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Research Article

Cultural Sustainability: Investigating User Preferences for Retail Lighting Conditions

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Abstract: This study investigates the cultural dimension in sustainable lighting design to create inclusive environments. India being one of the most culturally and ethnically diverse nations in the world, with a population of almost 18% of the world population, requires attention to include cultural dimension in the design of sustainable environments. With the changing lifestyle and growth in organized retailing, the Indian retail market needs an upgrade to create inclusive environments for shared retail experiences. Lighting is among most influencing atmospheric attribute to create simulating environment for a holistic shopping experience. Preference of lighting conditions vary across the store profiles and users' cultural background. Very little research has been carried out to understand the lighting preferences of retail customers in India. This study investigated the effects of correlated colour temperature and illuminance levels on spatial impressions and user preferences in mid-range store profile. This study involved ninety-three participants in evaluating high definition visualisations of the sixteen lighting conditions. The observations from this study emphasizes the necessity of similar studies across various states of India to identify the lighting preferences for other functional spaces and cultural backgrounds within the country. The findings may contribute towards providing recommended guidelines in lighting design and include a cultural dimension in the design of sustainable store environments.

Keywords: cultural sustainability; inclusive design; retail space; illuminance level; correlated colour temperature (CCT); spatial impression; user preference; Indian context

1. Introduction

Culture as a driver of sustainability connects different interest groups and contributes to the collective identity, development and inclusivity of a society [1]. Although sustainability has become a defining theme in creating preconditioned environments for quality lifestyle, sustainable societies need to involve a cultural dimension along with the ecological, economic and social components [2]. Cultural dimensions influence the perception of space and, in turn, users' decision making, which encourages the researchers to explore the localized design factors [3]. The concept of cultural sustainability includes the diversity of human values, subjective meanings and expressions that allow distinction between cultures [2]. However, cultural dimensions are less explored compared to the environmental and economic dimensions. Consequently, there is a lack of knowledge to maintain inter-cultural standards within the design process.

India being one of the most culturally and ethnically diverse nations in the world, requires an essential understanding of how its sub-cultures perceive certain design elements to create an inclusive environment. Indian retail market is gradually experiencing the benefits of organized retailing, with increasing urbanization, rising household incomes, connected rural consumers and aspirations of the middle-class population to maintain a high-quality lifestyle [4,5]. Driven by a shift in consumers' expectations and a broader target market, retail environments need an inclusive design for shared retail experiences.

Retail design trends suggest that shoppers are increasingly expecting a stimulating atmosphere for a holistic shopping experience [6–8]. Increasingly competitive markets and demanding customers are driving retail outlets and showrooms to display products in an attractive environment [9]. Lighting is a key influencer within retail environments and plays a vital role in enhancing brand visibility and increasing footfall [10–12]. Lighting requirements may vary across different retail segments and stores based on the requirements of the displayed merchandise or for creating a distinct brand identity.

Spatial perception and preference for lighting conditions vary with the type of spaces, ethnic groups and familiarity with local lighting in similar ambiences [13–16]. The selection of the correlated colour temperature (CCT) of light sources depends on the classification of the retailer, quality of merchandise and client preferences [17]. Very little literature has been found to understand customer preferences in retail lighting, thus creating a need to understand the lighting preferences of retail customers.

This study aims to investigate the effects of lighting conditions on spatial impressions and determines users' lighting preference for retail apparel stores within the Indian context. The study also analyses the relation between the quality of lighting and spatial impression. The observations from this study aim to provide guidelines in retail lighting design and include a cultural dimension in the design of sustainable retail environments.

1.1. Related Research

1.1.1. Retail lighting

Retail stores perform the dual role of being able to purchase goods after physically examining while providing a social experience. Retail environments, therefore, need to be inviting, stimulating and satisfying. Several studies [18–20] show that physical environments influence consumer behaviour and preferences in retail stores. The atmosphere of the space in which a product is purchased influences the purchase decision, sometimes more than the product itself [9]. Store atmospheres can be improved by environmental variables such as colour, light, scent, texture, etc. [12,21,22], where lighting is an effective stimulus to influence the atmosphere, spatial impression and consumer behaviour [19,23]. Several studies acknowledge that the lighting has a profound impact on the atmosphere of the retail setting and the appearance of the displayed merchandise [10,24–27].

Early research indicates that light distribution and illuminance levels significantly impact the perception of space [28,29]. Light was found to be one of the two essential factors that influence time spent in the store and willingness to interact with the store personnel [30]. Perception is not limited to visual clarity as it impacts the impression of the space [16], but also be used to communicate corporate identity [31]. Light distribution and illuminance levels impact the perception of attributes like clarity, spaciousness, relaxation, privacy, pleasantness and order. [32]. Lighting was found to be the most influential atmospheric factor out of colour, furnishings, layout, lighting and style for a hotel lobby space [33]. Further, CCT also impacted the time spent in a furniture store and the order of visiting illuminated furniture [34]. Lighting also has a measurable impact on space perception in the retail environment [10]. Lighting attributes, CCT and Illuminance, can impact the perceived image of a store as a discount store, speciality store, boutique, etc. [26,27].

1.1.2. Lighting conditions and spatial perception

Illuminance levels and CCT influence space perception and impact mood [35]. In an office space, 4000K CCT gave an impression of more comfort and spaciousness than 2700K CCT, while 2700K was perceived as more relaxing than 4000K [14]. Perception of atmosphere in a restaurant at different CCT and illuminances depended on the attribute measured, such as privacy, pleasure, arousal, dominance and spaciousness. Overall preference was for a low CCT of 2700K and high illuminance of 500 lux [15]. Thus, the choice of a particular CCT depended on the attribute measured. Further, the preference of CCT was dependent on the purpose of space and the specific activity performed in the space [13].

Research efforts in the past concentrated on understanding the effects of lighting in an office environment [36]. Recently several studies were taken up concerning retail stores. Even though retail stores have several visual cues, lighting was found to significantly impact the perceived atmosphere [10]. Lighting design specifically affects the perception of the pleasantness of the space, the price point of the retail products and their quality [25]. Similarly, in a semi-realistic retail store setting, changes in light settings alone significantly impacted the type, perception of quality, and price point of the store [26]. In retail spaces, the preference for CCT also depends on the specific area that is illuminated; for hangers and table displays, 3000K was preferred, but for mannequins, 4500K was preferred [37].

Apart from the function of a place and the task performed in it, the preference for specific lighting conditions is also dependent on the culture of the users. Lighting design is dependent on visual cues interpreted by users of a shared culture and background [16]. "A large body of evidence suggests that at least up to a point, increasing exposure to (and therefore familiarity with) a wide range of stimuli enhances affective reactions to these stimuli." [29].

Specific experiments conducted to compare the cultural impact on the preference of CCT have confirmed these. In a living room, higher CCT was considered livelier by Chinese participants compared to a similar study conducted by Vogels for Dutch participants where lower CCT was felt as livelier [38]. Europeans preferred less than 4000K in a model office setting, while Asians and Africans preferred 4000K to 5000K [39]. In separate studies for office ambience, 4000K was preferred by Indians living in Tier 1 City Hyderabad [40] and Malaysians [41]. The Chinese preferred 4300K for unfamiliar artwork, while Americans preferred 6000K[42]. Along with ethnicity, the current place of stay also impacts the preference for CCT. For coloured object combinations, Chinese living in Germany had different preferences compared to Chinese living in China or Europeans living in China. [43].

In the case of retail stores, Americans prefer 3000K CCT, whereas Koreans prefer 5000K [44]. Apart from cross-cultural studies, studies conducted in specific countries yielded different CCT preferences for retail stores - Turkish prefer 2700K for a retail store [34], Chinese prefer 5500K [45], South Koreans prefer 3000K and 4500K for different regions of the store [37]. Cultural impact is also seen on illuminance levels where Americans preferred low-intensity warm lighting, but Koreans preferred high-intensity warm lighting for a hotel [46].

1.1.3. Simulations in lighting research

Lighting research experiments are often held in laboratories or real-time spaces [47]. Conducting these traditional lighting experiments for different lighting conditions will incur a higher cost for luminaires, equipment and spaces for the activity setup, be it real-time space or mock-up space [48]. It takes longer for setting up the space with various lighting conditions and the measurement of the results. Further, it limits the sample space, as the participants are limited to the geographical area around the experimental area. Environmental psychologists and theorists have explored static and dynamic simulated environments, which gave similar results as the real environments [49].

Images are used to evaluate architectural spaces instead of real or mock-up spaces. Multiple studies have established that evaluating architectural spaces by images is similar to assessing them physically [50–52]. In particular, some studies demonstrated that images could be used for assessing lighting in architectural spaces [13,53,54]. Comparison between the evaluation of lighting conditions in physical clothing, book and furniture

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stores with digital photographs of the same spaces has confirmed that digital photographs can be reliably used instead of real environments [11].

While photographs increase the geographical reach of the experiments, the twin challenges of time and cost remain. With the development in technology, photorealistic computer simulations and lighting simulations are widely used by researchers, architects and lighting designers to analyse various aspects of lighting quality of daylighting and electric lighting in both indoor and outdoor environments. These simulations provide the opportunity to assess multiple design solutions and improve lighting quality in the environment. Computer simulation has become a widely used tool to explore lighting and user perception in architectural spaces [25,27,31,37,55–57]. Several studies have established that the perception of lighting using simulations is similar to that of mock-up spaces. [37,54,58–60].

An early study has established that high-quality visualisations can elicit similar responses to real spaces in validating lighting conditions in terms of psychological impressions, perceptual clarity, spaciousness and visual warmth [61]. Computer simulations and display methods can be effective in lighting research and design process to analyse and validate parameters like pleasantness, contrast, diffuseness, uniformity, shadow, cosiness, liveliness, tenseness, detachment [60]. The simulated images can be presented on a single calibrated display in an experimental room or on the participants' displays. If the sample size is sufficiently large, there are no significant differences between these two methods as the large sample size nullify any differences due to calibration differences [62]. Further, these calibration differences can be minimised by specific instructions to calibrate participants' displays.

2. Materials and Methods

2.1. Methodological approach

The goal of this experimental study is in line with the increasing interest in lighting design consultants to create stimulating environments for spaces based on activity and user profile. Many studies have acknowledged there have been efforts to find a correlation between lighting conditions and spatial impression, spatial perception and preference, and users' personal profile and preferences for various functional spaces. Thereby, this study attempts to quantify the lighting conditions based on visual and spatial impressions; and identify preferred illuminance and CCT by Indians for a retail apparel store.

The study explores the following hypotheses:

H1. Preference for a specific CCT and average illuminance can be identified for a retail apparel store in the Indian context.

H2. Illuminance and CCT influence spatial perception attributes of a retail apparel store.

H3. Spatial perception attributes influence the users' overall preference on lighting conditions for a retail apparel store.

Experimental design and procedure: Retail lighting design through a simulation-based subjective approach for sales area was used to understand the preference and perception of luminous environment. The advantage of virtual model experimental space is that it was relatively quick and easy in involving diversified participants from different locations. A 4 X 4 factorial design was employed with two independent variables: CCT (2700K, 3000K, 4000K and 5700K) and illuminance level (300 lx, 500 lx, 700 lx and 900 lx). The luminous intensity distributions data of light sources used in the simulation model was collected from the manufacturer's specification as IES format files. The sixteen resulting lighting conditions tested in this study were evaluated on the calibrated digital display during the data collection. The simulated lighting conditions were presented on the screen with a display resolution of 1920 x 1080, followed by the bipolar adjective questionnaire. Participants were asked to rate the lighting conditions for spatial impressions and overall

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preference for each scene. The scene evaluation was performed with 93 Indian participants (47 women and 46 men) aged between 18 and 60. The scene sequence was randomised to eliminate order effects.

2.2. Experiment settings - Retail virtual environment

Virtual environment: A retail environment with sixteen scenarios of varying CCTs and illuminance levels was initially simulated in DIALux Evo to achieve desired lighting conditions. The virtual model for retail space of mid-range (shops with value for money and quality profiles) shop type with grid plan layout was later developed in a high-fidelity computer simulation using 3Ds Max for modelling, rendered in V-Ray and mapped into high-quality images on a computer screen. The rendered visualizations were managed to satisfy realistic lighting scenes and replicate photometric measurements as in real space. The investigated virtual retail space of dimensions 9m X 15m and a height of 3.5m was assumed to be located in India's tier 1 city. There was no direct access to daylight in the rendered space, and the evaluation of space was restricted to the only sales area. The wall, ceiling and floor colour were white with surface reflectance of 80% for the ceiling, 60% for walls and 20% for the floor. **Figure 1** represents the floor plan and luminaire layout as used for the renderings.

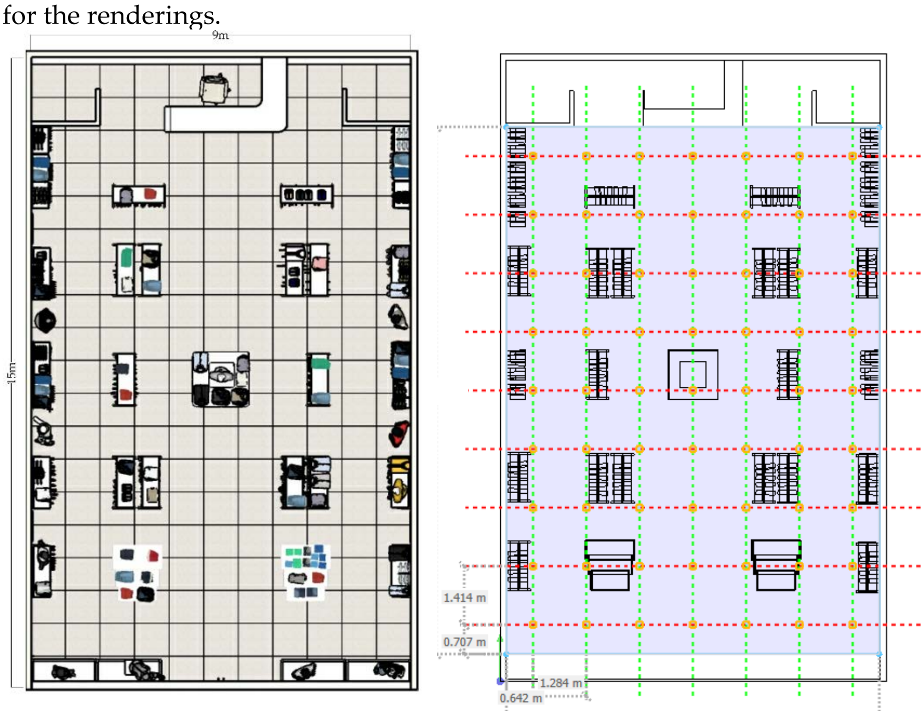

Figure 1. Floor plan and luminaire layout of the simulated retail apparel store.

Lighting conditions: The scope of illuminance levels for the category 'retail premises' was taken from minimum lighting recommendations by ISO-CIE [63], Indian Standard "IS3646 (Part 1) 1992 [64] and National Light Code 2010" [65], European Standard "EN12464–1" [66], North American Standard "The Lighting Handbook, 10th Edition" [67]. The experiment was performed considering the benchmark values from the standards at identified average illuminance levels 300lux, 500lux, 700lux and 900lux. IESNA handbook suggested illuminance levels for a retail store based on the visual age, and the visual age category for the experiment is below 65 years. The colour temperature variable is tested at 2700K, 3000K, 4000K and 5700K. The scope of correlated colour temperature was limited to the availability of light sources in the domestic market. All luminaires were recessed diffused downlight based on LED technology with a colour rendering index of R_a = 80. Figure 2 demonstrates the rendered visualizations of CCT and illuminance conditions.

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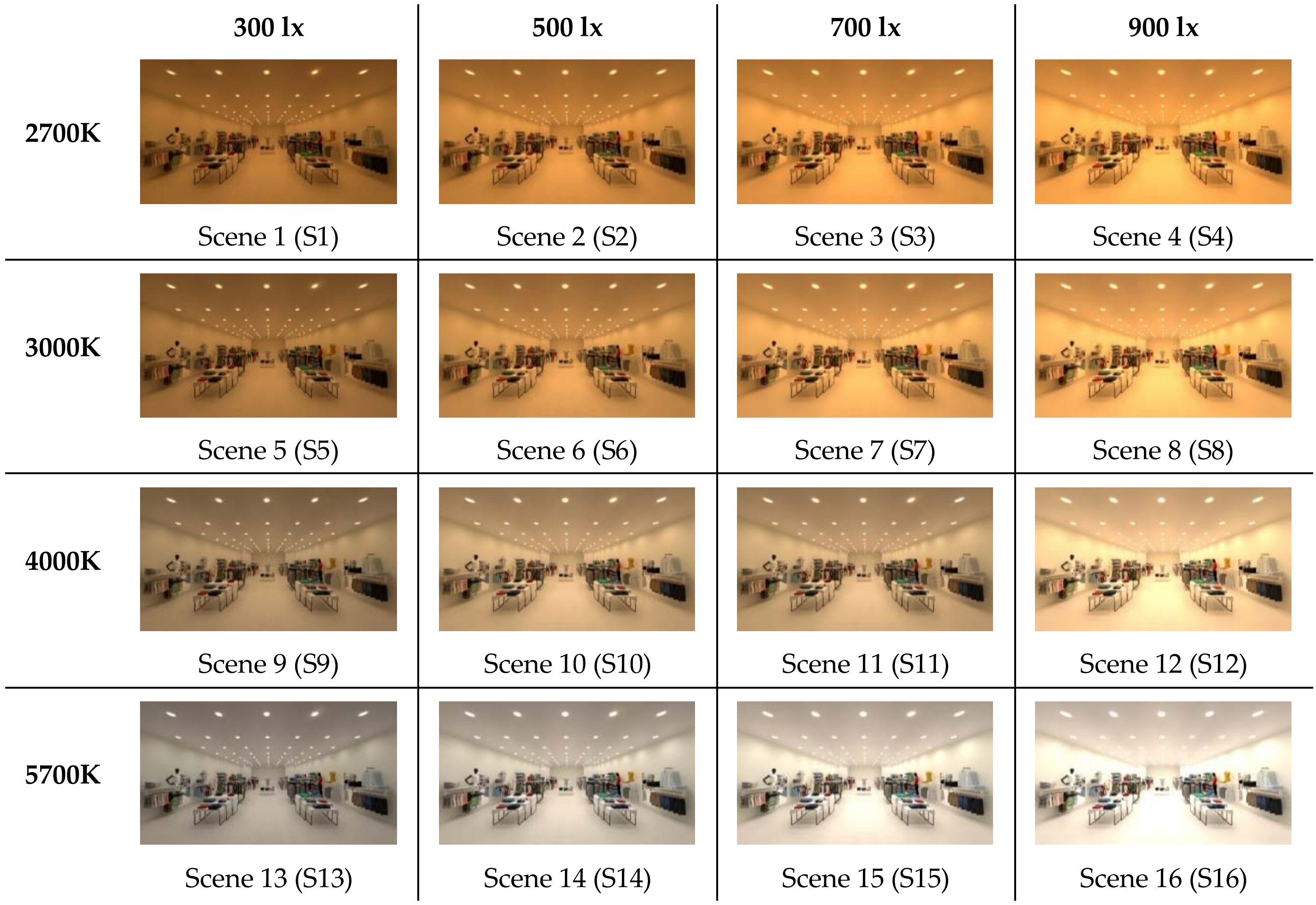

Figure 2. Light scenes 1-16, rendered visualizations of CCT and illuminance conditions.

Simulation of lighting conditions in DIALux Evo: Calculation of lighting conditions was performed using the lighting simulation program DIALux Evo 10.1[68], as a measure of pre-calculation of the lighting design concepts prior to visualization of the virtual experiment space. The reliability of this simulation program has been reportedly proven by several research studies [25,69–73]. This simulation program offers various options for the presentation of the results, and for the purpose of this study, isolines and false colour rendering maps were used. The illuminance distribution for all lighting conditions was measured at the working plane (height: 0.8m FFL). The simulated luminance false colour images and isoline contours labelled with their associated value are presented in **Table 1** for all four identified average illuminance levels.

Sample group: The subjective evaluation was performed with 93 participants (mean = 26.23, standard deviation = 6.9) without abnormal vision from the state of Tamil Nadu in India, 47 women and 46 men aged between 18 to 60. The observers were screened for colour vision deficiencies using Ishihara Colour Test, and their age, gender, geographical location and past experiences were recorded for the purpose of statistical analysis. No participant reported any colour vision deficiency. Participants wearing glasses or corrective lenses were requested to wear them for the entire assessment of scenes. All the participants gave their informed consent before participating in the experiments, and none of them had specific experience in the field of light.

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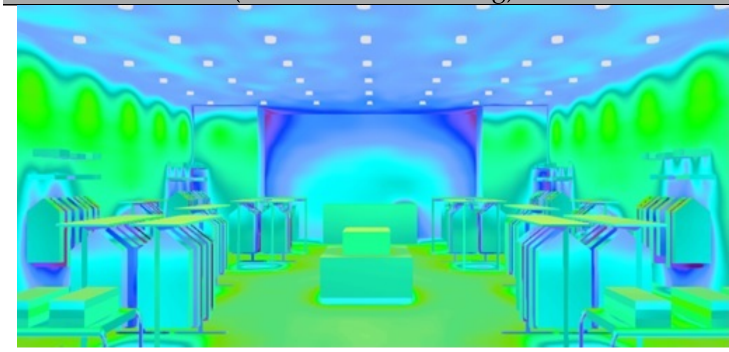
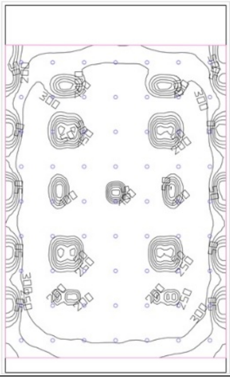
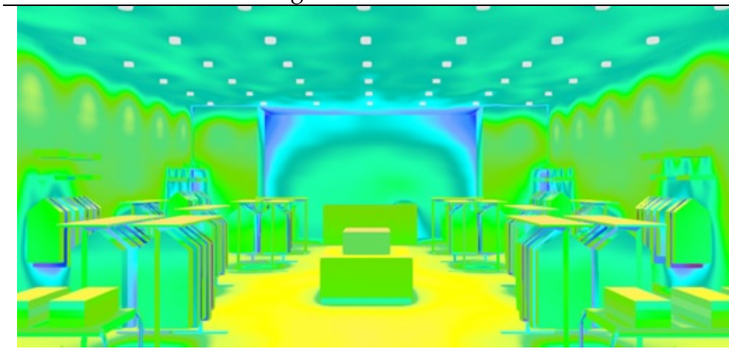
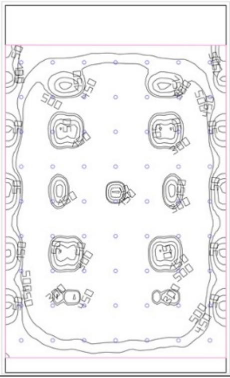
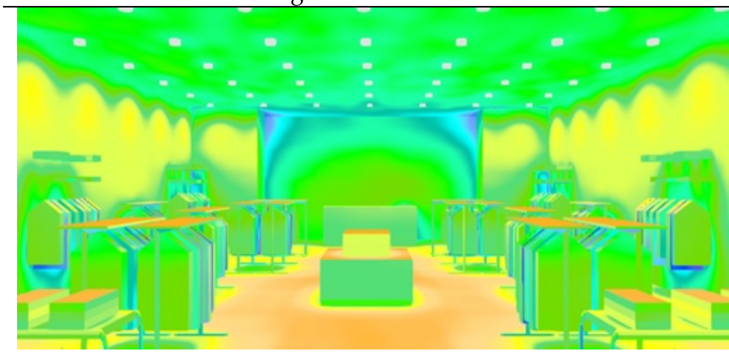
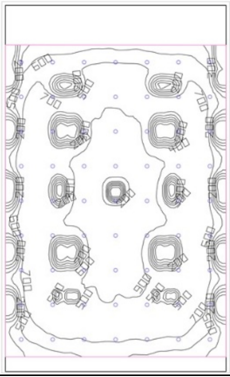
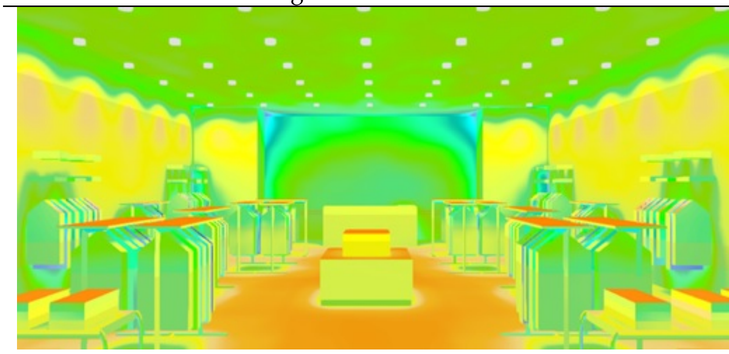
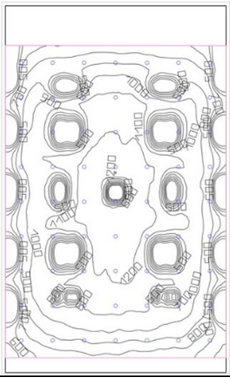
Table 1. Simulation results of lighting conditions.

Simulated Luminance Image (False colour rendering)	Illuminance Distribution Map (Isolines)
 Average Illuminance: 300 lx	
 Average Illuminance: 500 lx	
 Average Illuminance: 700 lx	
 Average Illuminance: 900 lx	

Rating scale: Participants completed semantic rating scales for a subjective appraisal of simulated space under each lighting condition. All scenarios were rated with seven adjective pairs, using a seven-point bipolar semantic differential scale. Many studies have

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explored semantic differential scale and evaluated it positively [53,58,74,75]. Overview of the indices and items of the experiment are listed in **Table 2**.

Table 2. Overview of indices and items for the experiment.

Category	Psychological Impression			Warmness
Index	Pleasantness	Attractiveness	Visual Interest	Visual warmth
Item	Pleasant/ Unpleasant	Attractive/ Unattractive	Interesting/ Boring	Warm/ Cool
Category	Perceptual Clarity		Volumetric Perception	Overall preference
Index	Visual clarity	Brightness	Spaciousness	Preference
Item	Clear/ Unclear	Bright/ Dim	Large/ Small	Preferrable Least preferrable

Data collection: Psychological evaluation data of the participants under different lighting conditions was performed with the help of a questionnaire. The questionnaire consists of three parts: the personal profile of the participant and the subjective evaluation of the sixteen scenarios (a. spatial impression and b. preference). The first part includes the vision test, gender, age, geographical locations, economic condition, educational qualification and past experiences with a similar environment. The second part had a questionnaire that rated the visual impression of space, as perceived by the participants for sixteen lighting conditions. The visualizations of the sixteen scenarios were rated with seven adjective pairs, using seven-point bipolar semantic differential scale with labels: pleasant/unpleasant (pleasantness), attractive/unattractive (attractiveness), boring/interesting (interest), clear/unclear (visual clarity), warm/cool (visual warmth), bright/dim (brightness), and large/small (volume). The third part rated the overall preference (preferred/unpreferred) of lighting conditions using a seven-point scale. The left end of the rating scale was labelled with terms related to the most negative response, and the right end was labelled with the most positive response. There was no time limit for completing the questionnaire. The order of visualizations was randomized to avoid bias. A numerical value of -3 to 3 was assigned to each attribute of the participants' responses to facilitate the statistical analysis.

Statistical analysis: This study used the statistical package Minitab 20 [76] to analyse the collected subjective responses from the participants. The α level was set at 0.05 for all statistical tests, and all p-values were two-tailed except the Mann-Whitney test. As the data was ordinal, non-parametric tests were performed to calculate the mean ranks and compare medians.

3. Results

Two independent variables, CCT and illuminance, were varied through sixteen lighting conditions to understand the impact of lighting attributes on visual perception. Seven attributes of perception (pleasantness, attractiveness, visual interest, visual clarity, brightness, visual warmth and spaciousness) were rated by the ninety-three participants, along with the overall preference for all the scenes. For the analysis, the responses from the bipolar adjectives semantic scale were converted into a range of values between -3 to +3 with neutral 0 in between, where +3 represented extremely positive responses and -3 represented extremely negative responses. Reliability analysis using Cronbach's alpha was applied to test the consistency and reliability of the questionnaire.

Reliability analysis of questionnaire: Cronbach's Alpha (α), usually used as an estimation of reliability, was applied to measure the reliability of the questionnaire. The reliability coefficient of the scale derived from Cronbach's alpha reliability test was found to be

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0.9269. An α greater than 0.6 indicates acceptable reliability and beyond 0.9 shows excellent reliability. In this study, a high value of Cronbach's α of 0.9269 demonstrated a high internal consistency of the questionnaire. The independent variables and the reliability coefficient used in the rating scale are given in **Table 3**. The α values above the acceptable threshold of reliability indicated the questionnaire's high internal consistency and reliability.

Table 3. Inter-rater reliabilities.

Cronbach's Alpha – Reliability of variables							
Pleasant/ Unpleasant	Attractive/ Unattractive	Interesting/ Boring	Clear/ Unclear	Bright/ Dim	Warm/ Cool	Large/ Small	Preferred/ Unpreferred
0.9125	0.9087	0.9114	0.9105	0.9203	0.9283	0.9218	0.9237
Cronbach's Alpha – Reliability coefficient of the scale							
0.9269							

Contour plots were generated from the stored data worksheet of the survey results in the Minitab. Contour plots display a two-dimensional view with contour lines connecting the same response value.

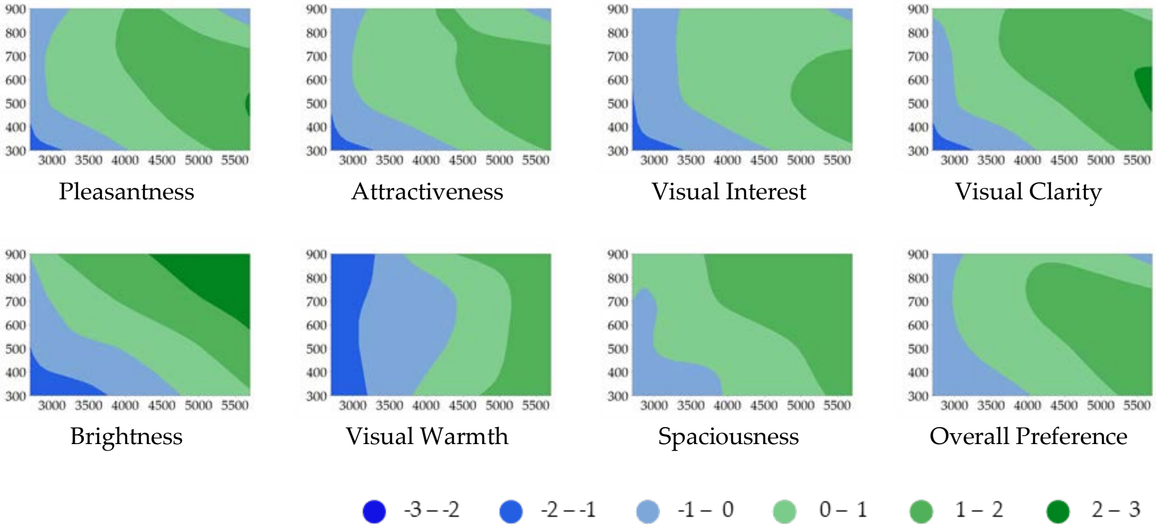

Figure 3. Graphical representation of participants' ratings on the perception of lighting conditions. (The x-axis represents CCT, and the y-axis represents illuminance levels).

Figure 3 summarizes the participants' ratings on the perception of lighting conditions graphically. The horizontal axis represents the CCT ranging from 2700K to 5700K, and the vertical axis represents the illuminance levels ranging from 300 lux to 900 lux. The contour charts demonstrate the participants' positive and negative ratings on the perception of lighting conditions, where blue represents negatives ratings, and green represents positive ratings. The darker colour on both ratings represents a higher score.

In the following three subsections, the results are analyzed statistically. The preference of specific CCT and illuminance was analysed with MANOVA, Kruskal-Wallis and Mann-Whitney tests. The impact of the perception attributes on the overall preference was analysed with Kruskal-Wallis and Mann-Whitney tests. Spearman's correlation was used to explore the relationship between perceptual attributes and preference.

3.1. Preference of lighting attributes – CCT and illuminance

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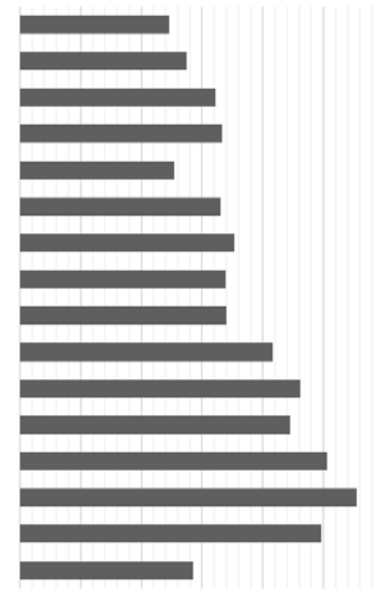
Hypothesis 1: Preference for a specific CCT and average illuminance can be identified for a retail apparel store in the Indian context.

The most preferred scenes were 5700K/500lux, 5700K/300lux and 5700K/700lux with mean values 1.710, 1.387 and 1.323, respectively. The t-test with significant p-values confirmed that means are not zero, i.e., all these three scenes have non-neutral preferences. Mean rank and median values further confirm the preference for the same scenes. The summary of statistics is presented in **Table 4**. The graphical representation based on the means ranks depicts a trend of increasing preference with increased illuminance levels and CCT. The bar chart based on mean ranks also confirms that the lighting condition 5700K/500lux was the most preferred scene.

Table 4. Summary of statistics across all sixteen scenes.

Variable	Mean	t-value	p-value	Median	Mean Rank	Graphical Representation
2700K/300lux	-1.011	-5.50	< 0.001	-1	490.7	
2700K/500lux	-0.645	-3.68	< 0.001	-1	549.7	
2700K/700lux	-0.280	-1.44	**0.152**	-1	643.6	
2700K/900lux	-0.172	-0.88	**0.380**	-1	664.7	
3000K/300lux	-0.882	-4.65	< 0.001	-1	509.0	
3000K/500lux	-0.172	-0.96	**0.338**	-1	659.9	
3000K/700lux	0.032	0.18	**0.859**	1	706.3	
3000K/900lux	-0.086	-0.44	**0.661**	1	676.9	
4000K/300lux	-0.054	-0.29	**0.771**	0	679.7	
4000K/500lux	0.602	3.29	0.001	1	833.7	
4000K/700lux	1.000	5.95	< 0.001	1	922.5	
4000K/900lux	0.839	4.62	< 0.001	1	889.7	
5700K/300lux	1.387	9.56	< 0.001	2	1011.8	
5700K/500lux	1.710	11.78	< 0.001	2	1109.8	
5700K/700lux	1.323	9.06	< 0.001	2	993.6	
5700K/900lux	-0.602	-3.04	0.003	-1	570.3	

Bold values indicate that the mean preferences are not statistically different from neutral

Levene's Test was performed to confirm the homogeneity of the variances between the scenes, and the variances were found to be homogenous. A repeated measures analysis of variance (ANOVA) confirmed that at least two means of the preferences between the scenes were significantly different from each other ($F = 22.61$, $p < 0.001$, $R^2 = 16.95\%$). The test explained only 16.95% of the overall variance in preference. Since the data is ordinal, further confirmation was achieved between medians through Kruskal-Wallis Test with a large effect size ($\eta^2 = 0.99$). Mann-Whitney Test confirmed that the median of 5700K/500lux is significantly higher than 5700K/700lux ($p = 0.009$) and 5700K/300lux ($p = 0.004$), confirming that 5700K/500lux is the most preferred scene.

3.2 Impact of lighting attributes on perception attributes

Hypothesis 2: Illuminance and CCT influence spatial perception attributes of a retail apparel store.

The survey results were grouped by CCT and illuminance and summarized in **Table 5**. In the table, p-values were used to measure if the means are statistically significant from neutral; i.e., there is a significant preference / non-preference for each CCT and illuminance. Based on the mean values and p-values, CCTs 2700K and 3000K are not preferred, and 4000K and 5700K are preferred. Similarly, for illuminance levels, 500 lux and 700 lux are preferred, while the preference to 900 lux and 300 lux is neutral; i.e., they are neither preferred nor unpreferred. These preferred CCTs and illuminance levels were further confirmed by the mean ranks, while medians provided partial support.

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Table 5. Summary of descriptive statistics across CCT and illuminance.

	CCT				Illuminance			
	2700 K	**3000 K**	**4000 K**	**5700 K**	**300 lux**	**500 lux**	**700 lux**	**900 lux**
Mean	-0.527	-0.277	0.597	0.954	-0.14	0.374	0.519	-0.0054
t-value	-5.66	-2.98	6.76	10.63	-1.38	3.85	5.59	-0.05
p-value	< 0.001	0.004	< 0.001	< 0.001	**0.167**	< 0.001	< 0.001	**0.957**
Mean Rank	587.2	638	831.4	921.4	672.8	788.3	816.5	700.4
Median	-1	-1	1	2	0	1	1	1

Bold values indicate that the mean preferences are not statistically different from neutral

Levene's Test was performed, and the homogeneity between the variances of CCT ($p = 0.002$) and illuminance ($p < 0.001$). Multiple Analysis of Variances (MANOVA) has confirmed that there is a significant effect of CCT ($F = 56.48$, $p < 0.001$, $R^2 = 10.07\%$) and illuminance ($F = 10.08$, $p < 0.001$, $R^2 = 1.8\%$) on preference. The variance explained by MANOVA results was low, and since the data is ordinal, Kruskal-Wallis Tests were performed. Based on the effect values, it was confirmed that CCT ($\eta^2 = 0.42$) had a large effect on the preference while illuminance levels ($\eta^2 = 0.07$) had a medium effect.

Mann-Whitney Tests were performed between all the pairs of medians to confirm which of the CCTs and illuminance levels were most preferred among the above. These tests confirmed that the median of 5700K is significantly higher than 4000K ($p < 0.001$), making it the most preferred CCT. For illuminance levels, Mann-Whitney tests confirmed that there is no significant difference ($p = 0.191$) between the preference for 700 lux and 500 lux, and 700 lux is more preferred than 900 lux ($p < 0.001$) and 500 lux is more preferred than 900 lux ($p = 0.003$). From these results, it may be deduced that both 500lux and 700lux are equally preferred compared to other illuminance levels.

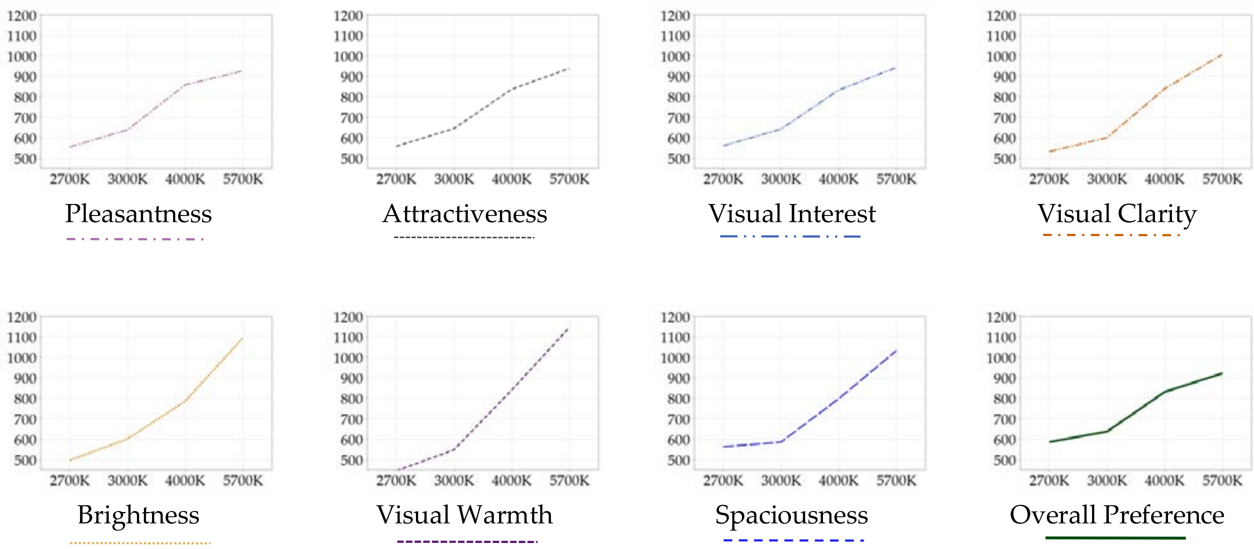

Figure 4. Graphical representation of participants rating on perception attributes at identified CCT. (The x-axis represents illuminance levels, and the y-axis represents the mean rank of rating).

Figure 4 depicts the impact of CCT on perception attributes. The perception of all the attributes (attractiveness, brightness, pleasantness, spaciousness, visual clarity, visual interest and visual warmth) shows an increasing trend with the CCT, and the perception was highest at 5700K. The Kruskal-Wallis Test results were grouped by CCT and illuminance and are summarized in **Table 6**. Kruskal-Wallis tests for each attribute confirm that at least two medians are significantly different, and the effect sizes are large for all the attributes. Pairwise comparison by Mann-Whitney test, between 5700K and 4000K con-

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firmed that median for each of the attributes (attractiveness, brightness, pleasantness, spaciousness, visual clarity, visual interest and visual warmth) peaks at 5700K (p = 0.001 for pleasantness and p < 0.001 for all other attributes).

Table 6. Kruskal-Wallis Test for perception attributes - effect sizes and p-values.

		Pleasantness	Attractiveness	Visual Interest	Visual Clarity	Brightness	Visual Warmth	Spaciousness
CCT	η^2	0.52	0.51	0.51	0.81	1.15	1.67	0.82
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Iluminance	η^2	**0.13**	**0.14**	**0.11**	0.17	0.71	**0.00**	**0.12**
	p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.497**	< 0.001

Note: Small effect if η^2 is less than 0.06, moderate effect if η^2 is in the range of 0.06 - 0.14 and large effect if η^2 is greater than 0.14. Non-Significant p-values are in bold

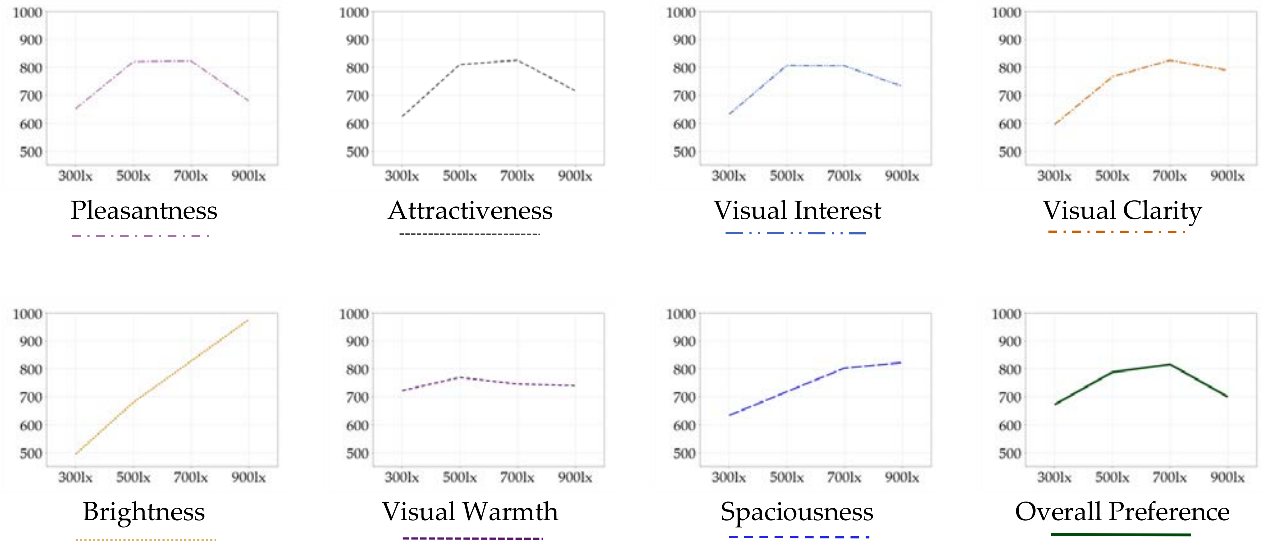

Figure 5. Graphical representation of participants rating on perception attributes at identified illuminance levels. (The x-axis represents illuminance levels, and the y-axis represents the mean rank of rating).

From **Figure 5**, it is observed that the pleasantness, attractiveness and visual interest are higher at the medium intensity levels, i.e., 500 lux and 700 lux and lower at both low and high-intensity levels, i.e., 300 lux and 900 lux. The perception of brightness increases markedly with illuminance as expected. Spaciousness also increased with illuminance levels though the effect tapered off at higher lux levels. Visual warmth does not show any clear trend and is almost a flat line. This result was expected as visual warmth does not vary between illuminance levels. **Table 6** also summarizes the Kruskal-Wallis Tests performed for each of the attributes for median values across illuminance levels, which confirmed that at least two medians are significantly different from each other for all the attributes except for visual warmth, which did not have any impact confirming the observation from the chart.

The effect sizes (η^2) greater than 0.14 are considered large, less than 0.6 are considered small, and those between 0.6 and 0.14 are considered to have a medium impact. Brightness and visual clarity have the largest effect sizes in alignment with the observation from the chart. Visual warmth has no effect, while the rest of the attributes have medium impacts. The chart shows that attractiveness, visual interest, pleasantness and spaciousness peak at 500 lux or 700 lux with almost similar means between the two. Mann-Whitney test con-

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firmed the perception of brightness is highest at 900 lux, but the perception of spaciousness and visual clarity were equally high at 900 lux and 700 lux. Similarly, the perception of attractiveness, pleasantness, and visual interest were found equally high at 700 lux and 500 lux.

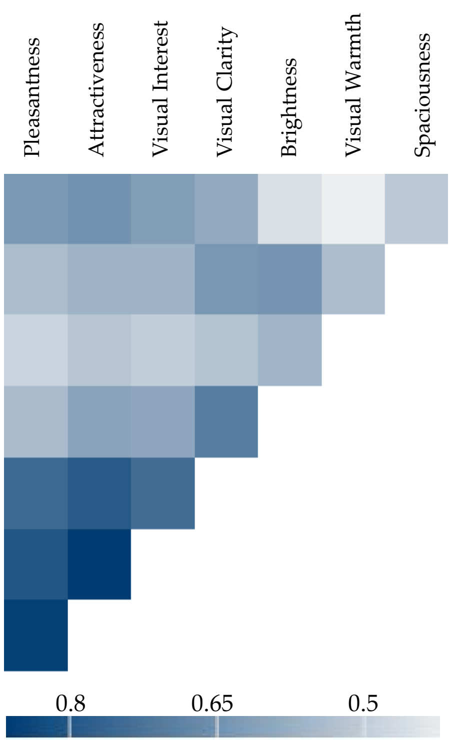
3.3. The relationship between preference and perception attributes

Hypothesis 3:	*Spatial perception attributes influence the users' overall preference on lighting conditions for a retail apparel store.*

To understand the relationship between preference and perception attributes, correlation analysis was performed using Spearman Rank Correlation as the data were ordinal in nature. The results of the correlation analysis are summarized in **Table 7**. p-values indicate that all the correlation coefficients are highly significant.

Table 7. Correlation coefficients (and p-values) of aggregated preference and perception attributes.

Pleasantness	**Attractiveness**	**Visual Interest**	**Visual Clarity**	**Brightness**	**Visual Warmth**	**Spaciousness**	
0.627 (< 0.001)	0.645 (< 0.001)	0.623 (< 0.001)	0.576 (< 0.001)	0.450 (< 0.001)	0.430 (< 0.001)	0.496 (< 0.001)	Overall Preference
0.535 (< 0.001)	0.560 (< 0.001)	0.557 (< 0.001)	0.630 (< 0.001)	0.636 (< 0.001)	0.539 (< 0.001)		Spaciousness
0.501 (< 0.001)	0.535 (< 0.001)	0.506 (< 0.001)	0.537 (< 0.001)	0.556 (< 0.001)			Visual Warmth
0.522 (< 0.001)	0.577 (< 0.001)	0.569 (< 0.001)	0.684 (<0.001)				Brightness
0.746 (< 0.001)	0.779 (< 0.001)	0.736 (< 0.001)					Visual Clarity
0.801 (< 0.001)	0.865 (< 0.001)						Visual Interest
0.857 (< 0.001)							Attractiveness



Correlation

The visual representation of the correlation statistics is represented as a correlogram in **Table 7**. The correlation matrix chart provides a quick overview of the relationship between each pair of the perception attributes dataset. The correlogram generated from Minitab used a colour gradient to indicate low and high correlation coefficient values. Sequential from low to high gradient was used to highlight variables with strong relationships, with high values in dark blue and low values in light blue and light grey, as represented in the correlation bar below the correlogram.

From the values in **Table 7**, it is clear that the correlations between all the variables (attractiveness, brightness, pleasantness, spaciousness, visual clarity, visual interest and visual warmth) with "overall preference" is statistically significant and are linearly correlated. The attractiveness with a correlation coefficient of 0.645 highly influences preference, followed by pleasantness with a correlation coefficient of 0.627 and interest with

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0.623, indicating that attractiveness, pleasantness, and interest attributes significantly influence the overall preference of lighting conditions. Further, there seems to be a strong correlation between pleasantness, attractiveness, visual interest and visual clarity.

4. Discussion

Lighting is widely considered as one of the most important atmospheric attributes to affect the spatial impression and preferences of a retail environment. The purpose of this study focuses on the influence of CCT and illuminance level on the spatial impression and preference for a mid-range retail apparel store in the Indian context. The participants viewed and rated the visualisations developed with high-fidelity computer-based simulations of lighting conditions for a mid-range apparel store. The study followed a 4 X 4 factorial design with two independent variables: CCT (2700K, 3000K, 4000K and 5700K) and illuminance level (300 lx, 500 lx, 700 lx and 900 lx) to form 16 scenes, which were perceived as different atmospheres by the participants. A preference of a specific CCT of 5700K and an illuminance level of 500 lx was identified for a mid-range retail apparel store in the Indian context.

Considering CCTs independent of illuminance levels, the most preferred CCT was 5700 K for a mid-range retail apparel store. This result is closer to the finding that participants preferred 5500K China which examined the most preferred lighting for blue jeans by varying CCT uniformly between 2500K and 6500K [45]. In addition, the colour rendering property of the lighting varied and the blueness of the jean was examined, so the results may not be comparable. The CCT preferred in the current study is different from those observed in another study where South Korean Participants preferred 3000K for display table lighting in a retail fashion store comparable to ambient lighting [37]. Different preferences of participants from different countries further confirm the studies reporting that lighting preference is based on the region and culture [23,77]. The ethnicity or culture-based preference was further observed for a generic retail store mock setup where the American participants preferred 3000K while Korean participants preferred 2700K [44]. Dugar has identified that the participants in Telangana, a different state in India, preferred 3000K-4000K for retail space, though the study was not specifically for a mid-range retail store [40]. The difference in lighting preference may be attributed to the cultural and ethnic background of the participants from different states. The participants for the current study were limited to the Indian state Tamil Nadu, one sub-culture of India, and further investigation with other states and sub-cultures may result in a comprehensive understanding of lighting conditions in the Indian context. Further, there is a possibility that the true preferred CCT is higher than 5700K and investigation with higher CCTs may be required to confirm the lighting preference.

This study also indicates that 500 lux and 700 lux are equally preferred illuminance levels for a retail mid-range fashion store since there was no statistical difference between the preferences. We can infer that the participants prefer either the entire range of 500 lux to 700 lux or a specific preferred illuminance in between this illuminance levels range that needs to be explored with further studies. The range of 500 lux to 700 lux is at the higher end of recommended standards for retail spaces in India (IS Standard). Preference for illuminance levels in a retail apparel store was not part of previous studies. However, in a restaurant, Taiwanese preferred 500 lux [15], and in a general setup, Dutch preferred 350 lux and a mixed group of Europeans, Asians and Africans preferred 750 lux for office setup [39]. These observations indicate that the preference may depend on purpose, ethnicity and culture. For certain ethnic groups like Asians and Africans, the preference for CCT depends on the illuminance levels [39]. This finding may explain the fact that in the current study, while there is no statistically significant preference between 500 lux and 700 lux, there was a clear preference for 5700K/500 lux over 5700K/700 lux. Thus, the combination of CCT at 5700K with illuminance levels of 500 lux may be recommended for mid-range retail apparel stores in India, specifically for the state of Tamil Nadu.

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In the current study, the perception of brightness increased as the level of illuminance as expected and observed in multiple studies [57,78–81]. Perception of brightness also increased with CCT, similar to the effects observed in other studies [78,79,81–85], while a study by Houser did not find any such relationship between CCT and brightness [86]. Zhai et al. had observed that the brightness perception was highest at 5000K but reduced at 6500K [80]. Since the current study did not extend beyond 5700K, further investigation is required to determine if the perception of brightness increases or reduces above 5700K in the Indian context. Another observation from the current study was that higher CCTs were perceived as cooler, while the lower CCTs were perceived as warmer, and this observation is similar to those made in multiple previous studies [44,77,78,81,87]. This observation was constant in numerous studies in various countries, and now it is observed in India too. The perception of visual warmth as an attribute for CCT may be a universal perception.

The perception of spaciousness increased with the increase in CCT and illuminance levels separately. The impact of the illuminance level was moderate in this study compared to the impact of CCT on the perception of spaciousness. An increased spaciousness with an increasing illuminance level was perceived in many studies. [16,56,88,89]. Manav had observed an increased perception of spaciousness both with the illuminance and CCT, but the impact of illuminance on the perception of spaciousness was much larger than the impact of CCT on spaciousness [14]. This difference may be attributed to the large difference in illuminance levels in this study, 500 lux and 2000 lux. Li et al. investigated dynamic white lights manipulating luminance, hue and chroma to observe that the perception of spaciousness increased with luminance and reduced at warm hues [77]. In the current study, the impact of spaciousness increased linearly with the illuminance up to 700 lux, but beyond 700 lux, it remained constant with no statistically significant increase. This finding can guide architects or lighting designers while deciding the illuminance levels of a real store in the Indian context, as maximum perceived spaciousness can be achieved with 700 lux. The study suggests that it would not be necessary to use unusually high average illuminance in the pursuit of increasing the visual perception of spaciousness for general lighting in a store.

It was observed that the perception of attractiveness was highest at 5700K and equally at 500 lux and 700 lux. Baron et al. did not find any significant impact of illuminance and CCT on perceived attractiveness [29]. Hawkes et al. manipulated the lighting distribution while maintaining a constant horizontal illuminance resulting in increased perceived brightness and attractiveness with certain lighting distributions [90]. Similarly, the perception of pleasantness was highest at a CCT of 5700K and illuminance levels of 500 lux and 700 lux, reducing at 900lux. This finding is in contradiction with an earlier study, where the pleasantness increased with illuminance level constantly and was at its highest at 900 lux [81]. However, Baron et al. identified lower CCTs as more pleasant [29]. These differences could be attributed to the cultural differences among the participants in these studies. A study for viewing fine art paintings had observed that the pleasantness reduces with increasing CCT but increases with increasing illuminance levels [80]. These differences could be attributed to the function of space, culture and ethnicity.

Visual clarity was highest at a CCT of 5700K and illuminance levels of 700 lux and 900 lux. This finding is similar to the observations of Wu & Wang that clarity is highest at 5600 K, but the clarity peaks at 300 lux for 2700 K [15]. Increasing visual clarity with increased illuminance were noticed in other studies [29]. Visual interest was highest at a CCT of 5700K and illuminance levels of 500 and 700 lux. This finding is partially aligned with the finding of Boyce & Cuttle that the increasing illuminance levels are stimulating while CCT had no impact [91]. However, Li et al. found that warm CCTs were more interesting [77]. The difference may be attributed to changes in the culture and ethnicity of the participants. In the current study, the impact of the CCT on visual clarity and visual interest attributes was more significant than that of the illuminance levels on these attributes.

It was observed that all the perception attributes are positively correlated with the overall preference of the lighting conditions. There were strong and positive correlations among attractiveness, pleasantness, visual interest and visual clarity, indicating that these four attributes move together with changes in CCT and illuminance levels. This result could either mean that the participants were unable to distinguish between these factors, or these factors are related in the same direction for CCT and illuminance levels. The correlation strength between the perception attributes and the overall preference is medium, indicating that each of these may not explain the preference by itself, but all these attributes together may explain the overall preference.

The findings of this study and the above discussion indicate that the preference of lighting conditions and perception of lighting attributes may depend on the function of the space, culture and ethnicity. India is a conglomerate of many sub-cultures, and further studies are required to understand the lighting preferences of each subculture in India for each of the retail formats.

5. Conclusions

The study was to evaluate the preference of illuminance and CCT in a mid-range retail apparel store within the cultural context of India. The result of the study indicates that the most preferred combination of CCT and illuminance for a mid-range store in India is 5700K with 500 lux. Taken individually, the most preferred CCT is 5700K, while the most preferred lux may be anywhere between 500 lux and 700 lux.

Spatial perception attributes are influenced by CCT and Illuminance levels. The perceived brightness increases with increasing CCT and Illuminance levels, and perceived warmth increases only with CCT. Perceived spaciousness increases with both CCT and illuminance, but it is perceived at the same level between 700 lux and 900 lux. Pleasantness, attractiveness, visual clarity and visual interest linearly increase with CCT, but with illuminance levels, they are highest in the range of 500 lux and 700 lux. All these variables have a medium correlation with overall preference.

The findings from this study would help researchers to explore more about the preference of lighting conditions specific to the Indian context, where the population is almost 18% of the world population. This study can also support the national standards governing bodies to align the lighting recommendations with the preferences of Indian users. Further research with similar experiments across different states of India may guide the lighting industry to identify the preference of lighting conditions for various functional spaces and cultural backgrounds within the country.

Supplementary Materials: Not applicable.

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