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REVIEW ARTICLE

Examining the Effect of Blue-Enriched Light on Selective Attention in Light-Dependent Occupational Activities: A Narrative Review

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ABSTRACT

Background: Given the increasing prevalence of modern artificial light sources and electronic displays in work environments, exposure to blue light has emerged as a significant environmental factor. Moreover, studies have demonstrated that blue light contributes to enhanced alertness and the improvement of cognitive functions, including selective attention.

Methods: This narrative review was conducted with the aim of providing a synthesis of the existing scientific literature on the effects of blue-enriched light on selective attention. The study commenced with a search of PubMed, Web of Science, Scopus, and SID databases. The search was conducted by utilizing "blue light" or "short-wavelength light" and "attention" or "alertness" keywords from 2010 to June 2025.

Results: By outlining the underlying physiological and neural mechanisms—particularly the role of ipRGCs and the melanopsin pigment—this study illustrates how blue light influences circadian rhythms, alertness, and cognitive performance. Empirical evidence consistently indicates that blue light can enhance alertness, reaction time, and performance on specific cognitive tasks such as working memory and sustained attention. However, its effects on memory and sleep remain variable, and inappropriate exposure, particularly during nighttime, may disrupt circadian rhythms and lead to adverse health outcomes.

Conclusion: The strategic management of blue-enriched light in occupational environments holds potential for enhancing selective attention, improving overall cognitive performance, and contributing to a safer, more productive, and healthier workforce. Realizing this potential requires rigorous and ongoing scientific research, along with a comprehensive approach to workplace lighting that integrates both visual and non-visual biological considerations.

KEYWORDS: *Blue-Enriched Light; Circadian Rhythms; Workplace; Selective Attention; Cognitive Performance*

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INTRODUCTION

Selective attention is a fundamental cognitive ability defined as the capacity to prioritize and focus on relevant sensory information while actively suppressing irrelevant or distracting stimuli. It involves managing both external distractions (such as background noise or visual clutter) and internal distractions (such as intrusive thoughts or habitual responses). This cognitive function is essential for maintaining efficiency and productivity across a wide range of everyday and professional tasks [1].

In occupational settings, deficits in selective attention can have serious consequences, leading to the oversight of critical details or failure to recognize hazards. In hospitals and healthcare facilities, where staff often work long and irregular shifts, selective attention is crucial for preventing medical errors. Attention-related lapses can result in medication mistakes, misdiagnoses, or other hazardous incidents [2]. Moreover, selective attention is a foundational skill for academic and professional development, underpinning abilities in language processing, literacy, and mathematics. Research indicates that these skills are not fixed but can be trained and improved through intervention, highlighting their vital role in overall cognitive performance [3].

Shorter wavelength (around 400–490 nm) blue light with higher energy has increasingly become part of our everyday light milieu. This is the result of widespread application of new artificial light technologies, such as light-emitting diodes (LEDs), in commercial and industrial settings, as well as in the widespread use of electronic displays (such as television, computers, smartphones, tablets) [4]. Scientific research has established that blue light exposure has a complex set of effects on the psychology and physiology of humans with both positive and negative impacts on cognitive ability and well-being. Of particular significance, beyond its role in image-forming vision, light and particularly blue light has a significant impact on the regulation of non-visual physiological processes. It includes regulation of the circadian rhythms, modulation of the degree of alertness, and direct effect on various aspects of cognitive function [5].

As the importance of cognitive performance, including selective attention, in many tasks at work is great, numerous studies have assessed the application of blue light or blue-enriched white light. These studies have been conducted in various types of working environments and under varying conditions. So, this narrative review was conducted with the aim of providing a synthesis of the existing scientific literature on the effects of blue-enriched light on selective attention.

MATERIALS AND METHODS

This narrative review was conducted with the aim of developing a comprehensive synthesis of the available scientific literature on the effect of blue-enriched light on cognitive performance, especially on selective attention, and its applicability and consequences in the work environment. The study began by conducting a search of the PubMed, Web of Science, Scopus, and SID databases, as well as the Google Scholar search engine. The search focused on exploring articles that were published after 2010 to June 2025, and they addressed “blue light”, “blue-enriched light”, “short-wavelength light”, “attention”, “cognitive performance” and “alertness” in working environments.

Primary focus was on original studies that included employees or populations with similar shift work schedules and lab studies that considered attention-related tasks. Review articles and systematic reviews were employed to put findings into context and assist in comprehension but were not considered a replacement for primary research.

Articles were screened by two researchers for topic relevance, and key references followed up through tracing citations. High inclusion criteria were not employed, as the review was narrative and not systematic, though care was taken to include recent, peer-reviewed work. This allowed thematic synthesis of occupational and physiological information on blue light effects within work environments for attention.

RESULTS AND DISCUSSION

Non-Image-Forming Photoreceptors

Other than the classic photoreceptors—the rods (night vision) and cones (color vision and high acuity)—the mammalian retina also possesses a third category of unique photoreceptors: intrinsically photosensitive retinal ganglion cells (ipRGCs). The ipRGCs stand out because they are directly light-sensitive and vastly predominate non-image-forming photoreception. This system is also crucial in the regulation of vital biological processes that are not linked with conscious visual perception, such as circadian photoentrainment (entrainment of the internal clock of the body to the day-night cycle) and the pupillary light reflex [6].

The photopigment most responsible for ipRGCs’ intrinsic photosensitivity is melanopsin (Opn4). Melanopsin is maximally sensitive at 470–480 nm, and therefore ipRGCs are maximally sensitive to blue wavelengths. Blue sensitivity is exceptionally effective at modulating non-image-forming physiological responses because of the distinctive spectral sensitivity. Melanopsin RGCs give rise to a direct neural pathway known as the retinohypothalamic tract (RHT) [7].

Neural Pathways and Effects on Circadian Rhythms and Alertness

The retinohypothalamic tract (RHT) is the primary route for the transfer of light information from ipRGCs to the suprachiasmatic nucleus (SCN) of the hypothalamus, which is commonly referred to as the master circadian clock of the brain that governs circadian rhythms throughout the body. Blue light exposure, particularly between 460–480 nm, is highly effective in regulating the human circadian clock. Its best-known effect is the suppression of the release of melatonin, a hormone whose release typically accompanies the start of darkness and brings about sleep [8].

While nighttime blue light exposure is both sleep disruptive and circadian phase delaying due to melatonin suppression [9], properly timed daytime exposure also affects the circadian system. By suppressing melatonin early during the day, blue light exposure can phase advance circadian rhythms [10].

Beyond its effect on melatonin control, blue light's alerting properties during the day have more direct neural mechanisms. ipRGCs indirectly influence the activation of other brain regions crucial for arousal, such as the locus coeruleus (LC). The LC, through blanket release of norepinephrine in the cortex, further triggers the noradrenergic effect. This noradrenergic effect is associated with increased physiological arousal and heightened alertness [11].

Moreover, blue light has also been shown to directly stimulate cognitive brain activity. Functional neuroimaging studies (fMRI) show that exposure to blue light enhances activity in key prefrontal cortical regions like the dorsolateral prefrontal cortex (DLPFC) and ventrolateral prefrontal cortex (VLPFC). These regions are responsible for executive functions, working memory, and controlled cognitive processing. For instance, increased activation of VLPFC has been linked to faster reaction time on cognitive tasks [12]. Blue light enhances functional and goal-directed connectivity between regions such as the amygdala and prefrontal cortex, regions responsible for mood and cognition [13].

While melatonin suppression is a strong, well-established mechanism for blue light's alerting effects, particularly nighttime exposure, there is some evidence that direct neural circuits—i.e., ipRGC projections to the locus coeruleus (LC), resultant norepinephrine release, and direct activation of the prefrontal cortex—are critical for cognitive benefits during the day. This would speak to a more complex and direct neuromodulatory role beyond mere suppression of sleep-linked signals [14].

Blue light does not simply "wake us up" by suppressing a sleep hormone. Rather, it actually activates and increases brain regions directly involved in higher-order cognitive processing, such as executive functions and working memory, through separable and more explicit neural networks. This renders its impact on selective attention under wakefulness more potent and concentrated. This information lends evidence to the proposition of strategic blue light exposure during working hours—not only as a countermeasure to fatigue but as an active method of enhancing cognitive performance [15] (Table 1).

Neural Mechanisms of Selective Attention

Selective attention is not a unitary process but a complex interaction of neural mechanisms modulating information processing from early perceptual brain areas to late integrative decision-making areas. Some of the key mechanisms are the following:

Target Amplification

This involves selective amplification of the neural activity that corresponds to target stimuli. Some of the evidence for this includes increased neuronal discharge rates, enhanced gamma-band oscillatory synchrony (a marker for synchronized neural activity), increased event-related potentials (e.g., the P1 wave in early extrastriate visual areas), and BOLD responses measured in fMRI studies. This kind of amplification guarantees efficient transmission of task-relevant information along neural pathways [16].

Distractor Suppression

Simultaneously with selective attention, active suppression of neural responses to irrelevant or distracting stimuli occurs. Studies demonstrate that if a neuron's receptive field contains more than one stimulus, the neural response can be identical to that when the target is present alone, which suggests active suppression of distractors [17].

Table 1. Neural Mechanisms Underlying Blue Light's Cognitive Effects

Component	Primary Role in Blue Light Processing	Key Impact on Cognition/Physiology
Intrinsically photosensitive retinal ganglion cells (ipRGCs)	Non-image-forming photoreceptors, contain melanopsin, peak sensitivity to blue light (470–480 nm)	Regulation of circadian rhythms, pupillary light reflex, mediation of non-visual light effects
Melanopsin (Opn4)	Principal photopigment in ipRGCs, responsible for their intrinsic light sensitivity	Mediates melatonin suppression, circadian phase shifts, effects on alertness and cognition
Retinohypothalamic tract (RHT)	Direct neural pathway from ipRGCs to the SCN	Transmits light information for circadian rhythm entrainment
Suprachiasmatic nucleus (SCN)	Master brain clock, regulator of circadian rhythms	Coordinates the body's biological rhythms with the light-dark cycle
Pineal gland	Produces and secretes melatonin (sleep hormone)	Blue light suppresses melatonin production, influencing sleep–wake cycles
Locus coeruleus (LC)	Brainstem nucleus, releases norepinephrine	Enhances alertness and physiological arousal via indirect ipRGC influence
Norepinephrine	Neurotransmitter released by LC	Increases general alertness and modulates cognitive processing
Prefrontal cortex (DLPFC/VLPFC)	Brain regions involved in executive functions, working memory, and controlled cognitive processing	Increases activation and functional connectivity, improving performance on cognitive tasks, especially working memory

Fronto-Parietal Network Engagement

Voluntary and top-down attentional control is regulated primarily by the network of regions in the frontal and parietal cortices. The dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex (ACC), posterior parietal cortex/intraparietal sulcus (IPS), and inferior frontal regions are significant regions. They constitute the core of the dorsal and ventral attention networks that are important for the focusing of attention on specific dimensions of the world and on goal-oriented behavior [18].

Oscillatory Synchrony

Neural oscillations within the gamma (approximately 30–90 Hz) and beta (approximately 15–30 Hz) frequency bands have been suggested as fundamental neural mechanisms for the dynamic coordination of activity between and among neural populations. Oscillations may act as a selective filter by generating windows of increased or decreased excitability and thereby facilitating information transfer. Selective attention was found to enhance gamma-band oscillatory synchrony among various brain regions [19].

Monitoring and Resolving Response Conflict

With competition among distracting stimuli for response selection, some neural networks are brought in to resolve such conflict. These include the anterior cingulate cortex (ACC), the thalamus, and bilateral frontal regions—the dorsolateral prefrontal cortex (DLPFC) and the right inferior frontal junction (IFJ). The ACC is thought to monitor response conflict and signal frontal regions to come online to resolve interference and thereby contribute to successful working memory performance [20].

The Role of Selective Attention in Cognitive and Occupational Performance

Selective attention plays a crucial role in promoting efficiency and productivity in everyday tasks. It allows individuals to attend effectively to goal-oriented tasks and, simultaneously, respond to or handle random environmental changes. It exerts a significant effect on working memory performance. The ability to utilize selective attention effectively during the encoding phase, particularly by inhibiting irrelevant information, is critical for the optimization of working memory capacity and accuracy [21].

At work, several examples demonstrate the importance of selective attention. In office work, being able to focus in the presence of background noise and disturbance in an open-plan office is crucial [17]. When

Table 2. Principal Studies Reviewed on Blue Light and Attention/Cognitive Performance in Workplace Settings

Study	Exposure and Blue Light Parameters (Wavelength, Intensity, Duration, CCT)	Participants (Number, Age Range, Type)	Cognitive Tasks Used	Key Findings (Specific Effects on Attention, Reaction Time, Accuracy, Neural Activity/Brain Regions)	Occupational Relevance
Charkhabi et al. [39]	High CCT and intensity	Systematic review	Attention, alertness, reaction time, memory, sleep	Blue light increases alertness, attention, and reaction time; effects on memory and sleep are variable	Enhanced workplace performance
Tonetti et al. [27]	Blue light (unspecified), 1 min	32 young adults (mean 24.06 years)	Lexical Decision Task (LDT), Attention Network Test (ANT)	Stronger semantic priming (LDT), improved orienting network efficiency (ANT)	Cognitive performance enhancement in young adults
Matsuo et al. [28]	Blue color (font), unspecified	13 young adults (mean 21.2 years)	Clinical Assessment for Attention (Cancellation Test)	Fewest errors, fastest task completion time under blue font	Improved attentional performance through colored information
Golmohammadi et al. [26]	Shorter wavelength, higher intensity, higher CCT	Systematic review	Attention, reaction time	Melatonin suppression, increased alertness, improved attention, faster reaction times	Modulation of neural responses in workplace cognitive tasks
Alkozei et al. [10]	Exposed to either blue (469 nm) (n = 17) or amber (578 nm) (n = 18) wavelength light for 30 minutes in a darkened room	35 healthy adults (18 female) (18–32 years)	N-back task (working memory)	Faster reaction times, increased DLPFC and VLPFC activation	Broad implications for workplaces requiring alertness and rapid decision-making (offices, cockpits)
Silvani et al. [25]	Blue light (various)	Systematic review	Cognitive performance, alertness, reaction time, accuracy	Cognitive performance increased (4/7 studies), alertness improved (7/10), reaction time reduced (9/13), accuracy (1/4)	Enhanced office and driving performance
Kim et al. [29]	Two types of colored light (blue light and red light) with two brightness levels (400 lux for the darker environment and 1000 lux for the brighter environment)	A total of 25 participants without cognitive disabilities, comprising 16 men and 9 women (Their average age was 22.04 ± 1.74 years)	Long-term memory retrieval	Blue light superior to red light in enhancing long-term memory; effect increases with illuminance	Cognitive enhancement (memory, attention, working memory) in the workplace
Lin et al. [30]	1 h of 40-Hz or 1 h of 0-Hz light (centroid wavelength = 472 nm, irradiation power density = 0.03 mW/cm^2) exposure in the interval between the two memory experiments	Forty-four (12 female, 32 male) volunteers (aged 18–24 years)	Working memory, brain activation	Superior regulation of working memory, broader brain activation; 40 Hz modulates activity and connectivity in memory-related regions	Potential for cognitive modulation in workplace settings

driving, it is essential to maintain attention on the road and traffic signs and ignore irrelevant stimuli such as music or conversation with other car occupants [22]. In work or hazardous settings, a supervisor monitoring a suspended load in a warehouse must maintain keen focus on the load while still maintaining general attention to other arising conditions or potential hazards in the overall environment (e.g., other vehicles, falling objects) to prevent accidents [23].

A detailed description of the neural processes of selective attention, including target enhancement, distractor inhibition, and fronto-parietal network activation, demonstrates that it is not a passive "focusing" ability but rather an active and complex neural process. This type of process is integral to effective higher-order cognitive functioning and, more importantly, maintaining safety in dynamic work environments. That this selective attention is trainable and can be enhanced by a variety of training methods (e.g., action video games, meditation, targeted educational interventions) further increases its worth as a trainable asset for individuals and organizations. By characterizing its neural basis, selective attention is elevated from a simple behavioral observation to a complex, measurable, and trainable cognitive process. Its active role in suppressing irrelevant information is particularly critical for preventing "tunnel vision" and enabling employees to notice unexpected hazards in complex and dynamic work environments. This observation strengthens the argument that interventions intended to enhance selective attention—environmental factors such as lighting among them—have immediate and practical implications for occupational safety and the reduction of human error. Such a perspective broadens the field of occupational health interventions [24].

Effects of Blue-Enriched Light on Selective Attention and Cognitive Performance at Workplace

Enhanced Alertness and Reaction Time

Empirical evidence consistently demonstrates that blue-enriched light exposure significantly improves fundamental cognitive functions, including overall alertness, vigilance, and reaction time. Evidence supports these observations as indicating that lighter wavelength (i.e., blue) light, higher intensity, and higher correlated color temperature (CCT) increases suppression of melatonin, increased alertness, reduced sleepiness, higher attention, and faster reaction times. Specifically, a systematic review was reported to report that blue light exposure resulted in 7 out of 10 studies having increased alertness and 9 out of 13 studied to have slower reaction times [25].

Controlled experiments have yielded that white light enriched with blue, particularly at high correlated color temperatures (such as 17,000 K), enhances prolonged attention and reduces reaction times significantly in stressful working situations, such as control rooms [26]. Indeed, even limited exposure—in as little as one minute—has been shown to enhance cognitive performance in young adults in the respect that the efficacy of the orienting attention network (as indexed by the Attention Network Test, ANT) was enhanced, and semantic alerting was enhanced [27].

Enhancement of Specific Cognitive Tasks

Apart from general vigilance, blue light has also been associated with improved performance on specific cognitive tasks for work purposes. This includes reported improvement in office work performance in general and driving tasks. In functional magnetic resonance imaging (fMRI) research, subjects who were exposed to blue light for 30 minutes had significantly faster reaction times on a working memory task (N-back task) compared to controls who were exposed to amber light. This behavioral improvement was followed by increased activation of the dorsolateral prefrontal cortex (DLPFC) and ventrolateral prefrontal cortex (VLPFC), brain regions well-documented to be crucial to executive function as well as working memory [10].

More importantly, greater VLPFC activation was positively linked with faster reaction times on the N-back task, with implications of a causal link between blue-light-induced neural adaptations and enhanced cognitive function. Even the color of information being presented influences attention. In a study, it was found that blue text, in a cancellation task, was associated with the most accurate attentional performance and fastest task completion times compared to red or black texts [28].

In addition to this, blue light has also been found to be involved in memory improvement. Studies have shown that it is better at retrieving long-term memory than red light, and as light intensity rises, so does the improving effect [29].

Effects of Light Parameters (Intensity, Wavelength, Color Temperature, Duration)

The efficacy of blue light on cognitive performance modulation is largely dependent on some exposure parameters.

Wavelength

Experimental data indicate that blue light (e.g., 460 nm) exerts a stronger modulatory effect on working memory tasks and elicits larger brain activity than other wavelengths, for example, green (550 nm) or violet (430 nm) [30].

Intensity (Illuminance)

Higher light levels are most typically associated with higher alertness, energy, physiological arousal, and improved performance on tasks requiring sustained attention. For example, increasing illuminance from 200 lux to 1000 lux has been shown to make cognitive performance more efficient, less drowsy, and reduce reaction times [26]. The illumination effect of light in enhancing long-term memory also increases with higher illuminance [29].

Corelated Color Temperature (CCT)

Increased color temperatures (i.e., 17,000 K) are always associated with better cognitive performance. While some studies have reported increased CCTs (i.e., 6,500 K) are associated with faster reaction times due to more potent melatonin suppression, others found an optimal CCT of roughly 4,300 K for focus and sustained attention under white LED desk lighting [31].

Duration

The performance-improving actions of blue light are observable well after about 30 minutes' exposure and can persist for some time afterwards [32]. Results of studies of shorter duration (e.g., <21 minutes) have generally failed to demonstrate such gains. Moreover, greater intensities and longer periods of exposure lead to stronger changes in brain function [33].

Frequency

Although less studied, frequency of light modulation is becoming a critical parameter. For example, blue 40 Hz light has been shown to alter the functional connectivity and activity of brain regions subserving memory, thus demonstrating its ability to effect cognitive adaptation [34].

Individual Differences and Environmental Factors

The effects of blue light can vary considerably based on individual differences.

Sex

Sex differences in response have been noted in certain studies, with males having larger physiological response to blue-enriched light and faster reaction times on sustained attention tasks compared to females, particularly when evening exposure occurs [26].

Individual Alertness Levels

One's baseline level of alertness can also modulate the impact of blue light. People with higher baseline alertness prior to light exposure respond more to blue-enriched light, with faster responses on sustained attention tasks [35].

Combined Environmental Factors

Light also combines with other environmental variables. Concurrent exposure to other adverse environmental conditions, i.e., noise, heat, or vibration, can have a strong influence on cognitive and physiological measures and in some instances negate the beneficial effects of light. For instance, high temperatures combined with lighting can have negative influences on cognitive processes and reduce performance [36].

Possible Applications in the Workplace

There is strong evidence for the beneficial effects of blue light on alertness, attention, and reaction time with significant implications for the ideal design of many working environments. This would mean blue-enriched lighting can be specifically applied in spaces where sustained alertness, quick decision-making, and high-level cognitive workload are a concern, such as office structures, industrial control facilities, aircraft cockpits, and hospitals [37].

Beyond specific purposes, the inclusion of blue-enriched light in office spaces can also support overall performance increase, increased focus, and enhanced mood for employees. In environments requiring intense teamwork and rapid decision-making, such as certain sports or emergency response scenarios, brief exposure to blue light can even be used to prevent injury by sharpening cognitive responses [38].

Continuous reports of the effects of exposure duration, intensity, and individual wavelength (with blue light showing superiority) definitely define a dose–response relationship. This consideration moves past the simplism of "blue light is good" to a better idea of "how much, when, and in what manner blue light is most effective." It implies that an unspecified "blue light" intervention would not be optimal. Its efficacy is largely dependent upon proper exposure parameters [9].

Short exposure may be sufficient to initiate neural changes, yet prolonged or amplified exposure appears to be necessary for significant and observable gains in behavior. This emphasizes the value of appropriateness in lighting intervention design and strategy. For the workplace, this would entail that merely installing "blue-enriched LED" lighting would be insufficient. Optimization of gains likely requires adaptive lighting systems capable of adjusting wavelength, intensity, and duration in response to time of day, tasks required of individual cognition, and even the profile of workers. This is an open invitation to personalized lighting for the workplace, away from fixed lighting towards adaptive and "intelligent" space [4].

CONCLUSION

This overview has investigated the multifaceted impact of blue-enriched light on selective attention in the workplace. The evidence unmistakably demonstrates that blue light, to a very great extent through its influence on intrinsically photosensitive retinal ganglion cells (ipRGCs) and their resultant neural action, is a potent human physiology and cognitive modulator. Repeated exposure to it enhances alertness, reaction speed, and performance on some cognitive tasks, particularly those involving executive functions and working memory. The efficiency of these actions is significantly contingent on such principal parameters as wavelength, intensity, and duration of exposure as well as on biological individuality.

Despite great advances, the area is constrained by inconsistent study findings, absence of standardized interventions, and the need for more powerful and longer human studies. Upcoming studies must focus on correctly defining optimum light parameters, probing subtle effects on different cognitive tasks, and translating laboratory findings into pragmatic and real-world work environments. The development of intelligent, dynamic, and biologically-tuned lighting systems that can adjust to single demands and task needs is a compelling developing frontier. In line with this, the tactical implementation of blue-enriched lighting in workplaces has great potential to enhance selective attention, maximize general cognitive function, and enable a safer, more productive, and healthier working population. Realization of this potential will demand strict and on-going scientific research, coupled with an integral approach to illumination in the workplace combining both visual and non-visual biological aspects.

Conflict of Interest
The authors declare no conflict of interest.

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Study Conception or Design: Z Zamanian
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All authors have approved the final manuscript and are responsible for all aspects of the work.

AI Statement
During the preparation of this work the authors used ChatGPT to translate and rephrase certain sections. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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