Examining the Impact of Color-Sound Interactions on Young Pedestrians' Emotions: A Virtual Reality Experiment on a Commercial Street

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Abstract. Optimizing the multisensory environment is critical to revitalizing offline commercial districts, yet empirical evidence for the coupling mechanism of color temperature and soundscape remains insufficient. This study aims to explore the coupled effects of color temperature and soundscape on emotional valence and arousal of young pedestrians in commercial streets. A 2 (3000K warm / 6000K cool) × 3 (human-dominant / vehicle-dominant / mixed) within-subjects VR experiment was conducted with 30 participants. Emotional responses were measured using the PANAS scale and analyzed by two-way ANOVA, t-test, and semi-structured interviews. Results reveal three consistent patterns: warm light combined with human-dominant soundscape produces the highest emotional valence, warm light with mixed soundscape yields the highest arousal, and cool light with vehicle-dominant soundscape results in the lowest valence. The findings suggest that multisensory coupling operates through synergistic, antagonistic, and compensatory mechanisms. Notably, warm lighting improves emotional responses under negative sound conditions. Soundscape appears to exert a more immediate influence on emotional perception. These findings highlight the importance of coordinated audiovisual design in commercial environments.

1 Introduction

The booming online commerce has posed challenges to the real economy, leading to the decline of traditional commercial districts. However, as the most visually prominent areas with complete commercial structures and rapid economic growth, traditional commercial streets occupy a crucial position in cities [1]. The environmental characteristics of commercial districts impact the consumer experience and behavior [2]. High-quality commercial spaces can enhance consumers' emotional experiences, thereby driving purchasing decisions, attracting extended customer dwell time, and stimulating purchasing activities [3-5]. Beijing's Wangfujing Commercial Street has increased the average customer dwell times to over three hours through optimized landscape design, significantly boosting store conversion rates. In 2024, Guangzhou's Yongqingfang achieved a 30% year-over-year revenue growth of customers by creating a diverse environment [6].

The impact of environmental elements in commercial districts on consumers' emotional experiences and behavioral decisions is primarily manifested on both visual and auditory perspectives [2]. Warm color temperatures typically enhance pleasure, a sense of belonging, and environmental comfort, while cool color temperatures tend to create a rational and tranquil spatial atmosphere [7-9]. Soundscapes serve as crucial environmental cues in commercial districts directly affecting emotional responses. An appropriate soundscape possibly enhance the vitality of a neighborhood, whereas excessive traffic noise may induce negative emotions such as irritability and tension, ultimately reducing environmental satisfaction [10-12]. Meanwhile, emotional valence and arousal levels are important variables influencing consumer behavior [13-16].

Although existing studies have separately validated the independent effects of color temperature and soundscape on consumer emotions, it is still unclear in understanding the interactive mechanisms of multi-sensory element coupling [3-5]. Thus, this study investigates the coupled interaction effects of both color temperature and soundscape on the valence and arousal levels of customers in commercial districts to enhance commercial district spatial quality.

2 Methodology

This study conducted an experiment to examine how architectural color temperature and soundscape type interact to influence consumers' emotional valence and arousal in commercial districts. A 2×3 design created six conditions combining 6000K/3000K lighting with human-dominant (10:1), vehicle-dominant (1:10), and mixed (1:1) soundscapes. Visual stimuli were first-person videos from a 3D model of a Chinese commercial street, varying only facade color temperature,

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displayed on a calibrated 27-inch monitor (Figure 1). Soundscapes were real recordings normalized to 60 dB and delivered via Sony headphones. Thirty participants (aged 18-45, normal vision/hearing, weekly commercial district visitors) were recruited via snowball sampling. The 20-minute protocol included informed consent, 3-minute acclimation, six randomized 60-second videos, PANAS scale completion after each video, and semi-structured interviews on color-sound preferences and dominant emotional influences. All sessions used pre-calibrated equipment. Data were analyzed using SPSS 26.0 (descriptive statistics, reliability, ANOVA, t-tests) and content classification for interviews.

Fig. 1. Renderings of streets and buildings in a commercial district

3 Results

A total of 30 valid responses were collected. The sample included 15 males and 15 females. Most participants were aged 18–25 years (53.3%), followed by those aged 26–35 years and 36–45 years (23.3%). In terms of occupation, students formed the largest group (40.0%), followed by corporate employees (30.0%), freelancers (23.3%), and others (6.7%). The questionnaire showed good internal consistency. Cronbach's alpha value was 0.889 for positive emotions and 0.738 for negative emotions, both above the acceptable threshold of 0.70. This indicates that the scale was reliable for further analysis. A one-way ANOVA across the six experimental conditions showed significant differences in both emotional valence and arousal. For both emotional valence ($F = 12.734$, $p < 0.001$) and arousal ($F = 20.416$, $p < 0.001$), the group effect was significant. Among all six scenarios, the highest emotional valence occurred in the warm-light + human-dominant soundscape condition (M = 10.4000), while the lowest occurred in the cool-light + vehicle-noise condition (M = 1.4667). For arousal, the highest score appeared in the warm-light + mixed pedestrian-vehicle sound condition (M = 4.3333), while the lowest appeared in the cool-light + human-dominant soundscape condition (M = 2.4333) (Tables 1 and 2).

Table 1. Variance analysis of emotional valence and arousal across

Factor		Sum of Sq.	Deg. of Freedom	Mean Sq.	F	p
Emotional valence	between groups	1596.050	5	319.210	12.734	0.000
	Within group	4361.700	174	25.067		
Arousal level	between groups	60.250	5	12.050	20.416	0.000
	Within group	102.700	174	0.590		

Table 2 Emotional valence and arousal across all 6 groups

Factor		Mean	Standard Deviation
Emotional valence	Human-dominant soundscape + 6000K (cold)	4.16667	6.08607
	Human-dominant soundscape + 3000K (warm)	10.4000	3.51940
	vehicle sound dominant + 6000K (cold)	1.4667	4.75419
	Vehicle sound dominant + 3000K (warm)	6.5667	4.52337
	Pedestrian and vehicle mixed traffic + 6000k (cold)	4.3000	5.87895
	Mixed pedestrian and vehicle traffic + 3000k (warm)	8.6000	4.83236
	average value	5.9167	5.76919
Arousal level	Human-dominant soundscape + 6000K (cold)	2.4333	0.77385
	Human-dominant soundscape + 3000K (warm)	3.4333	0.72793
	vehicle sound dominant + 6000K (cold)	2.9667	0.85029
	Vehicle sound dominant + 3000K (warm)	3.5667	0.67891
	Pedestrian and vehicle mixed traffic + 6000k (cold)	3.3667	0.85029
	Mixed pedestrian and vehicle traffic + 3000k (warm)	4.3333	0.71116
	average value	3.3500	0.95411

3.1. Soundscape Dominance

When sound type was analyzed separately, it still produced significant differences. Both emotional valence ($F = 5.452$, $p = 0.005$) and arousal ($F = 16.674$, $p < 0.001$) groups were significant. The human-dominant soundscape showed the highest valence (M = 7.2833), while the vehicle-noise-dominant condition showed the lowest (M = 4.0167). For arousal, the mixed human-vehicle condition was highest (M = 3.8500), whereas the human-dominant soundscape was lowest (M = 2.9333) (Tables 3 and 4).

Table 3 Variance Analysis of Emotional Valence and Arousal Under Dominant Sound Influence

Factor		Sum of Sq.	Deg. of Freedom	Mean Sq.	F	p
Emotional valence	between groups	345.733	2	172.767	5.452	0.005
	Within group	5612.017	177	31.706		
Arousal level	between groups	25.833	2	12.917	16.674	0.000
	Within group	137.117	177	0.775		

Table 4 Variance analysis description of emotional valence and arousal under dominant voice influence

Factor		Mean	Standard Deviation
Emotional valence	Voice-dominated	7.2833	5.84573
	vehicle sound dominance	4.0167	5.27061
	Pedestrian-vehicle mix	6.4500	5.75908
	average value	5.9167	5.76919
Arousal level	Voice-dominated	2.9333	0.89947
	vehicle sound dominance	3.2667	0.82064
	Pedestrian-vehicle mix	3.8500	0.91735
	average value	3.3500	0.95411

3.2. Color Temperature Dominance

The independent-samples t-test showed that color temperature had a clear effect on both emotional valence and arousal. Compared with cool light (6000K), warm light (3000K) produced higher valence ($M = 8.5222$ vs. 3.3111, $t = -6.777$, $p < 0.001$) and higher arousal ($M = 3.7778$ vs. 2.9222, $t = -6.715$, $p < 0.001$) (Table 5).

Table 5 T-test for affective valence and arousal level

Factor	Color	Mean	Standard Deviation	F	t	p
Emotional valence	6000k (cold)	3.3111	5.69377	4.701	-6.777	0.000
	3000k (warm)	8.5222	4.55978			
Arousal level	6000k (cold)	2.9222	0.90228	0.541	-6.715	0.000
	3000k (warm)	3.7778	0.80417			

3.3 Results of Interview

Preference data showed that the most favored scenario was warm light with human-dominant soundscape, selected by 10 participants, followed by warm light with mixed human-vehicle sound, selected by 9 participants. The least preferred scenario was cool light with vehicle-noise dominance, selected by only 1 participant. In the interview responses, 17 participants (56.7%) believed that soundscape composition had a stronger emotional impact, while 13 participants (43.3%) emphasized building color. Participants who prioritized soundscape often described vehicle noise as immediately irritating and human-dominant soundscapes as warm, reassuring, and more capable of shaping mood. Those who prioritized color argued that warm tones created an initial sense of comfort, while cool tones produced distance, calmness, or restraint.

4 Discussion

The results reveal three core emotional patterns across experimental conditions: the warm light plus human-dominant soundscape yields the highest emotional valence, the warm light plus mixed soundscape generates the highest arousal, and the cool light plus vehicle-dominant soundscape leads to the lowest emotional valence. Interview data confirm that participants perceived the warm-human combination as pleasant, relaxed, and socially welcoming, whereas the cool-vehicle combination was described as alienating, tense, and uncomfortable. Meanwhile, the mixed soundscape with warm light was rated as lively, dynamic, and moderately stimulating, maintaining stable high arousal without excessive tension. These findings align with environmental psychology evidence that pleasant visual and auditory cues jointly shape positive affective experiences in urban open spaces [6]. Such distinct emotional patterns imply that commercial street design should adopt scenario-specific sensory matching to create targeted emotional experiences for pedestrians.

The findings demonstrate significant synergistic and antagonistic effects between color temperature and soundscape, rather than simple independent effects. The combination of two positive stimuli (warm light + human-dominant sound) produces stronger positive emotions than either factor alone, while the combination of two negative stimuli (cool light + vehicle-dominant sound) amplifies negative feelings to a greater degree. Notably, under vehicle-dominant soundscape, emotional valence rose sharply from around 1.4 to 6.5 when shifting from cool light to warm light, indicating a strong emotional repair effect of warm lighting. This compensatory effect is supported by stress recovery theory, which holds that visual warmth can relieve psychological stress caused by unpleasant auditory stimuli [10]. In this case, warm light acts as a restorative factor that neutralizes irritation and tension from traffic noise, improving overall comfort even in a negatively valenced sound environment.

Soundscape appears to play a prominent role in emotional perception, and more than half of the participants regarded sound as one of the key factors influencing their emotions. Interview results show that sound triggers immediate and intense emotional fluctuations: vehicle noise instantly induces irritability and tension, while human-dominant soundscape quickly brings relaxation, peace and a sense of belonging. In contrast, the influence of color temperature is more subtle, slow and lasting. This phenomenon may be explained from the perspective of evolutionary psychology: the human auditory system has retained high alertness during evolution to rapidly detect environmental dangers and social signals, so sound triggers emotions in a more primitive, direct and instinctive way. This implies that in commercial environment design, soundscape management should be elevated to the same important level as visual design [17]. Ignoring soundscape quality will directly weaken spatial experience and significantly reduce pedestrians' comfort, sense of security and willingness to stay.

The findings of this study reveal that not all consumers seek high-pleasure, high-arousal warm lighting environments. Participants' preference for cool color temperature reflects not passive acceptance of negative emotions, but rather demands for rational, quiet consumption and immersive experiences. The calming, restrained, and low-stimulus characteristics of cool color temperatures effectively reduce emotional interference and enhance cognitive focus. Moderate integration of cool lighting with human-dominant soundscapes creates a composed yet warm atmosphere, fulfilling demands for slow-paced, high-quality, and extended-duration consumption experiences [18].

This study supplements and extends traditional environmental psychology theory, demonstrating that the multisensory coupling mechanism better explains emotional responses in real environments than single-sensory independent studies. Traditional research often treats visual and auditory stimuli as separate independent variables, but this study shows that the combined effect of color temperature and soundscape far exceeds the sum of individual stimuli. When two sensory stimuli act in opposite directions, one can effectively compensate for the negative effects of the other. For example, warm light relieves stress caused by traffic noise, and mixed soundscapes offset the potential reduction in arousal induced by warm lighting. These findings indicate that modern environmental psychology should pay greater attention to multisensory integration and cross-sensory compensation mechanisms rather than focusing solely on single-sensory effects. By validating the audio-visual coupling framework, this study enriches the theory of multisensory environmental perception and provides a solid theoretical basis for integrated audio-visual design in commercial streets.

5 Conclusion

This study conducted an experiment to investigate the impact of color temperature and soundscape on consumers' emotional valence and arousal levels. Findings reveal that both color temperature and soundscape types significantly affect emotional valence and arousal, with notable interactive effects: Warm color enhances positive emotions and overall comfort, while human-dominated soundscapes significantly boost emotional valence, and mixed pedestrian-vehicle soundscapes generate moderate yet stable high arousal levels. Within coupled effects, warm color temperatures paired with human-dominated environments achieve optimal positive emotional experiences. Therefore, commercial district environmental design should achieve precise visual-auditory element matching based on functional scenarios to enhance emotional experiences, prolong visitor dwell time, and stimulate the vitality.

This study has three limitations. The sample size was relatively small. The study relied mainly on subjective scales and interviews rather than physiological measures. And the experiment was conducted in a simulated laboratory setting rather than a real commercial street. Future research should expand the sample, add physiological indicators, and examine individual differences in sensitivity to soundscape and color temperature.

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