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# IMPACT OF RETAIL LIGHTING ON CONSUMER PSYCHOPHYSIOLOGY AND BEHAVIOR: SYSTEMATIC LITERATURE REVIEW

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***Abstract***: *In an increasingly competitive retail environment, physical stores must evolve into experiential landscapes in which atmospheric elements shape consumer behavior. Lighting functions as a fundamental atmospheric stimulus, yet its impact has been examined mainly through subjective evaluations, leaving underlying neurobiological mechanisms insufficiently explored. This Systematic Literature Review (SLR) investigates how retail lighting attributes mediate consumers' psychophysiological processing and shape behavioral outcomes within the Stimulus-Organism-Response (S-O-R) framework. Guided by the PRISMA protocol, a content analysis was conducted on 20 empirical studies published between 2014 and 2025. The synthesized evidence demonstrates that lighting parameters, particularly illuminance and correlated color temperature (CCT), act as key determinants for physiological responses (e.g., visual attention and brainwave activity) and psychological states (e.g., emotional responses and perceptual evaluations). Furthermore, causal mapping indicates a pronounced imbalance toward perceptual and attitudinal outcomes, with still limited evidence capturing observable consumer behavior. To improve empirical rigor and ecological validity, this review advocates triangulating physiological tools, psychometric measures, and real-time behavioral observation, thereby strengthening the foundation for evidence-based, human-centered lighting strategies.*
***Keyword:*** *Retail Lighting; Psychophysiology; Consumer Behavior*

**Abstrak:** Dalam lingkungan ritel yang semakin kompetitif, toko fisik perlu bertransformasi menjadi ruang pengalaman di mana elemen atmosfer membentuk perilaku konsumen. Pencahayaan berperan sebagai stimulus atmosferik yang fundamental, namun kajiannya masih didominasi oleh evaluasi subjektif, sehingga mekanisme neurobiologis yang mendasarinya belum banyak dieksplorasi. Systematic Literature Review (SLR) ini bertujuan untuk mengkaji bagaimana atribut pencahayaan ritel memediasi proses psikofisiologis konsumen serta membentuk luaran perilaku dalam kerangka Stimulus-Organism-Response (S-O-R). Dengan mengacu pada protokol PRISMA, analisis konten dilakukan terhadap 20 studi empiris periode 2014-2025. Hasil sintesis menunjukkan bahwa parameter pencahayaan, khususnya tingkat iluminansi dan correlated color temperature (CCT), merupakan faktor kunci yang memengaruhi respons fisiologis (seperti perhatian visual dan aktivitas gelombang otak) serta kondisi psikologis (seperti respons emosional dan evaluasi perseptual). Selain itu, pemetaan kausal menunjukkan ketimpangan, di mana penelitian lebih banyak berfokus pada persepsi dan sikap, sementara bukti mengenai perilaku konsumen yang teramati masih terbatas. Untuk meningkatkan ketelitian empiris dan validitas ekologis, kajian ini merekomendasikan triangulasi metode yang mengintegrasikan alat fisiologis, pengukuran psikometrik, serta observasi perilaku secara real-time. Secara keseluruhan, temuan ini memberikan landasan bagi perancang dan pelaku ritel dalam mengembangkan strategi pencahayaan berbasis bukti guna mengoptimalkan pengalaman dan perilaku konsumen.
**Kata Kunci:** Pencahayaan Ritel; Psikofisiologi; Perilaku Konsumen

## INTRODUCTION

Designers play a central role in shaping human experience and well-being through the built environments they create. As competition intensifies in the digital era, physical retail spaces are increasingly required to evolve from mere sites of transaction into experiential landscapes (Pine & Gilmore, 1999). Despite the pervasive disruption caused by e-commerce, physical stores continue to maintain an irreplaceable role within the retail ecosystem. A report by the International Council of Shopping Centers (ICSC, 2023) highlights that brick-and-mortar stores remain central to retail ecosystems, with 97% of Generation Z consumers still preferring in-store shopping due to the desire to see, touch, and experience physical spaces in a tangible and sensory manner.

To optimize these physical environments, retail lighting has emerged as one of the most fundamental and precisely controllable atmospheric components. However, historically, research on retail lighting has

predominantly focused on cognitive evaluations and aesthetic preferences assessed through self-reported questionnaires or interview-based methods (Chen et al., 2022; Phumchan & Tuaycharoen, 2022). Such subjective approaches entail inherent limitations, as consumers are often susceptible to cognitive biases and may be unable to accurately articulate internal reactions that occur within milliseconds.

The discrepancy between consumers' verbalized responses and their embodied experiences underscores the urgency of adopting more objective measurement approaches. Despite the considerable potential of psychophysiological data to capture these nuanced reactions, research integrating neurobiological instruments within retail lighting studies remains highly fragmented. Most existing studies continue to isolate basic parameters such as illuminance levels and correlated color temperature (CCT), often within laboratory-based simulation settings (Liu et al., 2024; Rebollar et al., 2017), while rarely examining their effects on consumers' actual physical behaviors in complex retail environments (Wu et al., 2021). As a result, the full causal relationship between physical lighting manipulation, subconscious neural activation, and transactional decisions remains insufficiently mapped. This gap poses a significant challenge for designers and retailers seeking to formulate lighting strategies that are scientifically validated to optimize spatial performance.

To address this critical gap and advance the scientific validation of retail environments, this Systematic Literature Review (SLR) examines how lighting parameters influence consumers' psychophysiological responses and assesses the relative effectiveness of subjective versus objective measurement approaches. Accordingly, this review is guided by the following overarching research question: (RQ1) How do retail lighting attributes mediate consumers' psychophysiological processing and directly shape their behavioral outcomes within the Stimulus-Organism-Response (S-O-R) framework?

To address this question, the study pursues three specific objectives: (1) to synthesize empirical evidence on how retail lighting shapes consumer experiences across the sequential stages of the S-O-R paradigm; (2) to integrate the identified pathways into a comprehensive conceptual framework; and (3) to critically examine the ongoing methodological shift toward objective biometric assessments in order to identify research gaps and directions for future investigation.

## LITERATURE REVIEW

### Retail Atmospherics and Lighting as Environmental Stimuli

In commercial settings, the physical environment fundamentally influences consumer perceptions and behaviors. The concept of retail atmospherics emphasizes that physical stores must function as experiential landscapes capable of fostering multisensory engagement (Pine & Gilmore, 1999). Among various atmospheric elements, retail lighting is identified as a fundamental and highly controllable architectural component. Empirically, lighting design extends beyond basic illumination to serve as an instrument for marketing communication, shaping the spatial atmosphere, and constructing quality perceptions (Schielke, 2015). Strategically optimized lighting has been shown to extend consumer dwell time, guide spatial navigation, and enhance perceived product value, thereby contributing to overall store profitability (Summers & Hebert, 2001; Biswas et al., 2017).

### The Stimulus-Organism-Response (S-O-R) Framework

The theoretical foundation for understanding the interaction between environmental cues and consumer behavior is widely grounded in the Stimulus-Organism-Response (S-O-R) paradigm introduced by Mehrabian and Russell (1974). Within this framework, physical retail lighting attributes, such as illuminance, correlated color temperature (CCT), and contrast, act as environmental stimuli (Stimulus). These physical cues trigger changes in consumers' internal cognitive and affective states (Organism). Subsequently, these internal processing mechanisms drive observable behavioral outcomes (Response), such as approach or avoidance tendencies and purchase intentions (Chen et al., 2022; Liu et al., 2024). The S-O-R model provides a structured causal chain to systematically evaluate how variations in spatial lighting translate into definitive physical actions.

### Psychophysiological Processing and Biometric Measurement

Historically, the assessment of the 'Organism' component in retail lighting research has relied heavily on self-reported questionnaires and subjective cognitive evaluations. However, human responses to environmental stimuli often occur at a subconscious level within milliseconds, making them susceptible to cognitive biases when articulated verbally. The integration of design physiology and neuro-architecture introduces objective biometric instruments to quantify these internal states more accurately. Wearable technologies such as electroencephalography (EEG) enable the real-time measurement of emotional valence, neural activation, and appetite stimulation during product evaluation (Berčík et al., 2016; Wang, 2020). Concurrently, eye-tracking and pupillometry provide precise metrics on the autonomic nervous system (ANS), revealing how lighting contrast and intensity dictate visual attention allocation and emotional arousal (Laski et al., 2018; Viedma-del-Jesús et al., 2025).

## RESEARCH METHOD

This study adopts a Systematic Literature Review (SLR) methodology structured in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009; Page et al., 2021). The application of the PRISMA framework ensures a rigorous, transparent, and replicable procedural structure, thereby minimizing selection bias in synthesizing interdisciplinary literature spanning retail design, neuroscience, and consumer behavior.

A systematic literature search was conducted across three major academic databases, Scopus, ScienceDirect, and Google Scholar, covering publications from 2014 to 2025. The baseline year of 2014 was strategically selected to capture the pivotal period when objective biometric instruments, such as electroencephalography (EEG), began to be integrated into retail and consumer behavior research, thereby significantly enriching the methodological scope of this review. The search process employed structured combinations of keywords encompassing retail contexts, lighting parameters, and instruments for measuring consumer responses. The specific search strings applied to each database are detailed in Table 1.

**Table 1**. Search Strings Used Across Academic Databases

| Database | Search Strings |
|---|---|
| **Scopus** | TITLE-ABS-KEY ( "lighting" ) AND ( "retail environment" ) AND ( "consumer" OR "customer" ) AND ( "physiological" OR "psychological" OR "behavior" ) |
| **Science Direct** | ("lighting") AND ("retail environment") AND ("consumer" OR "customer") AND ("physiological" OR "psychological" OR "behavior") |
| **Google Scholar** | "lighting" AND "retail environment" AND ("consumer" OR "customer") AND ("physiological" OR "psychological" OR "behavior") |

To ensure the validity and robustness of the synthesis, the extracted literature was required to meet stringent eligibility criteria. Studies were included if they met the following conditions: (1) the article reported original empirical research; (2) it focused on the manipulation of physical lighting attributes (e.g., illuminance, correlated color temperature, and contrast) within retail environments; (3) it explicitly measured consumers' psychophysiological or behavioral responses using either self-reported questionnaires or biometric instruments; and (4) it was published in English in peer-reviewed journals. Conversely, studies were excluded if they were conceptual or review papers, focused exclusively on energy efficiency or technical engineering issues without relevance to human behavior, or were conducted outside retail spatial contexts (e.g., office or medical lighting). Following the initial search results, a multi-stage identification and screening process was implemented in accordance with the PRISMA flow diagram (see Figure 1). After the removal of duplicates, abstract screening, and full-text assessment, a total of 20 empirical studies were deemed to meet all inclusion criteria and were retained for the final synthesis.

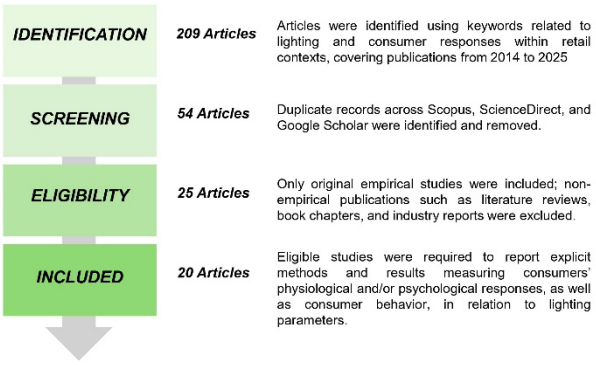


**Figure 1.** PRISMA Flow Diagram of the Article Selection Process

A systematic content analysis was conducted on the 20 selected articles to extract their methodological characteristics, operational variables, and key empirical findings. Data extraction was systematically structured using the Stimulus-Organism-Response (S-O-R) framework. The S-O-R paradigm was selected due to its well-established validity in explaining causal chains through which physical environments trigger internal human states that ultimately result in observable actions. Each article was decomposed into three thematic domains:

1. Stimulus (S): Physical attributes of retail lighting (e.g., illuminance, CCT, CRI, light distribution).
2. Organism (O): Internal consumer processing mechanisms triggered by the stimuli, encompassing subconscious physiological processes (e.g., visual attention, brain wave activity, pupil dilation) and conscious psychological evaluations (e.g., perception, emotion, preference).
3. Response (R): Observable behavioral outcomes within retail environments (e.g., purchase intention, purchase decisions, approach or avoidance).

To ensure methodological transparency and analytical rigor, a structured coding procedure was applied to all extracted data. Empirical findings from each article were systematically coded into a data matrix based on their S-O-R classification, by identifying independent (Stimulus), mediating (Organism), and dependent variables (Response). These variables were then standardized into categorical nodes, enabling consistent data organization, supporting the quantification of interaction frequencies, and facilitating the mapping of causal relationships.

As a final analytical step, the frequency of variable occurrences within each S-O-R domain and the density of causal relationships among them were visualized using a Sankey diagram. This visual mapping effectively highlights the dominance of mainstream research pathways while simultaneously identifying methodological gaps, particularly within biological processing pathways that remain underexplored in the current literature.

## RESULT AND DISCUSSION

The data extraction process indicates a clear and recurring focus within the literature on retail lighting as

a fundamental environmental stimulus influencing consumer experiences. In this review, lighting attributes are operationalized through distinct and measurable parameters, including illuminance, correlated color temperature (CCT), color rendering index (CRI), light color, lamp type, contrast and light distribution. Consumer responses are conceptualized as integrated outcomes that encompass both internal psychophysiological mechanisms, such as visual attention, brain wave activity, and perceptual processes and observable behavioral outcomes, including purchase intention and approach behavior.

Drawing on an in-depth examination of 20 eligible empirical studies, the results reveal consistent and theoretically aligned causal relationships structured within the Stimulus-Organism-Response (S-O-R) framework. The interconnections among these components, along with a comprehensive synthesis of the reviewed studies, are illustrated in Table 2 and Table 3, respectively. Overall, the accumulated evidence highlights the pivotal role of strategically designed lighting in shaping both subconscious and conscious consumer responses in contemporary retail environments.

**Table 2**. Operationalization of the S-O-R Framework Variables and Measurement Instruments

| Categories | Element | Measurement Instruments |
|---|---|---|
| **Stimulus (S)** | **Lighting Attributes:** Illuminance, CCT (Correlated Color Temperature), CRI (Color Rendering Index), Light Color, Lamp Type, Contrast, Light Distribution | Lux Meter, Spectroradiometer |
| **Organism (O)** | **Physiological Responses:** Visual Attention, Pupil Dilation, Brain Wave | Eye Tracking, Pupillometry, EEG |
| | **Psychological Responses:** Perception, Emotion, Preference, Willingness to Eat | Self-reported Questionnaires |
| **Response (R)** | Behavioral Outcome: Purchase Intention, Purchase Decisions, Approach or Avoidance, Satisfaction, Choice Behavior | Self-reported Questionnaires, Behavioral Observation |

**Table 3**. Summary of the Selected Empirical Studies and Key Findings

| No | Authors (Year) | Research Method | Stimulus-Organism-Response (S-O-R) | Key Findings |
|---|---|---|---|---|
| **1** | Liu et al. (2024) | Quantitative (Experiment with Questionnaire) | S: CCT, Lamp Type<br>O: Perception, Preference<br>R: Purchase Intention | High illuminance combined with specific CCTs enhances perceived freshness and redness of fresh meat products. |
| **2** | Chen et al. (2022) | Quantitative (Experiment with Questionnaire) | S: Illuminance, CCT<br>O: Perception<br>R: Purchase Intention | Warm CCT (3000K) with appropriate illuminance on dark backgrounds maximizes visual attention and purchase intention. |
| **3** | Hemalatha et al. (2022) | Quantitative (Experiment with Questionnaire) | S: Illuminance, CCT<br>O: Perception, Preference<br>R: Non Behavioral Outcome | CCT and illuminance jointly shape spatial perception, with 5700K at 500 lux optimal for mid-range retail settings in India. |
| **4** | Phumchan & Tuaycharoen (2022) | Quantitative (Experiment with Questionnaire) | S: Illuminance, CCT<br>O: Emotion, Perception<br>R: Non Behavioral Outcome | Customer emotions and visual preference are optimized by moderate illuminance (400 lux) and cool white lighting (4000K). |
| **5** | Rebollar et al. (2017) | Quantitative (Experiment with Questionnaire) | S: Illuminance<br>O: Perception<br>R: Purchase Intention | Illuminance influences product evaluation differently by gender, affecting perceived healthiness and sweetness. |
| **6** | Bercík et al. (2016) | Quantitative (EEG) | S: Illuminance, CCT, CRI, Light Color, Lamp Type<br>O: Brain Wave, Emotion<br>R: Non Behavioral Outcome | Illumination type and light color enhance emotional valence and visual attention in fresh food displays. |
| **7** | Lin & Yoon (2015) | Quantitative (Experiment with Questionnaire) | S: Contrast, CCT<br>O: Visual Attention, Emotion<br>R: Non Behavioral Outcome | Lighting contrast directly drives consumer pleasure and behavioral intention more strongly than CCT. |
| **8** | Viedma-del-Jesus et al. (2025) | Quantitative (Eye Tracking + Pupillometry) | S: Illuminance<br>O: Visual Attention, Pupil Dilation, Emotion, Perception<br>R: Non Behavioral Outcome | Lower lighting intensity increases emotional arousal and focused visual attention, as indicated by pupil dilation patterns. |
| **9** | Horská & Berčík (2014) | Quantitative (EEG + Experiment with Questi | S: Illuminance, CCT, CRI, Lamp Type<br>O: Brain Wave, Perception | CCT and CRI with accent lighting significantly shape consumer perception and purchase decisions for fresh foods. |

| | | | | |
|---|---|---|---|---|
| | | onnaire) | R: Purchase Decisions | |
| **10** | Laski et al. (2018) | Quantitative (Eye Tracking) | S: CRI<br>O: Visual Attention<br>R: Non Behavioral Outcome | Subtle modulation of CRI unconsciously extends browsing behavior and reduces gender differences. |
| **11** | Nagyová, L., et al. (2014) | Quantitative (EEG + Experiment with Questionnaire) | S: Illuminance, CCT, CRI, Lamp Type<br>O: Brain Wave, Emotion<br>R: Satisfaction | Strategic accent lighting improves visual appeal while maintaining energy-efficient retail operations. |
| **12** | Wang, C. Y. (2020) | Quantitative (EEG) | S: CCT<br>O: Brain Wave, Emotion, Perception, Willingness to Eat<br>R: Non Behavioral Outcome | Lighting color properties modulate neural appetite responses, with warm and red light enhancing food attraction. |
| **13** | Sato (2024) | Quantitative (Experiment with Questionnaire) | S: Illuminance, CCT, Lamp Type<br>O: Perception<br>R: Non Behavioral Outcome | Low CCT (~3000K) maximizes visual palatability, while higher CCT reduces perceived food quality. |
| **14** | Yılmaz (2018) | Quantitative (Experiment with Questionnaire) | S: Illuminance, Lamp Type, Light Distribution<br>O: Perception<br>R: Non Behavioral Outcome | Illuminance, lamp type, and light distribution alter perceived space, price, and product quality. |
| **15** | Batool et al. (2025) | Quantitative (Experiment with Questionnaire) | S: Illuminance<br>O: Visual Attention, Perception<br>R: Non Behavioral Outcome | Bright lighting increases perceived size of convex products but not concave ones. |
| **16** | Shen et al. (2025) | Quantitative (Experiment with Questionnaire) | S: CCT, CRI<br>O: Perception, Preference<br>R: Non Behavioral Outcome | Optimal CCT and CRI vary by product color, confirming the absence of a universal fresh-food lighting standard. |
| **17** | Wu, L., et al. (2021) | Quantitative (Experiment with Questionnaire) | S: Light Distribution<br>O: Perception<br>R: Approach or Avoidance | Focal lighting against dim ambient conditions enhances perceived intimacy and approach intention. |
| **18** | Biswas, D., et al. (2017) | Quantitative (Experiment with Questionnaire) | S: Illuminance<br>O: Unspecified Organism<br>R: Choice Behaviour | Ambient luminance nudges food choice by increasing alertness under bright lighting and impulsivity under dim lighting. |
| **19** | Veerasilp, W., & Sansena, N. (2022) | Mix Method (Observation + Experiment with Questionnaire) | S: CCT<br>O: Perception<br>R: Non Behavioral Outcome | Product appeal in fresh markets is strongly determined by CCT selection across food categories. |
| **20** | Yang et al. (2015) | Quantitative (Experiment with Questionnaire) | S: Light Color<br>O: Perception, Preference, Willingness to Eat<br>R: Non Behavioral Outcome | Light color significantly affects sensory evaluation and willingness to consume food. |

**Retail Lighting Attributes as Environmental Stimuli**

Within the Stimulus-Organism-Response (S-O-R) framework, retail lighting functions as a primary environmental stimulus that fundamentally shapes consumers' shopping experiences (Lin et al., 2015). Drawing on the 20 studies included in this review, lighting is no longer conceptualized merely as a functional source of illumination, but rather as a strategic atmospheric element capable of eliciting psychophysiological and behavioral responses. Collectively, lighting attributes manipulate visual perception and structure the initial interaction between consumers and products within the physical retail environment (Berčík et al., 2016; Viedma-del-Jesús et al., 2025). Conceptually, the literature operationalizes lighting stimuli through seven key technical parameters, including illuminance, correlated color temperature (CCT), light color, color rendering index (CRI), contrast, lamp type and light distribution.

Correlated color temperature (CCT) plays a critical role in shaping spatial atmosphere and influencing visual preferences. Warm lighting conditions (typically within the 3000K–4000K range) have been consistently shown to enhance appetite, visual palatability, and perceived quality of food products such as bread and fresh meat (Wang, 2020; Sato, 2024; Liu et al., 2024). In contrast, excessively high CCT levels associated with cool or bluish lighting often diminish the visual attractiveness of food items (Chen et al.,

2022). Studies conducted across diverse retail contexts, ranging from fresh markets to apparel stores, further emphasize that aligning CCT with product color characteristics is an essential strategy for optimizing retail identity and consumers' emotional perceptions (Shen et al., 2025; Phumchan, 2022; Veerasilp & Sansena, 2022).

Beyond color temperature, illuminance represents another foundational attribute influencing consumer attention and perceptions of product clarity. Empirical evidence demonstrates that variations in brightness levels generate markedly different visual evaluations. Higher illuminance levels tend to enhance perceived clarity and visual appeal, particularly in product categories such as bakery items (Chen et al., 2022). At a subconscious level, bright lighting can also alter perceptions of physical form, whereby products with convex surfaces are perceived as larger under higher brightness conditions (Batool et al., 2025). Nevertheless, illuminance manipulation must be context-sensitive, as changes in brightness levels differentially affect willingness to buy depending on the type of product being evaluated (Rebollar et al., 2017; Hemalatha et al., 2022).

Light color and color rendering index (CRI) constitute additional critical attributes that function as sensory stimuli to reinforce product representation. The application of specific chromatic lighting, particularly reddish spectral tones, has been shown to trigger brain wave responses associated with increased appetite (Wang, 2020) and to influence consumers' sensory acceptance of products (Yang et al., 2015). Meanwhile, a high CRI is crucial for ensuring color accuracy, allowing products to appear as natural as possible. This accuracy serves as a strong driver of perceived quality and purchase intention, especially in the display of fresh and artisanal products (Liu et al., 2024; Nagyová et al., 2014).

Light distribution and contrast further complete the stimulus configuration by establishing visual hierarchies within the retail space. From an architectural design perspective, lighting acts as an immaterial boundary capable of defining spatial volumes and establishing distinct retail zones without the need for physical walls. By strategically manipulating light distribution, designers can accentuate material textures, create spatial depth, and establish intuitive wayfinding that naturally guides the consumer's journey through the store layout. The interaction between accent lighting that selectively highlights products and more subdued ambient lighting has been found to be effective in directing consumer attention (Wu et al., 2021). Such contrast differences not only subconsciously guide consumers' visual exploration and expand in-store browsing behavior (Laski et al., 2018), but also contribute to creating a sense of spatial intimacy that fosters approach intention and extends store visitation time (Wu et al., 2021; Lin et al., 2015). Furthermore, the choice of lamp type, particularly the transition from traditional fluorescent sources to spectrally optimized LEDs, serves as a critical physical stimulus that significantly impacts color rendering and visual comfort (Yılmaz, 2018; Nagyová et al., 2014). Empirical evidence indicates that specialized LED lighting not only enhances the perceived freshness and visual quality of merchandise but also evokes more positive emotional evaluations from shoppers (Liu et al., 2024; Berčík et al., 2016).

Overall, the synthesized literature confirms that no single lighting standard can be universally applied across all retail contexts. The effectiveness of lighting as an environmental stimulus depends largely on the synergistic interaction among illuminance, CCT, CRI, and contrast, tailored to both product characteristics and the intended atmospheric goals of the store. These configurations of technical lighting attributes serve as the initial catalyst, which is subsequently processed internally by consumers and gives rise to diverse psychophysiological responses at the Organism stage.

**Consumers' Psychophysiological Response**

Within the theoretical framework of the Stimulus-Organism-Response (S-O-R) model, the Organism (O) component represents the internal processing mechanisms, both affective and cognitive, that mediate the relationship between physical stimuli and consumers' behavioral outcomes. In this context, these internal mechanisms are increasingly understood through a psychophysiological lens, which examines the continuous interaction between psychological states (such as emotion and perception) and their corresponding involuntary physiological manifestations (such as visual attention and brain wave activity). An analysis of the selected literature reveals a substantial paradigm shift in the assessment of these internal states, from a strong reliance on self-reported questionnaires toward the adoption of objective neuroscience-based measurements. While the application of biometric instruments, such as eye-tracking and electroencephalography (EEG), remains limited in the reviewed literature, these tools uniquely enable researchers to capture consumers' subconscious physiological responses, often occurring before they are consciously recognized at the psychological level.

Before examining these biometric tools, it is important to acknowledge that the vast majority of the reviewed literature conceptualizes the Organism component primarily through conscious psychological constructs, with a predominant emphasis on perception and emotion. Empirical evidence consistently demonstrates that physical lighting attributes function as salient environmental cues shaping consumers' conscious evaluations of retail spaces and merchandise. For example, well-calibrated combinations of illuminance and correlated color temperature (CCT) have been repeatedly shown to enhance perceived product freshness, quality, and visual appeal across various retail contexts (Chen et al., 2022; Shen et al., 2025). At the affective level, lighting manipulations have also been found to directly influence consumers' emotional states, most commonly operationalized through the dimensions of pleasure and arousal (Lin et al., 2015; Phumchan, 2022). Retail environments characterized by balanced lighting contrast and coherent illumination schemes tend to

foster positive emotional valence and a heightened sense of spatial comfort, thereby establishing a favorable psychological disposition toward the store. Nevertheless, while these subjective self-reported evaluations offer meaningful insights into consumers' conscious attitudes, they capture only a partial representation of the underlying cognitive and neurophysiological processes that govern consumer responses.

Beneath these conscious psychological evaluations, the first involuntary physiological processing stage directly triggered by lighting stimuli involves visual attention and pupillary responses, which can be objectively quantified through advanced biometric tools. Eye-tracking technology captures precise ocular movements, such as gaze direction, fixation duration, and initial areas of interest to reveal how environmental cues actively direct conscious and subconscious consumer focus. Through eye-tracking experiments, Laski et al. (2018) demonstrated that subtle dynamic modulation of the color rendering index (CRI) is capable of attracting consumers' visual fixations toward products outside their primary focus, thereby unconsciously expanding the spatial scope of browsing behavior. Furthermore, pupillometry offers critical insights into the autonomic nervous system (ANS). As demonstrated by Viedma-del-Jesús et al. (2025), lower light intensities trigger greater pupil dilation, which serves as a direct biomarker for higher emotional arousal. This physiological reaction indicates that dim lighting can foster a more inviting atmosphere, thereby strengthening visitors' emotional engagement. Light distribution and contrast further interact with the visual complexity of the retail environment to guide attentional allocation efficiently, reducing cognitive load during in-store visual information processing (Viedma-del-Jesús et al., 2025; Batool et al., 2025).

At the neurological level, the advent of wearable biosensors and portable electroencephalography (EEG) has transformed the measurement of the Organism (O) from a purely psychological construct into a neurobiological one. Retail lighting has been proven to directly modulate central nervous system activity associated with memory, emotion, and even primitive physiological drives such as hunger. Using a 16-channel mobile EEG measurements in real retail settings, Berčík et al. (2016) measured emotional valence by analyzing the asymmetry of alpha wave amplitudes in the left and right prefrontal cortex (F3–F4). They found that the application of accent lighting in food-related areas elicited significantly higher positive valence and neural activation compared to general lighting conditions. More fine-grained neurological analysis was conducted by Wang (2020) using event-related potentials (ERP). That study revealed that food products illuminated with warm light (4000K) and red chromatic lighting significantly enhanced the amplitude of the Late Positive Component (LPC), which is biologically linked to increased appetite stimulation.

These rapid physiological responses, occurring within fractions of a second, subsequently converge into the formation of conscious psychological perceptions and emotional evaluations. Manipulations of illuminance and correlated color temperature (CCT) have been consistently shown to alter consumers' emotional states, particularly along the dimensions of arousal and pleasure when evaluating retail environments (Phumchan, 2022; Lin et al., 2015). Furthermore, lighting interactions reshape cross-modal sensory perceptions, whereby lighting not only determines whether a product appears visually appealing but also psychologically alters perceived taste or quality. This effect is evident in findings showing that specific lighting conditions enhance visual palatability and perceived freshness in products such as bread and fresh meat (Sato, 2024; Liu et al., 2024; Chen et al., 2022).

Overall, this set of findings underscores that consumers do not process retail lighting passively. Instead, lighting attributes function as key determinants that initiate a cascading sequence of biological reactions, beginning with visual capture at the ocular level, progressing through emotional valence processing in the brain, and culminating in psychological perceptions that ultimately shape approach or avoidance tendencies at the subsequent Response stage.

**Consumer Behavioral Responses**

Within the Stimulus-Organism-Response (S-O-R) framework, the final Response (R) stage captures the outcomes that emerge from lighting-induced psychophysiological states. In retail environments, these outcomes manifest across a multidimensional spectrum, encompassing transactional tendencies, spatial interactions, definitive choice behaviors, and overall post-cognitive appraisals such as satisfaction.

Transactional behaviors, encompassing both the cognitive formation of purchase intentions and the execution of purchase decisions, represent a primary behavioral focus in the reviewed literature. Consistent evidence indicates that well-calibrated lighting attributes enhance consumers' economic evaluations of products. For instance, the combination of a high color rendering index (CRI) and an appropriate correlated color temperature (CCT) significantly elevates purchase intentions for fresh produce and bakery items by strengthening visual realism and perceived palatability (Liu et al., 2024; Chen et al., 2022). However, the translation of favorable perception into actual purchase decisions remains context-dependent, as illuminance exerts variable effects across product categories and consumer profiles (Rebollar et al., 2017).

Beyond transactional outcomes, lighting functions as a spatial regulator that shapes approach or avoidance behaviors. In a spatial context, lighting does not merely illuminate merchandise, it choreographs the human physical experience within the architectural envelope. The interplay of light and shadow dynamically alters how consumers perceive the scale and proportion of the retail space, thereby influencing their physical movement and interaction with the built environment. Strategic manipulation of lighting contrast, such as accent lighting within subdued ambient

illumination, enhances spatial intimacy, increases approach intentions, and extends dwell time (Wu et al., 2021; Lin et al., 2015). These lighting conditions also guide subconscious navigation, encouraging broader browsing patterns (Laski et al., 2018), and systematically influence choice behavior. For example, brighter ambient lighting promotes alertness and healthier food choices, whereas dimmer lighting fosters relaxation and impulsivity (Biswas et al., 2017). When lighting supports visual comfort and spatial exploration, it ultimately contributes to higher overall consumer satisfaction.

Despite the relevance of these behavioral responses, the literature remains dominated by non-behavioral endpoints. Most studies operationalize the Response stage through attitudinal or perceptual evaluations, such as aesthetic preference or perceived atmosphere, without tracking observable actions. Consequently, while existing research demonstrates that lighting alters psychological states and evaluations, its direct impact on actual consumer behavior remains insufficiently validated.

In summary, retail lighting functions as an active determinant of consumer outcomes, influencing approach–avoidance tendencies, choice behavior, satisfaction, and transactional decisions. Advancing the field requires future studies to move beyond passive evaluations and incorporate direct observation of real-world consumer actions.

**Integration of the S-O-R Pathways**

To provide a comprehensive representation of the complex interrelationships and the frequency of causal linkages among the extracted variables, a Sankey diagram was constructed based on the thematic coding of the 20 reviewed studies (see Figure 2). This visual synthesis effectively depicts the dominant relational pathways connecting the Stimulus, Organism, and Response components.

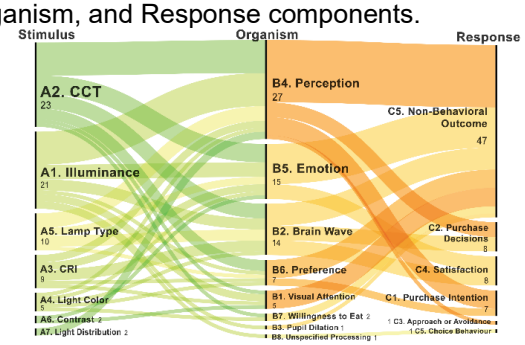


**Figure 2.** Sankey diagram illustrating the relational pathways and frequency of S-O-R connections

At the initial Stimulus stage, the flow distribution clearly indicates that correlated color temperature (CCT) and illuminance are the most dominant and frequently manipulated environmental stimuli. This highlights that the majority of retail lighting research is heavily anchored in testing fundamental photometric and colorimetric variables over other complex lighting parameters. As a result, more nuanced architectural lighting attributes, including color rendering index (CRI), contrast, light color, lamp type and light distribution, remain substantially underexplored in empirical research. This imbalance highlights an urgent need to expand the range of investigated stimuli in order to more accurately capture the multidimensional and dynamic characteristics of contemporary retail environments.

Moving to the Organism stage, the diagram reveals that the pathways predominantly converge on conscious psychological responses, with perception and emotion remaining the most heavily evaluated internal states. In contrast, the trajectories leading to subconscious physiological responses are visibly much thinner. This indicates that objective neurobiological measurements, such as visual attention, brain wave activity, and pupil dilation are still underexplored in the current literature, reflecting a strong historical reliance on traditional self-reported evaluations rather than biometric assessments.

Furthermore, the trajectories extending into the Response domain highlight a critical limitation in the existing literature, the transition toward actual observable behavioral outcomes remains limited. The terminal nodes are predominantly occupied by non-behavioral outcomes, suggesting that many studies conclude their investigations at the evaluation phase without measuring actionable consumer responses. Within the explicitly measured behavioral nodes, purchase decisions emerges as the most widely discussed transactional outcome. Conversely, actual spatial and consumption decisions, particularly approach behavior and choice behavior, are represented by much narrower pathways, reflecting a significant scarcity of empirical investigations in these specific areas.

Overall, this integrated visualization confirms that the current body of literature is heavily skewed toward one primary S-O-R pathway. The most extensively discussed trajectory flows from basic physical lighting attributes (CCT and illuminance) to conscious psychological states (perception), ultimately culminating in non-behavioral outcomes or anticipated purchase decisions. Conversely, the pathway connecting lighting stimuli to subconscious physiological activation, and subsequently translating into actual spatial or choice behaviors, remains the least explored. This imbalance reveals a substantial gap in the literature, presenting a clear direction for future biometric-based retail research.

**Methodological Gaps and Future Research Directions**

The analysis of the extracted literature reveals a pronounced methodological gap in the measurement of the Organism component. Current research remains heavily dominated by the use of self-reported questionnaires, while the application of objective biometric instruments is still relatively limited. This reliance on subjective evaluations is inherently vulnerable to cognitive bias, as consumers' conscious perceptions may not accurately reflect their underlying subconscious neurobiological activation. Consequently, the adoption of wearable biosensing technologies, such as mobile EEG, pupillometry, and eye-tracking glasses emerges as a critical priority for future research. The integration of these neuromarketing tools would enable the collection of precise, real-time psychophysiological metrics that capture

how consumers biologically respond to lighting design in retail environment.

Beyond instrumentation-related gaps, a significant imbalance is also evident at the Stimulus stage. The majority of experimental designs focus almost exclusively on basic photometric and colorimetric parameters (illuminance and CCT). In contrast, more architectural and dynamic lighting attributes, such as color rendering index (CRI), spatial light distribution, and contrast ratios remain largely underexamined empirically. Given the increasing adoption of adaptive and intelligent lighting systems in contemporary retail environments, future research must broaden the stimulus domain to encompass more multidimensional and dynamic lighting configurations.

At the Response stage, the synthesis highlights a pronounced scarcity of studies that measure consumers' actual physical behaviors. Most investigations conclude with passive evaluative metrics, predominantly focusing on non-behavioral outcomes (such as preference or perception), subjective satisfaction, and self-stated purchase intentions. Only a limited number of studies rigorously track observable, interactive behavioral outcomes, such as spatial approach or avoidance, definitive choice behavior, and actual purchase decisions. Bridging the gap between stated psychological intention and observable physical action represents a critical research frontier, essential for validating the true impact of lighting interventions on retail performance and profitability.

In conclusion, future research should place greater emphasis on integrating objective biometric measures while expanding the investigation of complex and multidimensional lighting attributes. Furthermore, to achieve comprehensive and ecologically valid results, studies must move beyond isolated measurement approaches. There is a pressing need to employ methodological triangulation, seamlessly integrating objective biometric measurement, subjective self-reported evaluations, and the rigorous observation of actual consumer behaviors within a single experimental design. Interdisciplinary collaboration among interior architecture, retail studies, and neuroscience is critical for addressing these methodological limitations. Such integrative efforts can elevate the S-O-R framework from a largely theoretical construct to a robust predictive tool, enabling retailers to develop lighting strategies that are empirically grounded and capable of optimizing consumers' psychophysiological states and subsequent behavioral responses.

## CONCLUSION

The primary objective of this systematic review was to examine how retail lighting attributes mediate consumers' psychophysiological processing and shape behavioral outcomes within the Stimulus-Organism-Response (S-O-R) framework. This review successfully addresses its core research question by systematically mapping the causal pathways linking physical lighting stimuli to psychological and behavior responses. While prior research has been dominated by subjective self-reported measures, the synthesized evidence demonstrates that objective biometric techniques, such as electroencephalography (EEG) and eye-tracking, offer distinct advantages in capturing subconscious neural and autonomic responses elicited by retail lighting conditions. Accordingly, neurobiological measurement tools hold substantial potential for uncovering the latent emotional and cognitive mechanisms underpinning consumer experience.

Drawing on 20 empirical studies, the review identifies a consistent pattern in which foundational lighting parameters, particularly illuminance and correlated color temperature (CCT), act as powerful triggers of not only physiological responses (e.g., visual attention, brainwave activity) but also psychological states (e.g., emotions, perception). Empirical findings indicate that specific lighting configurations can modulate neural activity patterns and pupil responses, alongside these subjective psychological evaluations, which in turn influence spatial approach behaviors and purchase-related tendencies. Nevertheless, the integrative synthesis reveals a pronounced imbalance in the existing literature, which remains heavily oriented toward conscious perception and attitudinal outcomes, while empirical evidence capturing actual, observable consumer behaviors remains scarce.

By consolidating these causal pathways, this review underscores critical methodological limitations that must be addressed to enhance ecological validity and explanatory power in future research. To address these limitations, methodological triangulation, integrating objective physiological indicators with subjective psychological measures and real-time behavioral observation, emerges as a necessary strategy for achieving robust empirical insight. Ultimately, the evolution of the S-O-R framework from a predominantly theoretical model into a predictive and operational tool depends on this multidimensional methodological advancement.

In addition to its academic contributions, this review positions retail lighting not only as a functional element but also as a strategic component of architectural and spatial design. For interior designers and retail planners, these findings provide practical implications, as lighting parameters can be deliberately adjusted to shape spatial perception, define visual hierarchies, and influence approach-related behaviors. Moving beyond intuition-based design, practitioners may apply these psychophysiological insights to inform targeted spatial interventions that support consumer decision-making, enhance satisfaction, and influence purchase behavior. This review therefore provides a valuable foundation for interior designers, retail practitioners, and scholars seeking to develop evidence-based, human-centered lighting strategies that optimize both consumer well-being and retail performance.

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