Wirz-Justice et al., 1996), and improving mood disorders (Golden et al., 2005; Pail et al., 2011).

Emotion, as an integral part of human life, plays a critical role in behavior, cognitive processes (Blanchette & Richards, 2010; Dolan, 2002; Jung et al., 2014; Tyng et al., 2017), and maintaining health (Uskul & Horn, 2015). In fact, emotion is recognized as one of the core components of health (Butler, 2011). This is particularly relevant today, as societies face rising mental health challenges (AIHW, 2018). Studies suggest that emotions exert a dual influence on health: directly by modulating the immune system's inflammatory response, and indirectly by shaping health-related behaviors (Kiecolt-Glaser et al., 2002). In addition, according to Engel's model (Engel, 1977), mental health is shaped by biological, psychological, and social factors, all of which are linked to emotion. Moreover, mental health is not merely the absence of mental illness but the presence of emotional, psychological, and social well-being (Keyes, 2014; Westerhof & Keyes, 2010).

Emotion is defined as automatic, involuntary, and affective responses to events, objects, and environmental stimuli (Ekman & Cordaro, 2011), as well as a neurophysiological experience with behavioral expression in response to sensory information (Barooah, 2019), leading to the formation of feelings. Based on this, emotion can be measured through neurophysiological, behavioral, and subjective experience indicators (Keil & Miskovic, 2015; Mauss & Robinson, 2009; Shu et al., 2018). Feeling refers to the subjective quality attributed to perceived stimuli (Reading, 2011), the mental representation of emotions (Damasio, 2001), and a personal experience related to emotion. According to the literature, mood is a generalized affective state that is less intense than emotions and feelings but lasts significantly longer. Unlike emotions, it is an indefinite state that may not be linked to anything specific or may relate to everything in general (Frijda, 2009). Affect, as an umbrella term, encompasses all psychological states and is defined as a neurophysiological condition accessible to consciousness, a simple primitive non-reflective feeling (i.e., immediate, automatic, and instinctive) (Russell & Feldman Barrett, 2009), covering both mood and emotion (Hume, 2012; Rosenberg, 1998). However, mood and emotion differ fundamentally in nature, cause, duration, intensity, the scope of affective states, measurement methods, and other characteristics (Ekkekakis, 2012; Godovykh & Tasci, 2022; Handayani et al., 2014; Larsen, 2000; Morris, 1992).

Understanding the impact of environmental factors, such as lighting characteristics, on emotions and related concepts has drawn the attention of researchers for over half a century. Numerous reviews have synthesized and described existing evidence, and proposed models or frameworks in this area. Regarding the influence of interior design factors on emotions, a systematic review by Bower et al. (Bower et al., 2019) found that previous studies examined the impact of 3D form or 2D geometry (3 studies), materiality or texture (2 studies), style and context of interior furnishings (2 studies), ceiling height (1 study) on emotions through neurophysiological correlates and subjective indicators. Several review studies have also explored the impact of environmental factors (Chowdhury et al., 2020; Clark et al., 2007; Engineer et al., 2021; Rautio et al., 2018; Rodríguez-Labajos et al., 2024), including interior lighting, on health and well-being. In this regard, a systematic review demonstrated that previous research assessed the impact of natural and artificial lighting in homes on mental, physical, and sleep health (Osibona et al., 2021). Another systematic review by van Duijnhoven et al. (Van Duijnhoven et al., 2019) analyzed studies on office lighting and health, highlighting a primary focus on illuminance and correlated color temperature (CCT). Further systematic reviews have explored the effects of electric lighting (Li et al., 2024) and natural daylight (Böhmer et al., 2021) on emotion-related concepts such as mood in healthy individuals. In contrast, other systematic reviews have focused on the therapeutic role of lighting in managing psychological and neurophysiological disorders (Mitolo et al., 2018; Shikder et al., 2010). Despite extensive reviews and the acknowledged importance of lighting and emotion, no comprehensive study appears to have systematically examined emotional states resulting from lighting conditions in physical or virtual indoor environments.

This research gap highlights the necessity of addressing this topic. Therefore, the purpose of this review is to collect and synthesize evidence, outline the current body of knowledge, and identify consensus on findings regarding the impact of indoor lighting on emotional states, through a systematic approach. By identifying the lighting components assessed, the methodologies and tools used to measure emotions in previous experimental studies, this review will facilitate the identification of research gaps and overlooked areas for future studies. To achieve these goals, the following research questions are posed:

1) What findings have previous studies reported regarding the impact of lighting conditions on emotional states in architectural interior spaces? What conclusions is there a consensus on?

2) Which components and characteristics of indoor lighting have been studied for their effects on emotions and affective states?

3) Methodologically, how are studies on the influence of interior lighting on emotions structured?

4) What aspects of the relationship between indoor lighting and emotional states have been overlooked in previous research?

This research seeks to provide designers and architects with strategies to enhance emotional states and ensure the mental health of occupants through principled design and science-based lighting interventions.

MATERIALS AND METHODS

Protocol

To clarify the systematic review process on the impact of lighting on emotions in interior architectural spaces, the PRISMA 2020 guidelines (Page et al., 2021), with a 27-item checklist, were followed.

Search Strategy

Records published up to May 2023 were identified using search terms related to the three domains of lighting, emotion, and interior environment, based on common terminology in the relevant literature and preliminary database searches. The search strategy (Table 1) was applied across five international databases—Scopus, Web of Science, ScienceDirect, PubMed, and APA PsycINFO—selected for their comprehensive coverage of resources in medical sciences, psychology, environmental psychology, architecture, and design.

Search filtering during the record identification stage was limited to research articles and academic journals published in English (Table 1).

Eligibility Criteria

The following criteria were applied to select eligible studies for inclusion.

Study Type

Since this study seeks to identify the established impact of light on emotions, the scope of the review is limited to experimental research conducted under controlled laboratory conditions to empirically explore this relationship. Accordingly, experimental (interventional) studies, in which researchers actively manipulated lighting conditions and subsequently observed and measured the effects of these interventions, were included without restrictions on study design (e.g., between-subjects or within-subjects). In contrast, theoretical studies, such as reviews that relied on literature-based analyses rather than experimental testing, were excluded.

Publication Type

Documents such as books, book chapters, conference papers, dissertations, editorials, letters, encyclopedias, and non-English studies were excluded.

Table 1. Search Strategy, Filters, and Number of Records Identified

Database	Area	Document type / Source type limited to	Species / Population limited to	Language	records
Scopus	Title; Abstract; Keywords	Article	No filter	English	1835
Web of Science	Title; Abstract; Keywords	Article; Early Access	No filter	English	1438
ScienceDirect	Title; Abstract; Keywords	Research articles; Short communications	No filter	English	327
Pubmed	Title; Abstract	No filter	Humans	English	316
APA PsycINFO	General	Academic Journals; Electronic Collections	Human; Female; Male; Transgender	English	981

Combination of the search terms: (Light OR Lighting OR Illumination) AND (Emotion* OR “Affective Appraisal” OR “Affective Assessment” OR “Affective Evaluation” OR “Affective Valuation” OR “Affective State” OR “Affective Response” OR “Affective Reaction”) AND (Interior OR Indoor OR Environment OR Surrounding OR Ambiance OR Space OR Building OR Architecture OR Room).
Due to the limitations on using (*) in the ScienceDirect database, the combination (Emotion OR Emotional) was used instead of Emotion*.

Population

Only studies with healthy human participants were included. Those on animals and individuals with physical or mental health conditions (e.g., seasonal affective and mood disorders, depression, autism, cancer) were excluded

Exposure

In general, studies investigating the effect of artificial or natural light (as the independent variable) on emotions (as the dependent variable) in architectural interior environments were included in the review. Studies conducted in outdoor settings or non-architectural interiors, such as cabins, vehicles, or spacecraft, were excluded. Additionally, studies that did not consider lighting as a factor in the functional elements of architectural interiors (including at least three vertical walls, a floor, and a ceiling) were removed. Furthermore, Experiments conducted under specific conditions, stressful environments and confounding factors (e.g., post-trauma, post-emotional stimulation, during pregnancy, or in care settings), as well as those that did not control other environmental variables, were also excluded. This study considers all quantitative and qualitative lighting characteristics, regardless of whether experimental scenes were presented in real environments or through virtual reality (VR). Factorial design studies that examined the interaction of lighting with other independent variables affecting emotions were also included.

Outcome Measures

This review includes studies that evaluated emotions elicited by exposure to lighting environments using at least one of the following indicators: subjective measures (e.g., self-report questionnaires like SAM), behavioral measures (e.g., facial expressions, vocal characteristics, and body behavior), or neurophysiological measures (e.g., metrics from the Autonomic Nervous System (ANS) and Central Nervous System (CNS) such as Galvanic Skin Response (GSR), electrocardiogram (ECG), electroencephalogram (EEG), and Functional Magnetic Resonance Imaging (fMRI)). Studies that relied on emotional vocabulary to assess Room Appraisal, Atmosphere Perception, or Space Impression were excluded. Additionally, because this research differentiates between emotion and mood, studies focusing on mood under lighting conditions were excluded. These included long-term studies, those aimed at improving mood disorders, and studies using mood-specific methods and questionnaires.

Study Selection

Considering the inclusion and exclusion criteria, the first and second authors independently screened the titles and abstracts of identified studies. The consensus assessment, evaluated using the kappa statistic, demonstrated acceptable agreement (K coefficient = 0.784, Pr(e) = 0.962), confirming the validity and reliability of the screening process. After discussing and agreeing on the exclusion of records that did not meet the criteria, both authors independently reviewed the full texts of the remaining studies, focusing on research questions, objectives, methodology, findings, and conclusions. To ensure selection accuracy and enhance result quality, both authors assessed study eligibility using a scoring matrix based on the PICOS framework (Population, Intervention, Comparison, Outcome, and Study Design). This approach ensured that the selected studies fully addressed the review's objectives while validating the selection process. A comparison of the evaluation tables revealed that both authors independently selected the same 14 articles for inclusion. One additional article was later included after reexamining the references of the selected articles.

Data Extraction

The required data were extracted from the included studies by the primary author, with approval from the second author, using a customized data collection form. The extracted data were categorized into three groups: 1) General study information (title, authors, year, journal details, and the country of research); 2) Study characteristics and conditions, including participant characteristics / Population (sample size, age range, mean age or standard deviation), Setting and experimental environment (interior space function, method of presenting the lit environment, experiment location, control conditions, and study duration), study design, lighting as the independent variable/intervention (type of lighting, examined components, lighting conditions), emotion as the dependent variable/outcome (applied model, dimensions or components, indicators, measurement methods, and tools), as well as additional independent, mediator, and dependent variables; and 3) Main findings (classified by various lighting components).

Study Quality Assessment

The studies included in this review are experimental (field or laboratory), where researchers actively intervene in lighting and environmental conditions. However, not all studies can be classified as randomized controlled trials. Therefore, to assess their quality, an adapted checklist based on the CASP Randomized Controlled Trial checklist was used, with the results indicating that the quality of the included studies is acceptable.

Data Analysis

Due to considerable heterogeneity in study design, lighting features, measured emotions, and findings across the included studies, a quantitative summary through meta-analysis was not feasible. Instead, the studies were synthesized qualitatively, and the findings were categorized based on emotional outcomes influenced by lighting.

RESULTS

According to the PRISMA flow diagram (Fig. 1), a total of 4,897 records were identified through keyword searches in five electronic databases: Scopus, Web of Science, ScienceDirect, PubMed, and APA PsycINFO. After removing duplicates using EndNote, 2,881 remaining studies were screened based on inclusion and exclusion criteria. First, 2,759 records were excluded based on title, followed by 70 more based on abstract, with consensus among the authors and an acceptable K coefficient. Next, the full texts of the 52 remaining studies were reviewed in detail, focusing on research questions, objectives, methodology, findings, and conclusions, and their eligibility was assessed using the PICOS framework. 14 studies were selected for inclusion based on agreement on their eligibility. Through reference screening, one more study was deemed eligible, increasing the total number of studies included in the review to 15.

General Study Information

Of the 15 included studies, 12 were conducted in the past decade (Fig. 2), reflecting a growing interest in the impact of lighting on emotions in architectural interior spaces. Most were published in Q1 journals, followed by Q2 (Fig. 3). Geographically (Fig. 4), 6 studies were conducted in the U.S., with one each from nine other countries (Table 2).

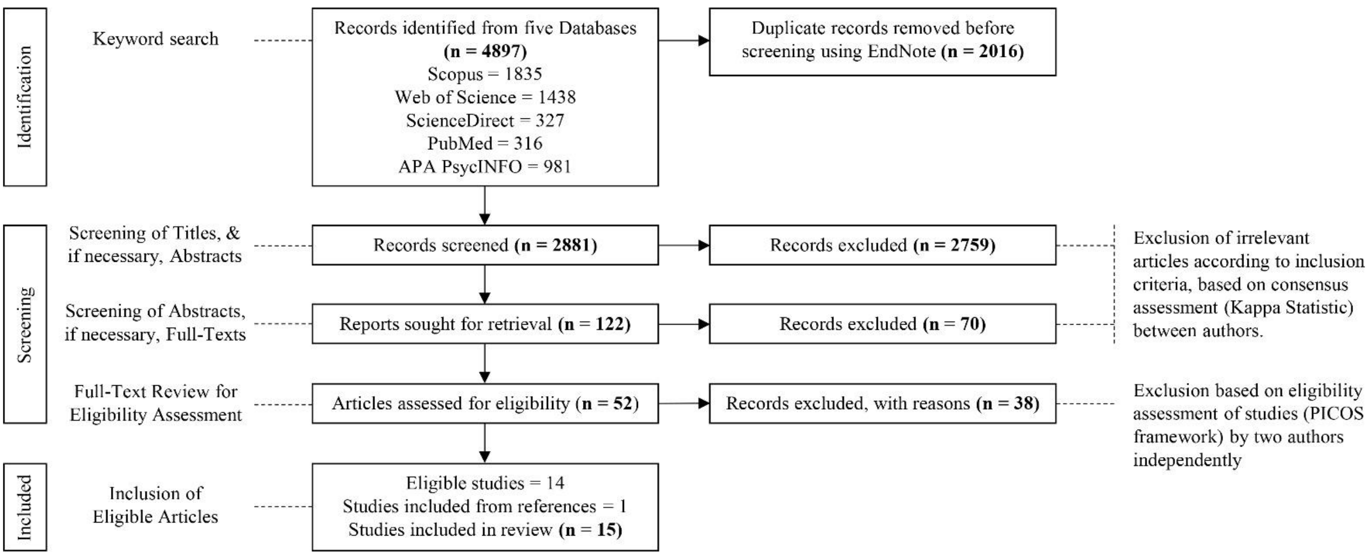

Fig 1. Process of Identifying Studies Through Database Searches to Study Selection Based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram

Table 2. General Information of Studies Included in the Systematic Review

	Title	Author(s) & Year	Journal details		Experiment Location
			Journal	Q	
1	Lighting environmental assessment in enclosed spaces based on emotional model	(Zhang et al., 2023)	Science of the Total Environment	1	China
2	The effects of retail environmental design elements in virtual reality (VR) fashion stores	(Sina & Wu, 2023)	The International Review of Retail, Distribution and Consumer Research	2	USA
3	Emotional responses of college students to filtered fluorescent lighting in a classroom (v3)	(Yuen et al., 2023)	Health Psychology Research	2	USA
4	The Effects of White versus Coloured Light in Waiting Rooms on People's Emotions	(Zhang et al., 2022)	Buildings	1	Spain
5	Effects of coloured lighting on pleasure and arousal in relation to cultural differences	(Lee & Lee, 2021)	Lighting Research & Technology	2	USA
6	Creating positive atmosphere and emotion in an office-like environment: A methodology for the lit environment	(Kim & Mansfield, 2021)	Building and Environment	1	UK
7	Color-filtered lighting: Visual and emotional impact in learning environments	(Suh et al., 2020)	International Journal of Architectonic, Spatial, and Environmental Design	4	USA
8	Lighting up the office: The effect of wall luminance on room appraisal, office workers' performance, and subjective alertness	(de Vries et al., 2018)	Building and Environment	1	Netherland
9	Perceptual and emotional effects of light and color in a simulated retail space	(Lombana & Tonello, 2017)	Color Research and Application	3	Argentina
10*	Effects of LED Color Temperature and Illuminance on Customers' Emotional States and Spatial Impressions in a Restaurant	(Wu & Wang, 2015)	International Journal of Affective Engineering	1	Taiwan
11	The effect on emotions and brain activity by the direct/indirect lighting in the residential environment	(Shin et al., 2014)	Neuroscience Letters	2	South Korea
12	As real as it gets: What role does lighting have on consumer's perception of atmosphere, emotions and behaviour?	(Quartier et al., 2014)	Journal of Environmental Psychology	1	Belgium
13	Effects of Semi-transparent glazing on the emotions of office workers	(Sylvester & Bowler, 2012)	Journal of Green Building	2	USA
14	The effects of lighting on consumers' emotions and behavioral intentions in a retail environment: A cross-cultural comparison	(Park & Farr, 2007)	Journal of Interior Design	1	USA
15	Effects of noise, heat and indoor lighting on cognitive performance and self-reported affect	(Hygge & Knez, 2001)	Journal of Environmental Psychology	1	Sweden

***** Included from References of 14 selected eligible studies

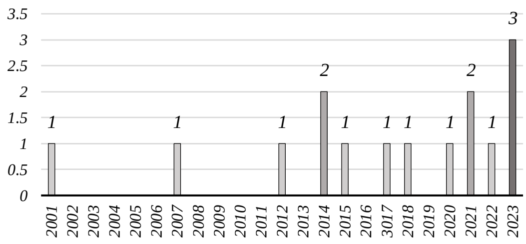

Fig 2. Publication Year of the Included Studies

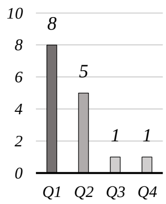

Fig 3. Journal Ranking

Fig 4. Countries Conducting Research on the Topic

Study Characteristics and Conditions

Participant Characteristics (Population)

The total number of participants across all studies is 2,082, with sample sizes ranging from 28 to 295 (Fig. 5). Studies 5 and 15 reported an equal number of male and female participants (50-50%), studies 1, 4, 6, 9, 11, and 14 had a relatively balanced distribution (up to 60-40%), while Study 3 did not report gender, and other studies showed imbalances. Study 2 included only female participants. Participants' ages ranged from 18 to 63 years, with mean ages from just over 18 (Study 15) to 38.38 years (Study 4).

Setting and Experimental Environment

In terms of spatial function, most studies primarily assessed the impact of lighting on emotions in three types of interior environments (Fig. 6): office spaces (4 studies), clothing/fashion stores (3 studies), and educational settings like classrooms or studios (2 studies). Additionally, six other environments—a special enclosed operating workplace, a waiting room, a laboratory booth (without a specific function), a restaurant, a living room, and a supermarket—were each investigated in a single study. To present lighting conditions to participants, thirteen studies employed one-to-one physical environments, while studies 2 and 13 used VR on PCs and time-lapse animations, respectively (Fig. 7). Eleven studies conducted all experimental phases, from scene presentation to emotional assessment, in simulated and controlled laboratory settings (Fig. 8). In contrast, studies 3 and 7 were conducted in real-world environments, such as classrooms or studios. According to reports or evidence from the articles, to eliminate unwanted effects from natural light or views, most studies utilized environments without windows or with covered windows (with the exception of Study 13, which addressed natural light). Additionally, five studies reported controlling environmental conditions of temperature (T) or relative humidity (RH), as follows: 1 (T=27°C, RH=55%), 4 (23.5°C, 56%), 6 (24°C), 11 (23.3°C, 21.3%), and 15 (21 and 27°C). In all studies, except for Study 9 (where wall color was an independent variable), walls and ceilings were consistently white or light gray. The arrangement of furniture and the spatial dimensions of the lit environment remained constant across the studies. The dimensions were reported in all studies, except for studies 2 and 7. The length or width of lit environments ranged from 1.75 (Study 14) to 13.3 meters (Study 3), the height from 2.2 (Study 1) to 3.2 meters (Study 14), and the area from 3.36 (study 1) to 113 square meters (Study 3). In Study 5, the displayed space was notably smaller, as lighting conditions were presented in rectangular booths (305×610×914 mm). In approximately half of the studies, participants' prior light exposure or the lighting conditions between the two experimental scenarios were reported. Some studies allocated a period of 1 to 5 minutes before the experiment to allow participants to adapt to the lighting conditions (Studies 1, 4, 9, 11, and 14). Additionally, a rest period ranging from 40 seconds to 5 minutes was provided in certain studies between the two experimental scenarios, during which participants either rested in a dimly lit or dark room or kept their eyes closed (Studies 1, 4, 5, 6, 10, and 14). According to reports from studies 1, 3, 4, 6, 7, 8, and 12, the entire experiment (presentation of all lighting conditions and emotional assessments) took between 14 days (Study 12) and 2 months and 16 days (Study 3).

Study Design

In six studies, within-group designs were used (Studies 1, 6, 8, 10, 11, and 13), four studies employed between-group designs (4, 7, 12, and 15), and Study 3 alone used the ABAB withdrawal design (Fig. 9). Four studies incorporating additional independent or mediating variables alongside lighting used mixed approach: Study 2 applied a within-group design for two greenery conditions and a between-group design for two lighting conditions; Study 5 used a within-group design for six lighting conditions and a between-group design for two ethnicities; Study 9 employed a within-group design for three lighting conditions and a between-group design for four wall colors; and Study 14 applied a within-group design for four lighting conditions and a between-group design for two cultural backgrounds.

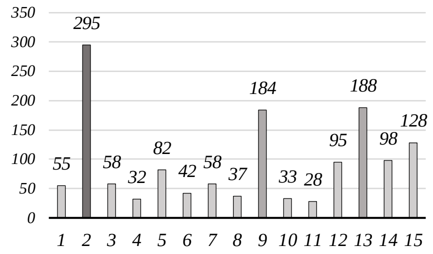

Fig 5. Number of Participants in each Study

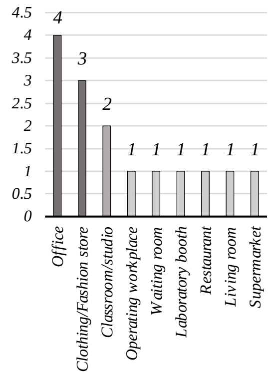

Fig 6. Interior Space Function

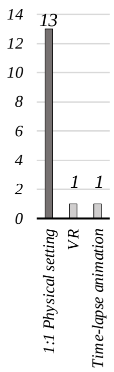

Fig 7. presenting the Lit Environment

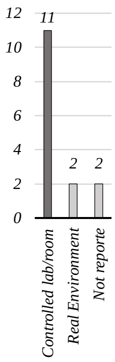

Fig 8. Experiment Location

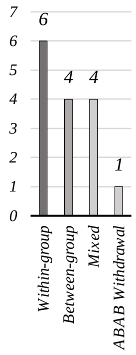

Fig 9. Study Design

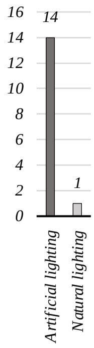

Fig 10. Type of Lighting

Lighting as an Independent Variable (Intervention)

All studies examined the impact of artificial lighting, except for Study 13, which evaluated the effect of natural light on emotions in interior spaces (Fig. 10). In six studies, lighting conditions resulted from modifications to two or more lighting components, while in nine studies, changes were made to only one component. The combinations of independent lighting variables are as follows:

a. The combination of Illuminance × CCT

In Study 1, six lighting settings (3×2 factorial) were created by combining two CCTs (3100K and 6500K) with three illuminance levels (250 lx, 600 lx, and 1000 lx). Similarly, in Study 10, six lighting settings were generated by combining two color temperatures (2700K and 5600K) with three illuminance levels (150 lx, 300 lx, and 500 lx).

b. Correlated Color Temperature (CCT)

Study 2 evaluated the effect of warm (3000K) and cold lighting (4200K) on participants' emotions.

c. Lamp Filtering (affecting luminous flux, glare, flicker, and light spectrum)

Study 3 investigated the emotional effects of two types of conventional overhead white fluorescent lighting: one unfiltered baseline and the other covered with fabric filters (thin, translucent, whisper white). The average luminous flux was 89.2 ± 18 lumens for the unfiltered fluorescent lighting and 55.3 ± 14.2 lm for the filtered lighting. Lamp filtering reduced luminous flux by 38%, eliminated glare, minimized flicker from fluorescent lamps, and transformed the lighting into a full-spectrum quality similar to that of LED and natural light.

d. Lighting Color

Three different light color combinations were examined in Study 4 as follows: 1. blue-green, 2. green-red, and 3. blue-red lighting. Before each lighting scenario, participants evaluated the experimental environment illuminated by white light (CCT=6500K, CRI>90, 120lx). In Study 5, the effects of six light colors, each with specific RGB and CIELAB values and varying illuminance levels, were examined: 1. Red (RGB = 245.7.3, CIELAB = 51.35/77.23/64.48, Illuminance = 118lx), 2. Green (60.172.60, 62.33/-53.56/46.98, 161lx), 3. Blue (0.137.191, 53.66/-11.27/-36.73, 194lx), 4. Yellow (255.210.0, 85.68/0.61/86.26, 205lx), 5. Orange (254.127.0, 66.71/42.94/73.75, 172lx), 6. Purple (119.10.255, 40.18/81.45/-94.55, 54lx). In Study 7, the effects of four lighting conditions, differing in CCT and illuminance (measured in footcandles, fc), were assessed in two distinct environments: The lighting conditions in the first environment were:

1. Existing light without filters (61.5 fc, 3270K), 2. Orange filter (50.4 fc, 2550K), 3. Green filter (45.9 fc, 3410K), and 4. Purple filter (38.6 fc, 3250K). The lighting metrics in the second environment were reported to be similar. It is important to note that in all three studies, the different lighting colors not only varied in terms of RGB and CIELAB values but also influenced the CCT and illuminance levels in the environment.

e. Lighting Distribution/Direction × Illuminance × CCT × Lighting Color

Study 6 examined the impact of 15 lighting scenarios, designed by professional lighting designers, on participants' emotions. The qualitative lighting variables were distribution and direction, achieved through various light arrangements, lamp placement, and the direction of light (direct/indirect), resulting in different task lighting functions (via ceiling lights, pendant lights, and table lamps) and accent lighting (via wall partitions and shelf lighting). Colored lamps (blue, cyan, etc.) were also used to produce different light colors. Additionally, illumination levels (250 and 1500 lux) and CCT (ranging from 2000K to 6500K) were studied as quantitative lighting variables.

f. Luminance

In Study 8, three average wall luminance levels were examined: 1. Low = 12 cd/m², 2. Medium = 36 cd/m², and 3. High = 72 cd/m². Notably, increasing wall luminance also led to higher vertical illuminance at the eye position in the viewing direction (Low = 206, Medium = 227, High = 254 lx), along with a slight increase in average ceiling luminance in the visible area (21, 27, 36 cd/m², respectively).

g. Lighting Distribution/Direction

in Study 9, three lighting types—front, overhead, and wall washer—were assessed using halogen lamps (CCT = 3000K). Each condition produced specific illuminance and luminance levels on different surfaces. In Study 11, two lighting settings in a controlled environment were evaluated: direct lighting (700 lux downlight) and a combination of direct and indirect lighting (400 lux downlight + 300 lux uplight). The total illuminance was set to 700 lux, with a controlled color temperature of 5000K.

h. Illuminance × CCT × Lighting Distribution/Direction

Study 12 investigated three lighting scenarios, each combining CCT (warm or cool), Illuminance (low, medium, or high), and lighting Distribution (accent or non-accent): 1. Warm accent with medium illumination, 2. Cool accent with high illumination, and 3. Non-accent with low illumination.

i. Light Transmittance (Window Transparency/Glazing) × Regional Solar Conditions

Study 13 on natural indoor lighting evaluated eight conditions (2×4 factorial), combining two window transmittance levels (100% clear glazing or 40% semi-transparent glazing) with four solar conditions from different regions (New York, Detroit, Houston, and Los Angeles).

j. Color Rendering Index (CRI) × CCT

Four ambient lighting conditions (2×2 factorial) were evaluated in Study 14, combining two CRI levels (75 or 95) with two CCT levels (3000 or 5000K). The illumination level was maintained at 600 lux.

k. Illuminance

In Study 15, the effect of two illuminance levels (300 and 1500 lx) on emotions was evaluated, with the color temperature maintained at 3000K and a CRI of 95.

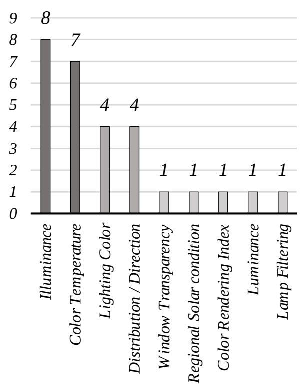

Fig 11. Frequency of Lighting Components

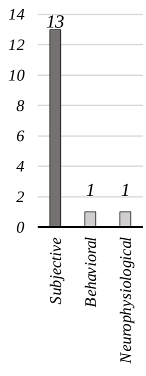

Fig 12. Emotion Assessment Indicator

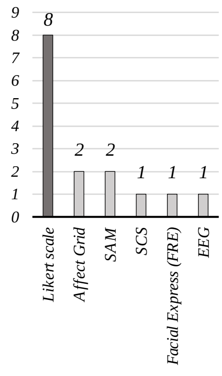

Fig 13. Measurement Method

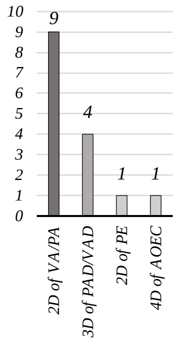

Fig 14. Emotion Model

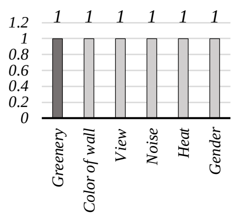

Fig 15. Other Independent Variables

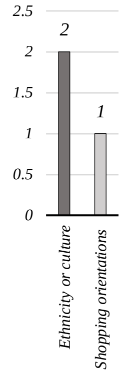

Fig 16. Moderator Variables

In most studies, the impact on emotions has been evaluated in the following order of frequency: Illuminance (8 studies), Color Temperature (7 studies), Lighting Color (4 studies), and Lighting Distribution/Direction (4 studies). Components such as Light Transmittance (window transparency/glazing) (1 study), Regional Solar Conditions (1 study), CRI (1 study), Luminance (1 study), and Lamp Filtering (1 study) have received less attention (see Fig. 11).

Emotion as the Dependent Variable (Outcome)

In 15 reviewed studies, emotional responses were measured using subjective (all studies), behavioral (1 study), and neurophysiological (1 study) indicators (Fig. 12). Common subjective methods include the multi-point Likert scale, Affect Grid, Self-Assessment Manikin (SAM), and Subjective Coordinate Scale (SCS) through self-report questionnaires (Fig. 13). Electroencephalography (EEG) was used to assess cortical signals as a neurophysiological indicator (Study 11), while facial expressions were evaluated using FaceReader (FRE) software as a behavioral indicator (Study 1). Self-report questionnaires were based on various models (Fig. 14): 2-dimensional Pleasure-Arousal/Activation (PA) or Valence-Arousal (VA) (9 studies), 3-dimensional Pleasure/Valence-Arousal-Dominance (PAD/VAD) (4 studies), 2-dimensional Pleasantness-Energy (PE) (1 study), and 4-dimensional Activation-Orientation-Evaluation-Control (AOEC) (1 study). These dimensions were used to categorize emotions, each measured through specific components on a multi-point scale (Table 3).

It is noteworthy that Study 15 considered emotion as a mediating factor influenced by lighting conditions, which in turn affect Attention and Problem-Solving.

Other Independent or Moderating Variables

The conditions of Greenery (greenery space or not, Study 2), Color of the wall (yellow-blue: contrasting, magenta: monochromatic, gray: achromatic, and green-magenta: complementary, Study 9), View (Window and Non-Window, Study 13), Noise (38 and 58 dBA), Heat (21 and 27°C), and Gender (Study 15) are considered independent variables (Fig. 15). Additionally, Shopping Orientations (Study 2) and Ethnicity / Cultural Background (Studies 5 and 14) were regarded as moderator variables (Fig. 16).

Other Dependent Variables

In all reviewed studies except Studies 5 and 13, additional dependent variables related to lighting conditions or emotions were examined. These variables include Atmosphere Perception (Studies 1, 6, and 12), Satisfaction, Purchase Intentions, and Perceived Merchandise (Study 2), Attention, Visual Clarity, and Headaches (Study 3), Comfort (Study 4), Description of Own Feelings (Study 7), Room Appraisal, Alertness, and Performance (Problem-Solving) (Study 8), Space Impressions (Studies 9 and 10), Brain Activity and Visual Analog Scales (Cool, Refresh, Comfortable) (Study 11), Shopping Behavior and Perception of Price, Quality, and Service Level (Study 12), Behavioral Intentions and Room Light Perception (Study 14), and Cognitive Performance (Attention, Problem-Solving, Long-Term, and Short-Term Recall) (Study 15). Evaluations of Atmosphere Perception, Room Light Perception, Room Appraisal, and Space Impressions were based on emotional vocabulary from the literature or adjectives associated with lighting (Table 4). These studies investigated whether the atmosphere of a space predicts emotional responses and the significant relationship between them.

Table 3. Emotion Dimensions and Related Components

Study	Dimensions	Components of each Dimension	Based on
1	VA	Valance (happy-unhappy); Arousal (sleepy-alert)	(Posner et al., 2005)
2	PA	Pleasure (7 pair of contended-depressed, happy–unhappy, satisfied-unsatisfied, pleased-annoyed, relaxed-bored, free-restricted, hopeful-despairing); Arousal (7 pair of stimulated-relaxed, excited- calm, jittery-dull, wide awake-sleepy, …)	(Robert & John, 1982)
3	PAD	Pleasure (6 pairs); Arousal (6 pairs); Dominance (6 pairs)	(Russell & Mehrabian, 1977)
4	VAD	Valance (happy-unhappy); Arousal (excitement - sleepiness); Dominance (uncontrolled- powerful)	(Mehrabian & Russell, 1974)
5	PA	Pleasure (pleasant–unpleasant, happy–unhappy, satisfied–dissatisfied, comfortable–uncomfortable Arousal (excited–calm, aroused– unaroused, wide awake–sleepy, stimulated–relaxed)	(Mehrabian & Russell, 1974)
6	VA	Pleasant (Pleasant-Unpleasant); Activation (Activation-Deactivation) lively (+P / +A); relaxing (+P / -A); tense (-P / +A); gloom (-P / -A)	(Russell et al., 1989)
7	PE	Pleasantness (Pleasant–Unpleasant); Energy (Low energy level-High energy)	(Rivers et al., 2013)
8	PAD	Pleasure (6 pairs); Arousal (6 pairs); Dominance (6 pairs)	(Mehrabian, 1995)
9	AOEC	Activation (tiredness, alertness, drowsiness); Orientation (interest, efficiency, indifference); Evaluation (safety, friendliness, sadness); Control (hesitation, independence, strength)	(Kuller et al., 2009)
10	PAD	Pleasure (Unhappy-Happy; Annoyed-Pleased; Unsatisfied-Satisfied; Melancholic-Contented; Despairing-Hopeful; Bored-Relaxed); Arousal (Calm-Excited; Sluggish-Frenzied; Sleepy-Wide Awake; Unaroused-Aroused; Dull-Jittery; Relaxed-Stimulated); Dominance (Controlled-Controlling; Influenced-Influential; Submissive-Dominant; Guided-Autonomous; Cared for-In control; Awed- Important)	(Mehrabian & Russell, 1974)
11	VA	Valance (happy-unhappy); Arousal (excited-relaxed)	(Bradley & Lang, 1994)
12	PA	Pleasure; Arousal	(Mehrabian & Russell, 1974)
13	VA	Pleasure (Pleasant-Unpleasant); Arousal (Arousal-Sleepiness)	(Russell & Pratt, 1980)
14	PA	Pleasure (Comfortable-uncomfortable, relaxing-tense, pleasant-unpleasant); Arousal (Stimulating-boring, wide awake-sleepy)	(Mehrabian & Russell, 1974)
15	VA	Pleasant (Pleasant-Unpleasant); Activation/Arousal (Activation-Deactivation) 8 affect states: High Activation (main indicator of arousal), Activated Pleasant, Pleasant, unactivated Pleasant, Low Activation, unactivated unpleasant, unpleasant, Activated unpleasant	(Knez & Hygge, 2001; Larsen & Diener, 1992)

A: Arousal/Activation; **C**: Control; **D**: Dominance; **E**: Evaluation/Energy; **O**: Orientation; **P**: Pleasure; **V**: Valence

Table 4. Dependent Variables as Additional Information Related to the Emotions

Study	Variable	Components	Based on
1	Atmosphere Perception	Alarmed, Stressed, Bored, Excited, Serene, Tense, Miserable, Droopy, Delighted, Satisfied, Furious, Sad, Fatigued, Happy, Relaxed, Angry, Gloomy, Alert, Pleased, Calm, Afraid, Depressed, Astonished, Content, Terrified	Not Reported
4	Comfort	Comfortable-uncomfortable	Not Reported
6	Perceived atmosphere	Tense, Energetic, Sleepy, Gloomy, Annoying, Delightful, Quiet, Pleasing, Unsatisfying, Activating, Stressful, Unhappy, Jittery, Miserable, Enthusiastic, Calm, Placid, Depressive, Exciting, Elating, Sad, Sluggish, Boring, Satisfying	(Russell, 1980; Russell & Pratt, 1980; Yik et al., 2011)
8	Room appraisal	Attractiveness (Unattractive-Attractive, Ugly-Beautiful, Unpleasant-Pleasant, Dislike-Like, Somber-Cheerful); Illumination (Vague-Distinct, Dim-Bright, Gloomy-Radiant)	(Veitch & Newsham, 1998)
8	alertness	Alert-Sleepy	(Akerstedt & Gillberg, 1990)
9	subjective impressions	Beautiful-ugly, Focused-unfocused, Big-small, Visually warm-cool, Dislike-like, Short-long, Simple-complex, Pleasant-unpleasant, Glare-non glare, Public-private, Confined-spacious, Relaxing-tense, Bright-dim, Stimulating-depressing, Distinct-vague, Satisfying-frustrating, Colorful-colorless, Functional-nonfunctional, Vivid-faded, Ordinary-special, Messy-neat, Stable-unstable, Minimalist-motley, Virtual-real, Meaningful-not meaningful, Vulgar-fine, Nice-not nice, With message-indifferent, Wide-narrow, Uniform-non uniform	(Flynn et al., 1979)
10	Space impression	Not clarity-Clarity, not spaciousness-Spaciousness, not privacy-Privacy, Annoyed-Pleased, Relaxed-Stimulated, Disordered-Ordered	(Flynn, 1977)
11	NR	Cool, Refresh, Comfortable	Not Reported
12	Atmosphere perception	Detached, terrifying, musty, threatening, cozy, oppressive, depressed, exciting, formal, hospitable, safe, pleasant, tense, inspiring, intimate, chilly, cozy, cool, lively, luxurious, mysterious, uninhibited, uncomfortable, restless, relaxed, personal, romantic, spatial, tranquil, boring, lethargic, stimulating, accessible, hostile, cheerful, warm, business	(Vogels, 2008)
14	room light perception	Color appearance (warm-cool); Visual clarity (bright-dim, Clear-unclear, distinct-vague), Preference (like-dislike), Attractiveness (attractive-unattractive, inviting-not inviting)	Not Reported

Main Findings

The emotional outcomes influenced by lighting, along with its interaction with other independent and moderating variables across the included studies, are summarized as follows:

a. The combination of Illuminance × CCT

The emotional evaluation using the SCS method in Study 1 revealed that lighting conditions of 3100K×600lx, 3100K×1000lx, and 6500K×600lx were generally associated with negative arousal and positive valence, indicating relaxed and pleasant emotional states. These settings were recognized as the most comfortable and satisfying. High-illumination lighting (6500K×1000lx) resulted in positive arousal and valence, evoking feelings of excitement and alertness, with an atmosphere described as exciting and tense. In contrast, low-illumination settings (3100K×250lx and 6500K×250lx) led to feelings of depression, tiredness, and frustration. The findings from the SCS were consistent with the results from the Ambience Atmosphere Perception assessment using the CATA (Check-all-that-apply) method, and the objective evaluation of facial expressions aligned with participants' subjective self-reported emotions. According to FRE, valence was highest under the 3100K×600lx, 3100K×1000lx, and 6500K×600lx conditions, while arousal peaked at the 6500K×1000lx condition. Both dimensions were lowest in low-illumination settings (3100K×250lx and 6500K×250lx).

In Study 10, the lighting condition of 2700K×500lx (warm and bright) resulted in the highest levels of pleasure, while 5600K×500lx (cool and bright) led to the highest arousal and dominance. In contrast, 5600K×150lx (cool and dim) produced the lowest pleasure, and 2700K×150lx (warm and dim) evoked the lowest arousal and dominance. Thus, warm ambient lighting at 2700K increased pleasure more than cool lighting at 5600K, while 5600K lighting evoked greater arousal compared to 2700K.

Additionally, higher illuminance was associated with increased pleasure, arousal, and dominance. The study's findings on space impressions revealed that lower color temperatures (2700K) enhanced participants' sense of privacy and could create a pleasurable atmosphere in places such as restaurants, evoking feelings of happiness, joy, and relaxation. Higher illuminance levels enhanced the impression of spaciousness, while reduced illuminance promoted relaxation and a sense of privacy. To achieve clarity, the ideal lighting condition was 2700K×300lx. Therefore, to create a quiet, romantic, and private atmosphere, a combination of low color temperature (warm) and low illuminance is recommended, as it fosters a comfortable setting for intimate conversation. Conversely, higher color temperatures and illuminance levels are suggested to promote customer interaction and create an efficient atmosphere.

b. Correlated Color Temperature (CCT)

Study 2 showed that cold lighting (4200K) led to higher arousal than warm lighting (3000K). Under greenery conditions, cold lighting was associated with greater pleasure, while under non-greenery conditions, it resulted in higher arousal. In both 4200K and 3000K lighting conditions, retail greenery produced more pleasure than non-greenery.

c. Lamp Filtering (affecting luminous flux, glare, flicker, and light spectrum)

The fluorescent filters used in the classroom (Study 3) had a positive impact on students' emotions, with significantly higher average scores across all three emotional dimensions compared to unfiltered lighting. The greatest change was observed in Pleasure, followed by Dominance and Arousal. Interviews also revealed that filtered lighting helped reduce headaches, improve visual clarity, and maintain students' attention throughout the class.

d. Lighting Color

According to Study 4, colored lighting (blue-green, green-red, blue-red) reduced Dominance, increased Arousal, and slightly decreased Pleasure compared to white light. Consequently, transitioning from white to colored light resulted in a reduction in Surprise, Disgust, and Joy, while Fear, Anger, and Sadness increased. However, no significant difference was observed in Comfort.

Study 5 demonstrated differences in pleasure and arousal levels affected by six lighting colors. Blue was the most pleasant color, significantly enhancing pleasure compared to red and purple. Red, being the least pleasant, yielded significantly lower pleasure compared to other colors. The pleasure levels for lighting colors were ranked from highest to lowest as follows: blue, yellow, orange, green, purple, and red. Conversely, effects on arousal were ranked from highest to lowest as: red, yellow, orange, purple, green, and blue. Thus, blue was the least arousing lighting color. Ethnicity significantly moderated the effect of light color on pleasure, but not on arousal. Asians exposed to red, orange, and purple light report more unpleasantness compared to Caucasians. Nonetheless, both groups perceived blue as the most pleasant color and red as the least pleasant lighting color.

Study 7 found that the highest levels of pleasure among students occurred under purple-filtered lighting, while the highest levels of energy were observed under green-filtered lighting. No significant differences were observed between the outcomes of experiments conducted in two distinct environments using the same color filters.

e. Lighting Distribution/Direction × Illuminance × CCT × Lighting Color

Based on Study 6, of the fifteen lighting settings designed for an office-like environment, two were found to evoke positive emotions of liveliness (+Activation, +Pleasant) with the following characteristics: 1. Task lighting with a CCT range of 5000K to 5500K, 2. Accent lighting with a directional pattern, and 3. Saturated blue and cyan accent lighting. Additionally, three settings were linked to relaxation (Deactivation, +Pleasant), characterized by: 1) Task lighting with a CCT of 2700K to 3000K, 2) A lamp diffuser, and 3) A cove or up-light effect is created by accent lighting. Gloom was observed under: 1) Low task illumination (~250 lx) with indirect 2000K lighting, and 2) Accent lighting with a wall-washing and cove effect. Tension was associated with the following conditions: 1) High task illumination (~1500 lx) and 2) Direct 6500K lighting. This study, through the evaluation of 24 descriptors using CATA, identified a strong connection between perceived atmosphere and emotional states, suggesting that atmosphere is a reliable predictor of emotions.

f. Luminance

No significant changes in PAD dimensions were observed with varying wall luminance levels in Study 8. A non-significant increase in arousal was noted with increased wall brightness in the office environment. However, higher wall luminance significantly improved room appraisal in both attractiveness and illumination. Unexpectedly, the study found that low wall luminance negatively impacted participants' subjective alertness.

g. Lighting Distribution/Direction

Study 9 indicated that emotional and perceptual indices were highest under overhead lighting with gray and magenta walls. Both scales improved from front to overhead lighting in gray and magenta conditions, then declined under wall-washer lighting.

In wall-washer environments, emotions peaked with complementary green-magenta walls, while perceptual impressions were highest with contrasting yellow-blue walls. Front lighting with a complementary green-magenta scheme was linked to alertness, whereas overhead lighting with monochromatic magenta was associated with interest. Among the four dimensions proposed by (Kuller et al., 2009), this study confirmed only activation and evaluation, both closely associated with excitement and pleasure.

In Study 11, combined direct and indirect lighting in a residential living room significantly increased pleasantness, as indicated by SAM valence ratings. However, no significant difference in arousal was found between the combined and direct lighting conditions. According to VAS results, participants felt cooler under the combined lighting (Direct + indirect); however, no significant differences were found in refreshment or comfort scores. EEG data showed increased theta oscillations at F4, F8, T4, and TP7 electrodes under the combined lighting, but no significant differences were observed in alpha, beta, or gamma frequency bands between the two conditions.

h. Illuminance × CCT × Lighting Distribution/Direction

The pleasure dimension of emotion was significantly influenced by the three lighting settings used in Study 12. The High-Quality setting (warm accent with medium illumination) was rated higher in pleasure compared to the Discounter setting (cold accent with high illumination) and was significantly more pleasurable than the Hard Discounter setting (no accent with low illumination). Additionally, The High-Quality setting achieved the highest, though not significant, scores for the Arousal Subscales: Relaxation-Tension and Boredom-Excitement. It also had a subtle yet favorable impact on atmosphere perception, enhancing cosiness and liveliness while reducing tenseness.

i. Light Transmittance (Window Transparency/Glazing) × Regional Solar Conditions

Study 13 found that while participants preferred clear glazed windows over those with 40% transmittance (reduced visibility) and expressed greater satisfaction with transparent windows, glazing did not trigger negative emotions. Participants reported moderate levels of pleasure and arousal in both conditions, suggesting that semi-transparent windows did not contribute to stress or unpleasant feelings. However, emotional responses (pleasure and arousal) were higher when participants were seated facing the window compared to facing the door.

j. CRI × CCT

Based on Study 14, in a retail space, a CCT of 5000K (cool) was found to be more arousing than 3000K (warm), with American respondents rating all lighting conditions higher in arousal compared to Korean participants. Warmer light (3000K) was rated as more pleasurable than 5000K, and Americans found lighting with a 95 CRI more pleasurable than 75 CRI, while Koreans exhibited the opposite preference. Regarding behavioral intentions (Approach-Avoid), participants perceived cooler CCT (5000K) as more approachable than 3000K, with Koreans rating 5000K higher in approachability. For room light perception, 3000K was perceived as warm and 5000K as cool, regardless of cultural or CRI differences. Participants associated 5000K with greater visual clarity and brightness, yet preferred 3000K overall, with Americans expressing a stronger preference. All participants favored lighting with 95 CRI over 75 CRI, and 3000K was consistently rated as more attractive than 5000K, regardless of CRI.

k. Illuminance

A cross-interaction between noise levels and illuminance was found for high activation (HA) and activated pleasure (AP) in Study 15. As illuminance increased from 300lx to 1500lx, HA significantly decreased under 38 dBA noise but slightly increased under 58 dBA. A similar pattern was observed for AP. This suggests that higher noise and illuminance levels contribute to increased activation. The highest HA and AP scores were recorded at 38 dBA × 300lx, and the lowest at 38 dBA × 1500lx.

Table 5 provides a synthesis of key data on the characteristics and conditions of the 15 included studies.

Table 5. Key Characteristics and Conditions of Studies Included in the Systematic Review

	Authors	Population		Study Design	Lighting and other Independent/Moderator variables				Emotion / Affective state (Dependent variable)			Other Dependent Variables	Setting and Experimental Environment							
		Sample size (N) Male-Female	Age (range, M, SD)		Type of lighting	Lighting Components (Independent)	Other Independent / Moderator variables	Lighting Conditions	Model	Dimensions and Components	Indicator and Measurement Method/Tool		Function of Interior Space	Envi Displaying	Place of testing	Experimental Control Conditions T (°C)	RH	Size (m)	Before/ Between Light Expo	Total Length of Expt
1	(Zhang et al., 2023)	55 25M +30F	M=23.73 SD=2.24	within-subject	Artificial lighting	CCT 3100 and 6500K Illuminance 250, 600 and 1000lx	Nothing	6 lighting settings (2×3 factorial): 1. 3100K×250lx, 2. 3100K×600lx, 3. 3100K×1000lx, 4. 6500K×250lx, 5. 6500K×600lx, 6. 6500K×1000lx	VA (Circumplex model)	1. Valance happy-unhappy 2. Arousal sleepy-alert	Subjective Self-reported qtn (SCS method, 6×6 matrix) Behavioral facial expressions (FRE)	Dependent: Ambience Atmosphere Perception (25 emotional descriptors, based on the VA model, using the CATA method)	Special enclosed Operating workplace	1:1 Physical setting	Controlled lab	27	55%	2×2.5×2.2(h)	5mins Adaptation, 5mins Rest	2 months
2	(Sina & Wu, 2023)	295 295F	18-23	within-subject: greenery, between-subject: lighting (2 groups)	Artificial lighting	Color Temperature (CT) 3000 and 4200K	Independent Greenery: 1. greenery 2. no greenery Moderator: Shopping orientations	4 Lighting Settings (2×2 factorial): 1. warm lighting (CCT:3000K) + retail greenery 2. warm lighting (CCT:3000K) + no greenery 3. cold lighting (CCT:4200K) + retail greenery 4. cold lighting (CCT:4200K) + no greenery	PA	1. Pleasure (7 pair) 2. Arousal (7 pair)	Subjective Self-reported qtn (online; 7-point Likert scales, 1 to 7)	Dependent: 1. Satisfaction, 2. Purchase intentions, 3. Perceived merchandise quality	Fashion stores (Retail)	VR on PC	NR	NR	NR	NR	Nothing	NR
3	(Yuen et al., 2023)	58 (727 responses during 20 days)	first-year graduate students (probably 22-25)	ABAB withdrawal (A1:4days, B1:5days A2:4days, B2:7days)	Artificial lighting	Lamp Filtering (creamy-colored plastic sheets cover, affecting luminous flux, glare, flicker, and light spectrum)	Nothing	2 lighting conditions (overhead white fluorescent): 1. Baseline Unfiltered (luminous flux mean=89.2 ± 18 lm), 2. Filtered (55.3 ± 14.2 lm, light filter eliminated glare, reduced flicker and converted fluorescent into full-spectrum lighting similar to LED and natural lighting)	PAD	1. Pleasure (6 pairs) 2. Arousal (6 pairs) 3. Dominance (6 pairs)	Subjective Self-reported qtn (online survey-SurveyMonkey)	Dependent: Experiences extracted from interviews: 1. Headaches, 2. Visual clarity, 3. Attention	Classroom	1:1 Physical setting	Real Envi	NR	NR	8.5×13.3	Nothing	2 months and 16 days
4	(Zhang et al., 2022)	32 17M +15F	M=38.38 SD=14.23	Between groups (3 groups)	Artificial lighting	Lighting Colour 1. white light as the reference baseline, 2. blue–green, 3. green–red and 4. blue–red light	Nothing	3 lighting scenarios: 1. white light to blue–green light, 2. white light to green–red light, 3. white light to blue–red light (white light = 6500K, CRI>90, 120lx, Colour light = 48lx); Constant: Lighting Direction	PAD/ VAD	1. Valance happy-unhappy 2. Arousal excitement-sleepiness 3. Dominance uncontrolled-powerful	Subjective Self-reported qtn (SAM scale, -5 to +5)	Dependent: 1. Comfort	Waiting room	1:1 Physical setting	Controlled lab	23.5	56%	3.8×2.6×2.3	2mins Adaptation, 2mins Rest	15 days
5	(Lee & Lee, 2021)	82 41M +41F	19-45 M=29.46 SD=13.52	Within groups: lighting, Between groups: Ethnicity (2groups)	Artificial lighting	Lighting Colour red, green, blue, yellow, orange, purple	Moderator Ethnicity: Asian (n=34) and Caucasian (n=48)	6 lighting colors (RGB | CIELAB | Illumination): 1. red: 245.7.3 | 51.35/77.23/64.48 | 118lx	PAD	1. Pleasure (4 pairs) 2. Arousal (4 pairs)	Subjective Self-reported qtn (7-point semantic differential)	Nothing	Laboratory booths (rectangular-shaped)	1:1 Physical setting	Controlled lab	NR	NR	3.05×6.10×9.14	40secs Rest	NR

	Authors	Population		Study Design	Lighting and other Independent/Moderator variables				Emotion / Affective state (Dependent variable)			Other Dependent Variables	Setting and Experimental Environment							
								2. green: 60.172.60 | 62.33/-53.56/46.98 | 161lx 3. blue: 0.137.191 | 53.66/-11.27/-36.73 | 194lx 4. yellow: 255.210.0 | 85.68/0.61/86.26 | 205lx 5. orange: 254.127.0 | 66.71/42.94/73.75 | 172lx 6. purple: 119.10.255 | 40.18/81.45/-94.55 | 54lx												
6	(Kim & Mansfield, 2021)	42 22M +20F	20-40	within-subject	Artificial lighting	Lighting Distribution Lighting Direction Illuminance CCT Lighting Color	Nothing	15 lighting scenarios differ in: Distribution Types: Task lighting (Ceiling lights, Pendant lights, Table lamps), Accent lighting (Wall partition, Shelf lighting), Dynamic lighting; Lighting Color; Direction: Direct or Indirect; Illumination: 250 or 1500lx; CCT: 2000, 2700, 3000, 4000, 5000, 5500, 6000, 6500K	VA (Circumplex Model)	1. Pleasant Pleasant-Unpleasant 2. Activation Activation-Deactivation	Subjective Self-reported qtn (Affect Grid, single-item scale, 9× 9 matrix)	Dependent: Perceived atmosphere of the space (24 Descriptors, using CATA)	Office-like	1:1 Physical setting	Controlled room	24	NR	5.7(l)×4(w)×2.9(h)	3mins Rest	2 months and 10 days
7	(Suh et al., 2020)	58 (studio = 25 and classroom = 33) 12M +46F	18-45	between-group	Artificial lighting	Lighting Colour (Filter): 1. Orange, 2. Green, 3. Purple, 4. Existing light (Unfiltered)	Nothing	4 lighting conditions × 2 learning environment: design studio (average illuminance, average CCT): 1. Orange filter (50.4fc, 2550K), 2. Green (45.9fc, 3410K), 3. Purple (38.6fc, 3250K), 4. Existing light (61.5fc, 3270K); Education classroom (average illuminance, average CCT): 1. Orange filter (50.3fc, 2670K), 2. Green (48.4fc, 3420K), 3. Purple (35.5fc, 3280K), 4. Existing light (66.2fc, 3280K)	PE	1. Pleasantness Pleasant-Unpleasant 2. Energy Low energy level-High energy	Subjective Self-reported qtn (electronic survey, 11-point Likert scale, 0 to 10)	Dependent: Description of the own feel under the current lighting condition by a word	Design Studio and education Classroom	1:1 Physical setting	Real Envi	NR	NR	NR	Nothing	4 weeks
8	(de Vries et al., 2018)	37 23M +14F	18-29 M=20.59 SD=2.49	within-subject	Artificial lighting	Luminance Wall: 12, 36, 72 cd/m^2 Ceiling: 21, 27, 36 cd/m^2	Nothing	3 lighting conditions: (average of wall and ceiling luminance, and Vertical illuminance at the eye respectively):	PAD	1. Pleasure (6 pairs) 2. Arousal (6 pairs) 3. Dominance (6 pairs)	Subjective Self-reported qtn (7-point scales, 1 to 7)	Dependent: 1. Room appraisal (using VAS), 2. Subjective alertness, 3.Performance (problem-solving via objective measures)	Office	1:1 Physical setting	Controlled room	NR	NR	7.2(l)×7.2(w)×3(h)	NR	2 months

	Authors	Population		Study Design	Lighting and other Independent/Moderator variables				Emotion / Affective state (Dependent variable)			Other Dependent Variables	Setting and Experimental Environment							
								1. Low: 12 cd/m2, 21 cd/m2 and 206lx 2. Medium: 36 cd/m2, 27 cd/m2, 227lx 3. High: 72 cd/ m2, 36 cd/ m2, 254lx (Constant: horizontal illuminance on the desk=500lx)												
9	(Lombana & Tonello, 2017)	184 84M +100F	18-60 M=26 SD=6.7	within-subject: lighting direction, between-group: color of walls	Artificial lighting	Lighting Distributions/directions front, overhead and wall washer	Independent Color of wall: 1. yellow-blue (contrasting), 2. magenta (monochromatic), 3. gray (achromatic), 4. green-magenta (complementary)	3 lighting conditions × 4 Color condition of wall: 1. front, 2. overhead, 3. wall washer Different in Illuminance and luminance Constant: CCT of halogen lamps=3000k	AOEC	1. Activation 2. Orientation 3. Evaluation 4. Control	Subjective Self-reported qtn (4-grade rating scales)	Dependent: subjective impressions (30 pairs of Perceptual/visual opposite semantic scales)	Clothing store (Retail)	1:1 Physical setting	Controlled lab	NR	NR	3(l)×3(w)×2.3(h)	1min Adaptation	NR
10	(Wu & Wang, 2015)	33 11M +22F	19-24	within-subject	Artificial lighting	Color Temperature (CTs) 2700 and 5600K Illuminance 150, 300 and 500lx	Nothing	6 lighting conditions (2×3 factorial) 1. 2700K×150lx, 2. 2700K×300lx, 3. 2700K×500lx, 4. 5600K×150lx, 5. 5600K×300lx, 6. 5600K×500lx	PAD	1. Pleasure (6 pairs) 2. Arousal (6 pairs) 3. Dominance (6 pairs)	Subjective Self-reported qtn (7-point Likert scales)	Dependent: Space impression	Restaurant	1:1 Physical setting	Controlled lab	NR	NR	2.5×2.5×3(h)	3mins Rest	NR
11	(Shin et al., 2014)	28 16M +12F	M=22.5	within-subject	Artificial lighting	Lighting Distributions/directions 1. direct + indirect, 2. direct	Nothing	2 lighting conditions: 1. direct + indirect lighting: 400 lx downlight + 300 lx up light, 2. direct: 700 lx downlight (Constant: CT=5000K, Illuminance=700lx)	VA	1. Valance happy-unhappy 2. Arousal excited-relaxed	Subjective Self-reported qtn (SAM, 9-point graphical rating scales) Neurophysiological EEG signals as a biological marker	Dependent: 1. Brain activity (delta, theta, alpha, beta, and gamma) 2. VAS including 3 emotion adjectives of Cool, Refresh, Comfortable	Living room	1:1 Physical setting	Controlled lab	23.3 (SD = 0.3)	21.3% (SD = 1.0)	4.7×4.4×3.1(h)	4mins Adaptation	NR
12	(Quartier et al., 2014)	95 30M +65F	18-63	between-subject	Artificial lighting	Illumination Low, Medium, High CCT: warm, Cold Distribution/Direction Accent, without accent	Nothing	3 lighting scenarios: 1. High quality: warm accent lighting and medium illumination, 2. Discounter: cold accent lighting and high illumination, 3. Hard discounter: without accent lighting and low illumination	PAD	1. Pleasure 2. Arousal	Subjective Self-reported qtn (7-point Likert scale)	Dependent: 1. Atmosphere perception (38 descriptors), 2. shopping behavior, 3. Image Perception (price, quality and service)	supermarket (Retail)	1:1 Physical setting	Controlled lab	NR	NR	9×9	Nothing	2 weeks
13	(Sylvester & Bowler, 2012)	188 126M +62F	M=20	within-subject	Natural lighting	Window Transparency/Glazing (Light Transmittance) 100% or 40% Regional Solar condition New York, Detroit, Houston, Los Angeles	Independent View: 1. Window or 2. Non-Window	8 lighting conditions (2 × 4 factorial) × 2 View condition 1. clear glazing (100% Transparency) × 4 regions differ in solar irradiance levels and the position of the sun (Sim.Sun & Refl.Light)	VA	1. Pleasure Pleasant-Unpleasant 2. Arousal Arousal-Sleepiness	Subjective Self-reported qtn (Affect Grid; 9× 9 matrix)	Nothing	Office	time-lapse animated sequences	NR	NR	NR	10×15 feet	NR	NR

	Authors	Population		Study Design	Lighting and other Independent/Moderator variables				Emotion / Affective state (Dependent variable)			Other Dependent Variables	Setting and Experimental Environment							
								2. semi-transparent window glazing (40%) × 4 regions												
14	(Park & Farr, 2007)	98 47M +51F	19-35	between-subject: Cultural Background within-subject: lighting conditions	Artificial lighting	CRI 75 or 95 CRI CCT 3000 or 5000K	Moderator: Cultural Background: 1. Caucasian-American (N=49; 22M + 27F), 2, Korean (N=49; 25M + 24F)	4 lighting conditions (2×2 factorial) × 2 Cultural Background 1. 75CRI×3000K, 2. 75CRI×5000K, 3. 95CRI×3000K, 4. 95CRI×5000K (Controlled: Lumen output; Constant: 600lx on the surface of the printed questionnaire)	PAD	1. Pleasure (3 pairs) 2. Arousal (2 pairs)	Subjective Self-reported qtn (7-point Likert scale)	Dependent: 1. Behavioral Intentions, 2. room light perception	Clothing store (Retail)	1:1 Physical setting	Controlled lab	NR	NR	2 cubic room, each one: 1.75×1.92×3.2	1min Adaptation, 1min Rest	NR
15	(Hygge & Knez, 2001)	128 64M +64F	18-19	between-subject	Artificial lighting	Illuminance 300 and 1500 lx	Independent Noise: 38 and 58dBA Heat: 21 and 27C Gender	2 lighting conditions × 2 Noise condition × 2 Heat condition × 2 Genders 1. 300 lx, 2. 1500 lx (constant condition: color temperature of 3000K (light source) and a color-rendering index of 95)	VA (Circumplex Model)	1. Pleasant 2. Activation (arousal) (48 adjectives representing 8 affect states)	Subjective Self-reported qtn (5-point Likert Scale)	Dependent: Cognitive Performance: 1. Attention 2. Problem-solving 3. Long-term and Short-term recall	Office (neutral off-white chamber furnished)	1:1 Physical setting	Controlled lab	21 and 27	NR	3.9×3.8×2.5	NR	NR

A: Arousal/Activation; C: Control; CATA: Check-all-that-apply; CCT: Correlated Color Temperature; CTs: Color Temperature; D: Dominance; E: Evaluation/Energy; EEG: Electroencephalogram; Envi: Environmental; Expo: Exposure; Expt: Experiment; F: Female; fc: footcandle; FRE: Face Reader; lm: lumens; M: Male; Mins: Minutes; NR: Not Reported; O: Orientation; P: Pleasure; qtn: questionnaire; RH: Relative Humidity; SAM: Self-Assessment Manikin; SCS: Subjective Coordinate Scale; Secs: Seconds; T: Temperature; V: Valence; VAS: visual analog scales

DISCUSSION

General Study Information

Based on the results of this review, it can be inferred that while research on the impact of lighting on emotional and affective states in interior spaces is limited, there is a growing interest in this field. The prevalence of studies indicates that developed countries tend to focus more on this topic, likely due to the limitation of publication language to English, as outlined in the search strategy.

Study Characteristics and Conditions

Methodologically, there are several noteworthy points regarding the conditions and characteristics of the studies, as outlined below:

In some studies, gender balance was not maintained, which could potentially introduce bias. The emotion assessment method seems to influence the number of participants. For instance, Studies 1 and 11, which used facial expressions as a behavioral indicator and EEG signals as a neurophysiological indicator, involved 55 and 28 participants, respectively, with small sample sizes but balanced gender representation. In contrast, studies employing subjective measures like questionnaires typically had larger sample sizes. This discrepancy likely stems from the high costs, technical complexity, and time-consuming data collection and analysis associated with EEG and FRE, as well as the stringent protocols required for controlled lab conditions. Participant age ranges vary across studies. Except for Study 3, which focused on first-year graduate students due to its educational lighting context, it is unclear whether the narrow and youthful age range in Studies 1, 2, 10, and 15 results from specific research objectives or simply from the availability of young university students. It is important to note that the variable of age may influence visual responses to lighting; however, in none of the studies was age considered as a mediator variable. Although studies ensured participants' health and, in some cases, the irrelevance of their academic background to the research topic, selecting only highly educated individuals may introduce bias by raising the education level above that of the general population.

For lighting assessment, participants were commonly placed in physical environments, except for Studies 2 and 13, which utilized VR and animation. Most research was conducted in controlled laboratory settings, except for Studies 3 and 7, which were conducted in real classrooms or studios despite controlling lighting and physical conditions, potentially introducing bias. While most studies reported the dimensions of the lit environments, only Studies 1, 4, 6, 11, and 15 mentioned humidity or temperature conditions. Approximately half of the studies controlled participants' prior light exposure or incorporated visual rest periods between the two experimental scenarios, with the allocated durations varying across studies. In contrast, the remaining studies did not address prior light exposure, resulting in inconsistent experimental conditions. Additionally, the duration of participant immersion and the total length of all experimental phases varied, leading to inconsistencies in temporal conditions.

A relatively wide range of lighting components has been evaluated, including quantitative parameters like illuminance, CCT, lighting color, CRI, and luminance (in order of frequency), as well as qualitative factors such as lighting distribution/direction, window transparency (glazing), regional solar conditions, and lamp filtering. There is a considerable lack of studies on natural lighting and insufficient attention to the quality of artificial lighting from a design perspective, particularly lighting, depending on architectural form and the physical structure of interior spaces.

Subjective indicators, including various types of self-report questionnaires, are commonly used for emotional assessment. In contrast, only two studies have used facial expressions as an objective behavioral indicator and EEG as an objective neurophysiological one. Consequently, the disregard for modern neuroscience methods, along with the wide variation in methodological and reporting procedures, has led to inconsistencies in emotion measurement methods and even data analysis.

Main Finding

The findings from all studies, except for Studies 8 and 13, indicate that emotions and affective states are influenced by lighting conditions. As noted in many studies, including Studies 8 and 9, changes in one lighting parameter often affect others. Specifically, lamp filtering impacts luminous flux, glare, flicker, and lighting spectrum (Study 3), color filters alter CCT (Study 7), and increased average wall luminance raises vertical illuminance at the eye and average ceiling luminance (Study 8). Additionally, changes in lighting color affect both CCT and illuminance (Studies 4, 5, and 7), while different lighting distributions/directions create varied luminance conditions or alter illuminance (Studies 6, 9, 11, and 12). Therefore, the observed emotional changes cannot be attributed merely to manipulation of individual lighting components, but likely result from the unintended interaction of multiple interrelated factors.

In four studies, the impact of lighting conditions on emotions was evaluated alongside other independent variables, increasing the risk of bias due to unintended effects of non-lighting factors. In Study 2, greenery conditions likely led to greater pleasure compared to non-retail greenery. In Study 9, alertness and interest may have been evoked by the magenta wall color. Additionally, in Study 13, a window view compared to a view of the door was associated with increased pleasure and arousal, and in Study 15, the increase in activation was attributed to higher environmental noise rather than increased illuminance. Furthermore, in many studies, other dependent variables besides emotional states were evaluated during the experiment. Although these additional variables may be minor, they could potentially affect emotional responses by diverting participants' attention to other issues.

The findings reveal a promising relationship between emotion and "atmosphere perception, room light perception, room appraisal, and space impressions, "suggesting that these factors can serve as predictors of emotion or enhance the interpretation of emotion assessment findings (Studies 1, 6, 8, 9, 10, 12, and 14). However, the emotional vocabulary used to measure these concepts is limited. It is recommended to employ specific emotional dimensions and methods for a more comprehensive and nuanced evaluation of current emotions. Notably, the CATA method for assessing Atmosphere differs from the SCS method for emotion measurement: CATA is more suitable for rapid and precise assessments, especially when the free emotional expression is not required and there are many participants or experimental settings (Study 1). Furthermore, since Study 1 found that facial expression assessments align well with subjective indicators, incorporating facial expressions as a supplementary method focused on behavioral and objective measures is recommended.

Given the limited number of studies in this field and some inconsistencies, drawing a definitive conclusion about the emotional outcomes of different lighting conditions is challenging. There is general agreement across several studies on certain effects: increased pleasure (or valence) with higher illuminance and decreased pleasure with lower illuminance, and a similar pattern for arousal (or activation) in relation to illuminance. Higher and lower levels of arousal are also associated with higher (cooler) and lower (warmer) color temperatures, respectively (Studies 1, 2, 6, 8, 10, 14). Since higher color temperatures make spaces appear brighter (Study 14), this may explain the link between high arousal and cooler color temperatures. Moreover, studies show that mixed lighting direction/distribution (Studies 9, 11, 12) and relatively complex lighting arrangements (Study 6) increase pleasure. However, the relationship between pleasure and color temperature is not fully consistent. The findings, though limited, suggest that high illuminance is linked to increased dominance (Study 10), colored light with lower dominance and higher arousal (Study 4), and red light with the highest arousal levels (Study 5). Although Study 4 indicates that the use of colored light reduces environmental pleasantness, Study 6 shows contradictions regarding the relationship between light color and pleasure, while Study 5 reports that blue light results in the highest level of pleasure. Furthermore, Study 3 presents a contradiction, as the use of lamp filters, which reduce classroom luminous flux by up to 38%, still leads to greater arousal compared to unfiltered conditions.

Future Research

Despite extensive research on the impact of artificial lighting parameters on emotions, the effect of indoor lighting quality from an architectural design perspective remains largely unexplored. In other words, the influence of lighting, as an integrated element of the architectural and physical structure of interior spaces, on emotional and affective states has yet to be thoroughly examined. Further investigation of this topic is recommended for researchers and designers. Additionally, a systematic review of the effects of lighting on mood, perception, spatial impressions, and other emotion-related concepts is suggested.

CONCLUSIONS

The findings of this systematic review, derived from the 15 included studies on the impact of lighting on emotions in architectural interior spaces, are summarized in response to four research questions:

1. Based on the evidence, some lighting conditions, as outlined below (Table 6), can significantly influence the emotional and affective states of occupants in interior spaces:

Table 6. Summary of the Main Findings from the Literature on the Impact of Lighting on Emotions in Architectural Interior Spaces

Lighting Components	Study	Key Findings from 15 Research Studies (Lighting Conditions ⇒ Emotional States)	Final Summary
Illuminance × Color Temperature	1	3100K×600lx, 3100K×1000lx, 6500K×600lx ⇒ -Arousal and the Highest +Valance (Relaxed, Pleasant, Satisfied); 6500K×1000lx (high Illumination and CT level) ⇒ +Valance and the Highest +Arousal (Excited, Alert, Tense); 3100K×250lx (low Illumination and CT level) ⇒ The Lowest -Arousal and -Valance (Fatigued and Depressed); 6500K×250lx (Cool and Dark) ⇒ +Arousal and -Valance (Afraid, Gloomy and Depressed)	↓V: Low Illuminance; ↑V: High Illuminance; ↑A: High Illumination and Cool; ↓A: Low Illumination and Warm
	10	Warm & Bright (2700K×500lx) ⇒ The Highest Pleasure; Cool & Dark (5600K×150lx) ⇒ The Lowest Pleasure; Cool and Bright lighting (5600K×500Lux) ⇒ The Highest Arousal and Dominance; Warm and Dark lighting (2700K×150Lux) ⇒ The Lowest Dominance and Arousal	↑P: Warm lighting (low CT); ↑A: Cool lighting (high CT); ↑P↑A↑D: High Illuminance
CCT	2	Cool lighting of 4200K under both greenery and non-greenery conditions ⇒ Higher Arousal; Both Cool (4200k) and Warm (3000k) lighting under greenery conditions ⇒ Higher Pleasure	↑A: Cool lighting (high CT)
Lamp Filtering	3	Filtered fluorescent light ⇒ Higher Pleasure, Arousal and Dominance (positive impact on emotions)	↑P↑A↑D: Lamp Filtering
Lighting Color	4	White to Colored light (blue-red, green-red, blue-green) ⇒ Decrease in Pleasure (insignificantly); White to Colored light ⇒ Increase in Arousal and Decrease in Dominance (significantly); White light to Colored light ⇒ Surprise, Disgust, and Joy decreased, while Fear, Anger and Sadness increased	↓P↑A↓D: Colored light
	5	Blue ⇒ The most Pleasant lighting color (Pleasure rating: Blue, Yellow, Orange, Green, Purple, Red); Red ⇒ The most Arousing lighting color (Arousal rating: Red, Yellow, Orange, Purple, Green, Blue)	↑P: Blue lighting; ↑A: Red lighting
	7	Purple-Filtered light ⇒ The Highest Pleasantness; Green-Filtered light ⇒ The Highest Energy	↑P: Purple filter; ↑E: Green filter
Distribution / Direction × Illuminance × CCT × Lighting Color	6	Cool Task lighting (5000-5500K)+Blue and Cyan Accent lighting (directional)⇒ Liveliness (Activation, Pleasant); Warm Task (2700-3000K)+Lamp diffuser+Accent (cove or up-light effect) ⇒ Relaxation (Deactivation, Pleasant); Warm (2000K)×250lx (Low Illuminance) Task lighting (indirect)+Accent lighting (wall-washing and cove)⇒ Gloom High Task Illumination (~1500 lx) by using direct lighting with a CCT of 6500K ⇒ Tense	↑A↑P: Cool Task, Blue & Cyan directional Accent lighting; ↓A↑P: Warm Task, Lamp diffuser, Cove or Up-light Accent lighting
Luminance	8	No effects were found on the PAD dimensions of emotion; Increase in wall luminance ⇒ Modest increase in Arousal	↑A non-significant: ↑Wall luminance
Lighting Direction / Distribution	9	Overhead Direction with gray and magenta wall color ⇒ The Highest Emotion rates of AOEC (specially Interest);	↑AOEC: Overhead Direction

Lighting Components	Study	Key Findings from 15 Research Studies (Lighting Conditions ⇒ Emotional States)	Final Summary
		Front Direction in the green-magenta wall color conditions ⇒ Alertness emotional scale	
	11	Direct + Indirect lighting ⇒ More Pleasant (Higher Valence) and Cooler feeling; Direct + Indirect lighting ⇒ Increase in theta oscillations at F4 and F8 (correlated with cool), T4 & TP7 electrodes No significant differences in Arousal and power in the Alpha, Beta, and Gamma frequency bands;	↑ P(V): Direct + Indirect lighting No effect on A
Illuminance × CCT × Distribution/Direction	12	Warm × Accent lighting × medium Illumination ⇒ The Highest Pleasure (more Pleasurable), the most favorable (not significant) score for Relaxation-Tension and Boredom-Excitement (Arousal Subscales).	↑ P: Warm × Accent lighting × medium illumination
Window Glazing × Solar Condition	13	All conditions ⇒ Moderate levels of Pleasure and Arousal (Affective States); Window glazing (lower transmittances) ⇒ did not create negative emotional responses.	No effect on P and A
CRI × CCT	14	Cool lighting (high CCT, 5000K) ⇒ Higher Arousal; Warm lighting (Low CCT, 3000K) ⇒ Higher Pleasure	↑ A: Cool lighting (high CCT); ↑ P: Warm lighting (low CCT)
Illuminance	15	Increase in Illuminance (300lx to 1500lx) × noise of 38dBA ⇒ Decrease in High Activation & Activated Pleasure Increase in Illuminance (300lx-1500lx)×58dBA ⇒ Increase in High Activation (HA) & Activated Pleasure (AP) 38dBA×300lx ⇒ The Highest score of HA and AP; 38dBA×1500lx ⇒ The Lowest score of HA and AP	↑ A: ↑ Illuminance and ↑ Noise

A: Arousal/Activation; **C**: Control; **CCT**: correlated color temperature; **CRI**: Color Rendering Index; **D**: Dominance; **E**: Evaluation/Energy; **O**: Orientation; **P**: Pleasure; **V**: Valence

Despite the diverse and sometimes contradictory findings from the studies (Table 6), there is a consensus on several key results, as follows (Table 7): Generally, all three dimensions of pleasure, arousal, and dominance are directly related to illuminance levels, while only arousal is directly and significantly affected by correlated color temperature (CCT). In other words, to enhance the levels of pleasure, arousal, and dominance, high illuminance in the environment is recommended. Conversely, utilizing low illuminance can reduce all three dimensions. Additionally, high (cool) and low (warm) CCT can be employed in the environment to achieve high and low arousal, respectively. Furthermore, the simultaneous use of direct and indirect lighting, along with relatively complex lighting distribution, enhances pleasure, while colored light is associated with an increase in arousal and a decrease in dominance. However, the effects of color temperature and lighting color on pleasure remain inconsistent.

As the main finding of this study, the above strategies are proposed for the practical application of the research findings, based on the consensus reached in the literature (Table 7). These strategies demonstrate how targeted emotional states (desired emotional outcomes) can be achieved through specific lighting interventions. It is important to note that, despite the growing interest in this field, the number of studies conducted remains limited, highlighting the need for further research to develop a deeper and more comprehensive understanding.

2. The existing literature predominantly focuses on quantitative parameters of artificial lighting in architectural interiors. Most studies have evaluated the effects of illuminance, correlated color temperature (CCT), lighting color, and lighting distribution/direction on emotions or affective states. In contrast, less attention has been given to regional solar conditions, color rendering index (CRI), luminance, and lamp filtering. Regarding natural light in indoor spaces, only the parameter of light transmittance (window transparency) has been evaluated.

3. Most previous studies have focused on administrative, commercial, and educational functions, often employing controlled physical laboratory environments to present lighting conditions. Methodologically, emotions are primarily measured through subjective indicators, utilizing self-report questionnaires based on the multi-point Likert scales, Affect Grid, Self-Assessment Manikin (SAM), and Subjective Coordinate Scale (SCS). The literature typically emphasizes two-dimensional (Circumplex model) and three-dimensional (Mehrabian and Russell) models, which encompass the dimensions of pleasure (or valence), arousal (or activation), and dominance. Each dimension is measured using a broad range of emotional components included in the questionnaires.

4. A considerable research gap exists in the current literature regarding emotional responses to indoor artificial lighting quality from an architectural design perspective, particularly the aspect of lighting that is dependent on the architectural and formal structure of interior spaces. Moreover, studies exploring the impact of lighting on emotions in interior spaces often neglect natural lighting, residential indoor settings, and objective behavioral and neurophysiological indicators that could provide more accurate measurements of emotional reactions. Future studies should address these areas to effectively bridge the existing research gaps.

It is hoped that this study's findings will be useful as a strategy for designers and architects to regulate emotions through science-based lighting interventions and, consequently, ensure the mental well-being of occupants.

Table 7. Lighting Strategies Based on the Main Findings on Which There is a Consensus in the Literature

Emotional Dimension		Illuminance	Color Temperature	Lighting Color	Lighting Direction/Distribution
Pleasure (Valence)	High	High	-	-	Combined and relatively Complex
	Low	Low	-	-	-
Arousal (Activation)	High	High	High (Cooler)	Colored light (Especially Red)	-
	Low	Low	Low (Warmer)	-	-
Dominance	High	High	-	-	-
	Low	Low	-	Colored light	-

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HOW TO CITE THIS ARTICLE

Mohammad-Moradi, A., Yazdanfar, S.A., Khanmohammadi, M.A. (2025). The Impact of Lighting on Emotions in Architectural Interior Spaces: A Systematic Review. *Int. J. Architect. Eng. Urban Plan,* 35(1): 1-28, https://dx.doi.org/ijaup.872.

URL: http://ijaup.iust.ac.ir