Sensory-Based Sleep Interventions: Light, Sound, and Temperature as Therapeutic Tools

A Foundation Paper

Prepared by:

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Abstract

Sleep is an essential phenomenon in human body and it is not only influenced by mental and behavioral functions, but also by sensory conditions that sleep is taking place. The main hypothesis of our foundation paper is that we will study three general groups of sensory based interventions i.e. light, sound and temperature and how they may induce therapeutic interventions in the promotion of sleep health. Phototherapy is a phase-shift and nighttime circadian modulator (primarily by suppression of melatonin but also phase-shift action) with clinical applications in the nighttime and daytime. White, pink, and brown noise, ASMR, music and natural sounds can all reduce environmental disruption but tend to be effective with respect to environmental disturbance only when used individually and depending on individual preference. Other factors that influence initiation and maintenance of sleep include ambient control and pre-sleep rituals particularly in communities faced with night sweats, menopause or climate challenges. These modalities are explored as supplements rather than alternatives to Cognitive Behavioral Therapy for Insomnia (CBT-I) with the objects of increasing the rates of adherence and success when individualized to the patient. There is present evidence showing that sensory interventions have low risk, accessibility, and adaptability to all clinical sectors, but there is need to conduct more rigorous trials to standardize these protocols and provide consistency on long term effects in the future. The best outcomes might be achieved by incorporating evidence-based light, sound, and temperature approaches into the framework of therapeutic practice and offering patients comprehensive, non-medication-related tools to support proper sleep and general wellness.

Keywords*: Sleep interventions; light therapy; circadian rhythms; melatonin; white noise; pink noise; ASMR; music therapy; sensory modulation; non-pharmacological therapy.*

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1. Introduction

Sleep has been globally acknowledged as a pivot to human health as it helps to restore the body physically, regulate emotions as well as perform cognitively. Sleep disturbances, not only correlate with fatigue and decreased productivity but also result in more serious conditions in the long run, e.g. cardiovascular disease, mood disorders and compromised immune system functioning. It is noted that occupational therapy and associated fields pay more attention to sleep as a significant occupation and the field of intervention, which is significant to the quality of life, in general [1].

Besides behavioral and cognitive factors, the sensory background also has a central place in defining the quality of sleep. Extrinsic factors, such as sensory stimuli e.g. light, sound and temperature, may either facilitate sleep initiation or maintenance, or, instead, they can increase arousal and thereby interfere with sleep. Studies point out the fact that different people have different responses to the stimulation of senses: what seems to have a calming effect on some individuals might cause stress and hyperarousal in others due to inconsistency of ambient noises or other changes [2]. These distortions in the processing of sensory stimuli can be described as being over-responsive or under-responsive and we can appreciate why blanket recommendations to follow sleep hygiene measures cannot be applicable to all.

In this paper, I suggest light, sound, and temperature as therapeutic means and argue that they can be tailored to a particular sensory profile. The paper has tried to invoke the question of what the sensory environment is, its working and integration in the evidenced-based care of Insomnia such as Cognitive Behavioral Therapy of Insomnia (CBT-I) in order to facilitate clinicians to use it in encouraging restful sleep. Anyway, the more person-centered approach to sensory interventions is promising because it is a low-cost intervention with minimal or no risk and is holistic.

2. Background: Sleep Physiology and Sensory Pathways

Sleep is a complex physical process that is controlled by two mechanisms that act on one another, the homeostatic drive and the circadian rhythm. The homeostatic process ensures that the longer a person is awake, the higher the urge to sleep, with the circadian mechanism acting via the suprachiasmatic nucleus and coordinating of the sleeping and wakefulness cycle to environmental conditions such as the light and temperature [3]. Sleep is organized into REM sleep

and non-REM with each performing its respective functions in the repair process which include, but are not limited to, memory consolidation, emotional stability, and physical recovery. Interruption of such processes is linked to the enormous number of disorders of sleep, such as insomnia or parasomnia.

Sensory processing, its turn, is an overly sensitive topic because it concerns the sense experiences of people and their ability to stay awake. The failures to regulate the individuals' reaction to salient sensory signals, which is called sensory modulation disorders, can prove to be a significant blow to sleep as adults and children cannot regulate to environmental stimuli that other people find to be neutral or relaxing. Improved sleep is rated as one of the most apparent wishes by the parents of children with sensory problems in terms of therapeutic intervention because sleep is considered as such an important component of normal functioning [4].

This is particularly the case with the population affected by neurodevelopment in which this association between the sense and sleep can be noted. An example of this increment in sensory sensitivity is found in autistic children (with autism spectrum disorder), not to mention their problems in sleeping throughout their lives. They went as far as hypothesize that sensory hyper hyper-responsivity such as light or sound annoyance could have contributed to delayed sleep onset, and partial rest in this group [5]. The results indicate that similarly to the biological rhythm, sleep should also be considered within the context of sensory profile perception of a particular person. With the combination of physiology of sleep processes and the sensory pathways, the clinicians would be better placed to develop interventions that will maximize the environment to facilitate sleep and satisfy the needs of an individual patient.

3. Light as a Therapeutic Tool

One of the strongest of such sensory cues is light. The suppression of melatonin and the phase-shifting effects of its regulation of circadian rhythms make it an important therapeutic agent to be utilized in the treatment of sleep disturbances throughout the lifespan. Light-based interventions offer a non-invasive and adjustable means in occupational therapy and other healthcare practices, particularly for individuals with chronic insomnia, developmental sleep disturbance, or irregular sleep-wake cycles [6].

3.1 Mechanisms of Action

Exposure to natural or artificial light directly influences the suprachiasmatic nucleus (SCN), the central pacemaker that regulates circadian timing and the sleep–wake cycle. Bright-light exposure during the morning can shift circadian rhythms to an earlier phase, allowing an individual to fall asleep earlier at night. Conversely, exposure to blue-enriched light in the evening effectively delays the release of melatonin, thus prolonging wakefulness.[7] This mechanism explains why some individuals with heightened sensory responsivity may perceive even low levels of illumination as disruptive, while others require structured light exposure as part of their regulatory routines.[8]

3.2 Clinical Applications Across Populations

Clinical applications of light-based interventions have been studied across the lifespan, with evidence emphasizing their role in circadian entrainment and sleep regulation.

Infants and young children: A systematic review of observational studies found that infants regularly exposed to natural daylight exhibited earlier circadian rhythm consolidation and shorter sleep latency compared with those without structured light exposure. Evening exposure to dim night-light environments further supported **increased total nighttime sleep duration**.[9]

Children with autism spectrum disorder (ASD): It is reported in a controlled trial that combining structured morning light exposure with massage therapy led to fewer nighttime awakenings, improved adaptability to environmental transitions, and reduced arousal levels. These outcomes were measured through parent-reported sleep logs and behavior scales[10]

Adults with chronic insomnia: Randomized controlled trials of bright-light therapy demonstrate significant efficacy. It is found that morning light exposure (>2,500 lux, 30–45 minutes) advanced circadian phase, reduced sleep onset latency by an average of 20 minutes, and improved Pittsburgh Sleep Quality Index (PSQI) scores over 4–6 weeks[11]

Together, these studies indicate that light interventions are clinically relevant in populations vulnerable to circadian misalignment, with outcomes measurable through validated scales such as PSQI, actigraphy, and standardized behavioral observations[12] [13]

Table 1: Effects of Light on Sleep in Selected Populations

Population	Light Intervention	Reported Outcomes	Reference
Infants	Consistent exposure to daylight, dim evening environment	Improved circadian consolidation and reduced sleep latency	Galland et al., 2012
Children with autism	Structured light exposure paired with sensory interventions	Reduced nighttime awakenings, improved adaptability	Escalona et al., 2001
Adults with insomnia	Morning bright light therapy	Advanced circadian phase, improved onset and maintenance	Gutman et al., 2017

3.3 Integration With Occupational Therapy Goals

In practice, light interventions are rarely applied in isolation; they are usually integrated with individualized goal-setting approaches such as Goal Attainment Scaling (GAS).[14] [15] This enables therapists to operationalize progress by setting concrete targets, such as scheduling morning walks with increased light exposure, reducing device usage in the evening, or modifying bedroom lighting conditions. Structured applications of this kind have demonstrated benefits not only for sleep outcomes but also for daytime functioning, self-regulation, and play in children.[16]

3.4 Practical Protocols and Considerations

The mode of light-based interventions should be concerned with intensity and timing. No less than 30 minutes in the morning of bright light (>2,500 lux) can be supportive of circadian phase advances, and dim lighting of the warm-spectrum is suggested in the evening.[17] Once again, these recommendations tend to depend on client-specific conditions, such as rural versus urban, availability of outdoor light, and cultural or occupational practices. Moreover, individual sensory profiles should be used to ensure personalization to observe the client sensitivities and achieve maximum effectiveness.[18]

Table 2: Practical Guidelines for Light-Based Intervention

Strategy	Timing	Clinical Rationale	Reference
Morning light walks	First 1–2 hours	Strengthens circadian	Fund et al., 2020

(natural light)	after waking	entrainment	
Warm-spectrum bulbs in evening	2–3 hours before bedtime	Reduces melatonin suppression and arousal	Foitzik & Brown, 2018
Device light filters / screen curfews	At least 1 hour before bed	Minimizes blue-light disruption	Kidney et al., 2020

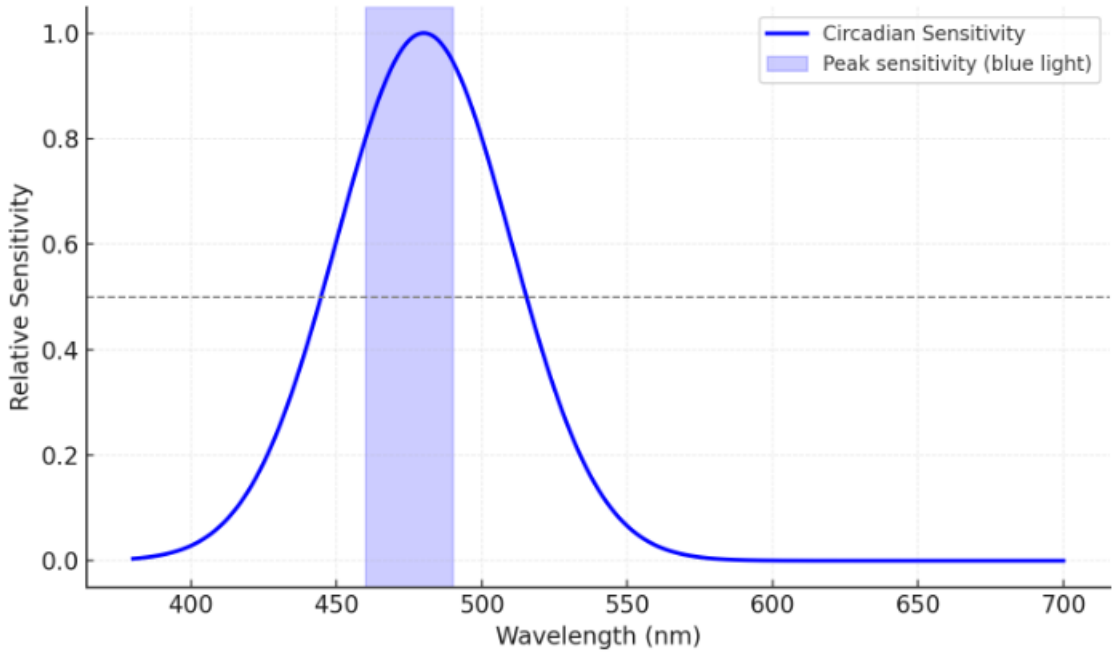

Figure 1: Light Spectrum and Circadian Sensitivity

The manipulation of light is also applicable as well as evidence-based interventions of augmenting sleep in any category of population such as infants, or adults. The success depends on the timing frequency and intensity and the fact that everyone processes the senses differently and it is evident that methods should be individualized. Together with other goal-specific methods and occupational therapy planning, light use strategies can have a considerable impact on both long-term effects of sleep quality, daily functioning and health.

4. Soundscapes for Sleep

Sound is a very ubiquitous aural factor in the sleep environment. In contrast to light that can be physically reduced or shaped, sounds are erratic and mostly uncontrollable and can include external noise, such as traffic, as well as household nuisance. In people with increased sensory

responsivity, e.g. sensory modulation disorders or autism spectrum disorder, even slight alterations of sound may impede sleep initiation and/or maintenance.[19] Sound can be used therapeutically as well, drowning out unwanted stimulus and also helping one become more relaxed when it is administered in a strategic manner.

4.1 Mechanisms of Auditory Influence on Sleep

Auditory system is also functional partially when a person is asleep, its purpose is to identify abnormal or even dangerous sounds in the surrounding. Though this evolutionary adaptation can improve survival, it may also interfere with rest when the system becomes hyper sensitive. In children and adults with sensory processing disorder (SPD), this hyperactivity of arousal elicitation often results in exaggerated arousal response and consequently, disrupted or poor quality sleep.[20] Any small and random sounds can cause awakenings or fail to allow normal transit between sleep phases, increasing existing sleep problems.

Controlled and predictable aural stimulation, on the contrary, has been demonstrated to exercise more successful arousal control. White, pink and brown sounds, which may be called noises, are a constant acoustic backdrop that covers all environmental disturbances caused by traffic or house sounds. These soundscapes reduce the variability in auditory information and aid in sustaining sleep continuity and creating a more relaxed sleep environment.[21] This camouflaging effect contributes to the feeling of safety because the brain will receive less obvious or threatening stimulation against the background of a steady sound.

Studies also show that inadequate sensory control in children is usually associated with poor sleep habits and this supports the need to ensure that sound at bedtime is well controlled through structure.[22] Regular sound stimulation, through noise machines, relaxing music, or sound environments inspired by nature can also enhance self-regulation and overall sleep outcomes. Therefore, auditory interventions can be used both as passive background noise and as active therapeutic tools that balance sensory processing and stimulating rest.

4.2 Clinical Applications and Populations

- **Children with ADHD**: Nielsen et al. (2017) conducted a multimodal occupational therapy study and found that auditory strategies embedded within structured routines significantly **reduced bedtime resistance** and improved **sleep efficiency**, as measured by actigraphy.

Sound-based interventions have been evaluated in diverse populations, particularly children with sensory processing challenges and developmental disorders.

- Children with ASD: Preschool children with heightened sound sensitivity often present with disrupted sleep. It is validated this association using the Children's Sleep Habits Questionnaire (CSHQ), showing that structured sound interventions (white noise machines, consistent auditory routines) reduced bedtime resistance scores and nighttime awakenings [23]
- Children with Sensory Processing Disorder (SPD): Mailloux (2007) performed a randomized controlled pilot study of occupational therapy for children with sensory modulation disorder. Parents reported improved sleep onset latency and fewer night awakenings when bedtime routines incorporated predictable soundscapes such as white or pink noise.[24]
- Adults with insomnia: Brown and pink noise have been studied in small clinical trials, demonstrating improvements in sleep continuity and slow-wave sleep duration, measured via polysomnography. [25]

Across groups, consistent findings indicate that predictable, low-decibel auditory input enhances sleep quality by reducing sensory hyperarousal. Outcomes are most reliably tracked using standardized parent-report questionnaires, actigraphy, and polysomnographic measures.

4.3 Sound Types: White, Pink, Brown, and Beyond

Pink noise has more focus on the lower frequencies, providing a softer feel that some individuals find more relaxing. Brown noise is shifted further toward low frequencies and resembles deep ambient thrums. Research in sensory processing highlights that individual preference often determines which type of noise is most effective, underscoring the need to personalize interventions according to sensory profiles.[26] Music, auditory sounds of nature, and structured auditory bedtime routines can also support sleep onset. Embedding these interventions within everyday occupational activities increases generalization and functional significance.[27]

Table 3: Common Sound Interventions and Sleep Outcomes

Sound Type	Description	Sleep-Related Effect	Population/Context	Reference
White	Equal intensity	Masks environmental	School-aged children	Owens et al.,

noise	across frequencies	noise, reduces awakenings	with poor sleep habits	2000
Pink noise	Emphasis on lower frequencies	Promotes relaxation, smoother transitions into sleep	Children with sensory sensitivities	McIntosh et al., 1999
Brown noise	Deep, low-frequency emphasis	Calms hyper-responsivity, reduces arousal	Children with SPD, adults with insomnia	Miller, 2006
Nature sounds	Water, wind, forest sounds	Induces relaxation, decreases sleep latency	Preschoolers with ASD	O'Donnell et al., 2012

4.4 Integration into Therapy and Goal Setting

The possibility to integrate sound-based sleep interventions in a structured way, especially with the help of Goal Attainment Scaling (GAS), is one of their main strengths. This method enables therapists and families to set specific, personalized goals, such as reducing night awakenings by one-third after four weeks of maintaining a consistent sound-based routine.[28] Using standardized approaches, improvements can be systematically tracked, ensuring accountability and making results more visible.

Enhancements in sleep quality represent only part of the benefits. Families often report secondary gains such as more meaningful daytime participation, greater emotional regulation, and more harmonious family relationships. These outcomes highlight the interconnections between sleep, occupational performance, and quality of life. In GAS-based intervention measurement, these multidimensional benefits are recognized, thereby capturing both clinical and real-world effects.

The successful inclusion of sound in bedtime routines depends heavily on occupational therapists. Their expertise in sensory profiles and daily life occupations helps create tailored, context-sensitive strategies that align with family resources. For example, therapists may guide parents in selecting appropriate noise types, adjusting sound intensity, or establishing predictable auditory cues within nighttime routines.[29] Such individualized interventions are more sustainable, culturally responsive, and adhered to over the long term. By embedding sound-based strategies

into systemic intervention and goal-setting frameworks, occupational therapists contribute to occupation-focused practices with enduring outcomes.

Table 4: Clinical Guidelines for Sound-Based Sleep Interventions

Strategy	Implementation	Key Consideration	Reference
Consistent bedtime sound routine	Use same sound nightly to cue sleep onset	Supports sensory predictability	Miller et al., 2007b
Noise machines or apps	Set at safe decibel levels (<50 dB)	Prevents auditory overstimulation	Owens et al., 2000
Music therapy	Calming, slow-tempo music	Tailor to sensory preferences	Milton & Lovett, 2014
Parent training	Teach caregivers to embed sound in routines	Enhances sustainability and adherence	Mailloux et al., 2007

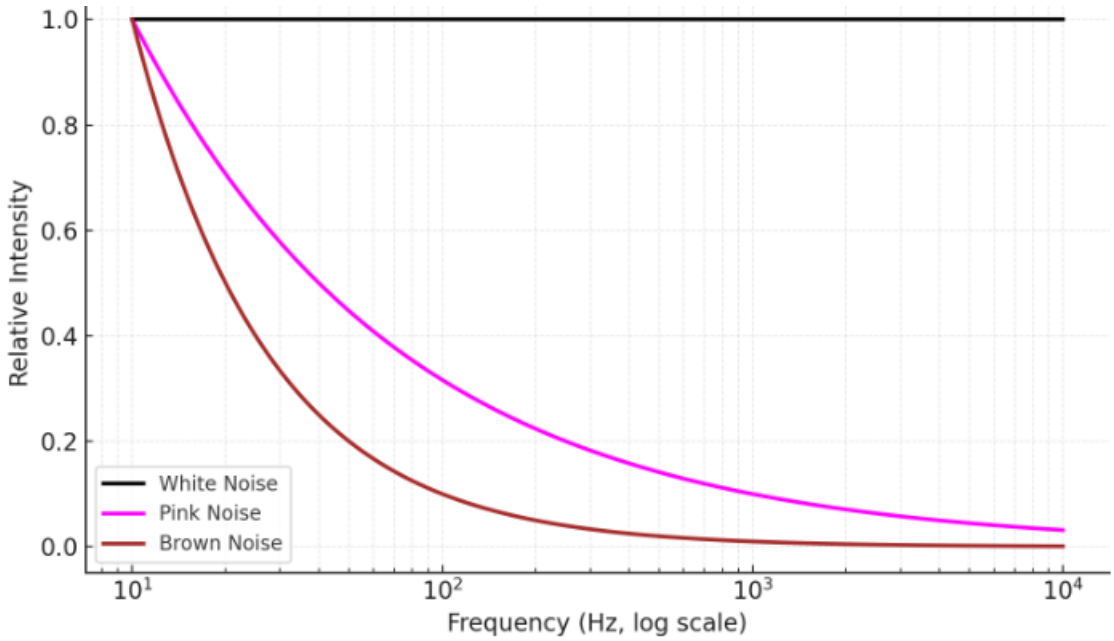

Figure 2: Auditory Spectrum and "Colored" Noise Profiles

The best way to explain soundscapes in sleep is that they are not simply background noise in the absence of plan. Supporting findings on sensory integration research and occupational therapy have shown that auditory strategies have a significant role to play in improving both the

nighttime rest and the daytime functioning, particularly in children with sensory or neurodevelopmental issues.

5. Temperature & Thermal Environment

Temperature plays a central role in the regulation of sleep. The body's thermoregulatory responses—such as the normal nocturnal decline in core temperature—are intimately linked to both the onset and maintenance of sleep. Environmental thermal factors, including bedroom temperature, humidity, and bedding, directly influence these physiological processes, either supporting restorative sleep or impeding it by prolonging sleep onset.

For individuals with sensory hypersensitivities, relatively minor changes in temperature can be perceived as aversive, leading to disrupted sleep routines.[30] Physiologically, as a person prepares for sleep, peripheral vasodilation occurs alongside a reduction in core body temperature. Sensory modulation difficulties may interfere with this natural process, particularly among children with autism spectrum disorders (ASD). Research indicates that heightened sensitivity to environmental temperature in this population contributes to poor nighttime sleep and frequent awakenings.[31]

Similar associations have also been observed in children with atopic dermatitis, where hypersensitivity to both temperature and touch correlates strongly with reduced sleep quality.[32] These findings highlight the need for tailored thermal regulation strategies as part of sleep interventions for children with sensory processing differences.

Table 5: Thermal Environment Interventions and Reported Outcomes

Intervention	Population	Reported Effect	Reference
Warm bath or massage before bedtime	Children with ASD	Reduced arousal, improved self-regulation	Silva et al., 2016; Schaaf, 2011
Climate-controlled bedroom (18–21°C)	Older adults	Enhanced sleep continuity, reduced nighttime awakenings	Smallfield & Molitor, 2018
Lightweight breathable bedding	Children with sensory hypersensitivity	Improved comfort, decreased night wakings	Shani-Adir et al., 2009

Cooling the sleep environment	Adolescents in warm climates	Shortened sleep latency, improved efficiency	Singh & Kenney, 2013

Thermal comfort strategies in occupational therapy include both environmental interventions—such as room temperature regulation, bedding layering, and adjustments to sleepwear—and formal sensory-integration activities. For example, pre-sleep warm baths or massage have been shown to decrease arousal and promote self-control in children with ASD.[33] [34] Massage protocols not only address thermal regulation but also integrate sensory strategies that reduce hyperresponsivity.

Environmental thermal management also demonstrates economic and clinical benefits for community-dwelling older adults. Systematic reviews indicate that interventions such as bedroom air conditioning and lightweight, adjustable bedding may stabilize sleep architecture and improve overall rest.[35] These approaches highlight the relationship between temperature, sleep quality, and occupational performance across the lifespan.

5.1 Cooling, Vagus Nerve Activation, and Sleep Regulation

It has been found that a body that is cooled before sleep or during sleep permits a reduction in core body temperature which is a natural signal that lets the body know that it is time to rest 46. A drop in temperature is directly linked to vagus nerve or much of the parasympathetic nervous system stimulation. Stimulation of vagal pathways enhances parasympathetic tone, leading to reduced heart rate, enhanced heart rate variability, and a general state of physiological relaxation[47]. These autonomic shifts facilitate quicker sleep onset and more restorative, deeper non-REM sleep stages. More recent clinical trials further emphasize this association, showing that cooling therapies like chilled bedding systems, wearable coolers, and thermoregulated mattresses can increase vagal activity and sleep efficiency in healthy adults as well as patients with insomnia[48]. Together, these results indicate that focused cooling strategies are a safe, non-medication-based means of maximizing vagal function and facilitating high-quality sleep.

Epidemiological studies also show that the rise in sleep problems among children and adolescents is influenced by neighborhoods, social, and behavioral factors.[36] Additional elements, such as housing quality, climate control access, and heat or cold stress, define the

broader thermal environment and require equity-focused interventions. Integrating strategies that address both individual sensory needs and systemic environmental factors enables clinicians to tailor temperature-oriented interventions for maximum effectiveness and real-world relevance.[37]

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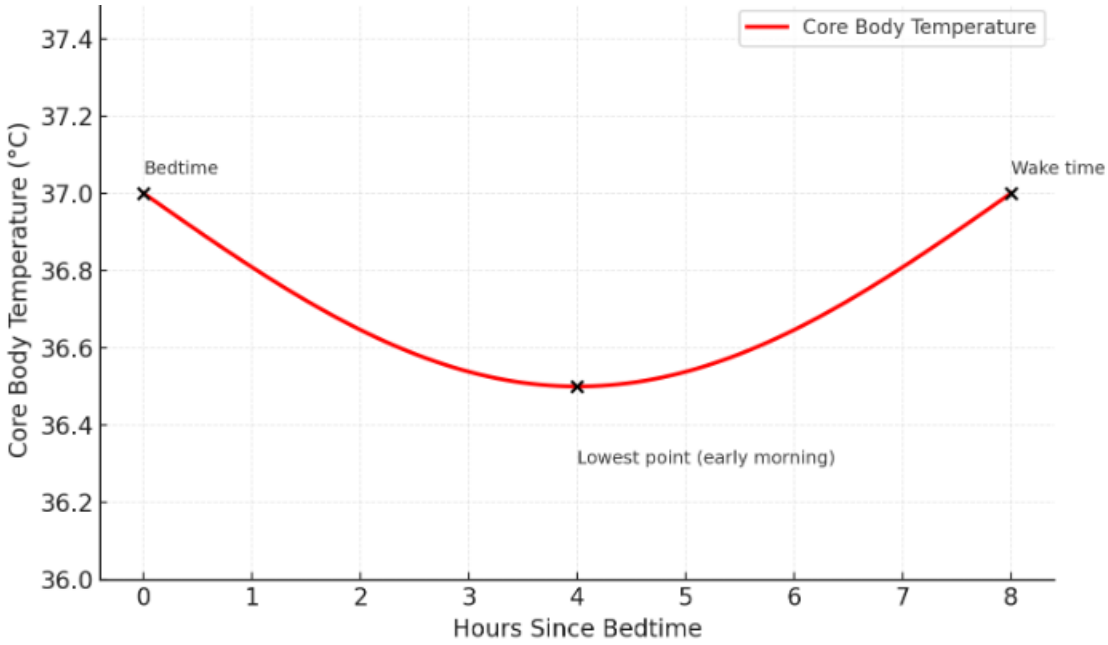


Figure 3: Thermal Curve Across Sleep Cycle

Children diagnosed with ASD, individuals with skin sensitivities, and older adults are at particular risk of sleep disturbances linked to thermal discomfort.[38] Evidence suggests that interventions aimed at thermoregulation—through temporal and spatial environmental modifications or sensory integration practices—can positively influence sleep quality. Considering thermal factors within occupational therapy practice ensures that sensory-based sleep interventions remain both evidence-based and adaptable across diverse populations and contexts.

5.2 Clinical Applications Across Populations (Temperature)

Thermal regulation strategies have demonstrated therapeutic benefits in both pediatric and adult populations, with evidence supporting their role in reducing arousal and improving restorative sleep.

- **Children with ASD**: It is conducted a randomized controlled trial of parent-delivered Qigong massage (including warm tactile stimulation), showing significant improvements in self-regulation scores and sleep onset latency, as reported on parent sleep diaries and standardized behavioral measures.
- **Children with atopic dermatitis:** It is observed that children with high thermal and tactile sensitivity who used lightweight, breathable bedding experienced reduced night wakings and improved parent-reported sleep quality, highlighting the importance of tailored environmental adjustments.
- **Adults with insomnia and healthy sleepers:** Controlled trials of cooling systems (e.g., chilled bedding, thermoregulated mattresses) demonstrate increased vagal tone, reduced heart rate, and improved sleep efficiency by 10–15% on polysomnography.

Collectively, these findings demonstrate that temperature-based interventions—whether behavioral (warm baths, breathable bedding) or environmental (climate control, cooling devices)—are effective in promoting sleep quality across populations, with measurable physiological and behavioral outcomes.

6. Darkness, Sleep, and Circadian Regulation

Lack of light is an important environmental parameter for circadian entrainment and sleep quality. Darkness facilitates the body's natural hormonal cycles, while inappropiate light exposure at night can inhibit sleep structure and lead to ill health consequences. Environmental adjustments and individual measures, including the use of blackout curtains or sleeping masks, offer effective means for maximizing darkness in the sleep environment.

6.1 Darker is Better for Sleep

Darkness is a primary cue for melatonin release, which synchronizes circadian rhythms and enables sleep onset[48]. Nighttime exposure to light, even of low intensity, inhibits melatonin release, delays circadian phase, and disrupts sleep. Epidemiological data associate evening exposure to light with enhanced risks of insomnia, metabolic disorders like obesity, and mood disorders, highlighting the necessity for darker environments to safeguard both sleep and health.

6.2 Darkening the Sleep Environment

Optimizing bed darkness entails reducing light intrusion from both external and internal sources. Routine measures include placing blackout curtains or layered drapes, sealing door gaps underneath, and taping over light-producing electronic equipment. Where safety visibility is needed, very dim, warm-spectrum nightlights can be reassuring without causing circadian displacement. These changes bring about a low-light environment that favors melatonin secretion and prolonged sleep.

6.3 Blindfolds and Sleep Masks

Sleep masks and blindfolds are useful devices for occluding remaining light in circumstances where environmental control is restricted, for example, in the hospital setting, travel, or shift work[49]. Controlled trials document gains such as the reduction of sleep onset latency, enhancement of slow-wave sleep, and enhancement of next-day intellectual functioning. Their portability and low cost render them a convenient intervention for individuals in a variety of different settings.

6.4 Problems with Sleep Masks

Though effective, sleep masks are not always well tolerated. Discomfort, heat, pressure against the eyes, or claustrophobia are common complaints from users. Compliance rates in hospital and clinical environments thus range widely, with some patients refusing to use them at all. Though these difficulties need to be respected, most people do adapt to masks and derive considerable advantage.

6.5 When Pitch-Black is Too Dark

To others, total darkness can evoke fear or nyctophobia that exacerbates insomnia and hinders the initiation of sleep. Poor sleepers have been observed to create increased discomfort or arousal when they are put in complete darkness. In such situations, compromise measures are advised, e.g., using dim, red-shifted nightlights placed strategically where there is minimal direct

exposure to the eyes. Such low-intensity lights minimize fear while maintaining circadian integrity.

7. Clinical Integration with CBT-I

The standard intervention in CBT-I is Cognitive Behavioral Therapy for Insomnia (CBT-I), a non-pharmacological therapy used to treat chronic insomnia by addressing maladaptive stress responses through the organization of behavioral and cognitive patterns. Its fundamental elements are stimulus control, sleep restriction, cognitive restructuring, and relaxation training all aimed at restructuring associations with sleep and enhancing overall sleep quality. However, even though CBT-I is a proven method, it tends to overlook the influence of the physical environment. The use of light-, sound-, and temperature-based interventions provides secondary external cues that can support therapy goals and improve patient compliance.[39] This section discusses the integration of sensory strategies within CBT-I through three domains: stimulus and behavioral conditioning, cognitive restructuring, and relaxation-based interventions.

7.1 Sensory Support for Stimulus Control and Sleep Restriction

Stimulus control is a foundation of CBT-I that works towards reconditioning the bedroom environment, to promote sleep as a signal instead of staying awake. Sensory-based changes can be effectively supplemented with traditional approaches that include restricting bed activity to sleep and sex, waking up when not able to sleep, and maintaining a regular bedtime. To illustrate, fading the lights during the evening or establishing a regular sound pattern provides consistent external cues that strengthen the desired sleep–wake relationship.[40] These signals are especially beneficial to people whose internal body clocks are disrupted, such as those with circadian rhythm abnormalities.

Sleep restriction, making sleep more time-bound, is another challenging but evidence-based CBT-I tool. In the initial phase, patients are more likely to experience frustration. In such cases, controlling temperature can be valuable: keeping the sleep space cool and clean minimizes discomfort and reduces the likelihood of external factors disrupting already limited sleep time.[41] A calm sensory background not only promotes compliance but also reduces anxiety associated with this stressful intervention. Sensory strategies, therefore, can be integrated into stimulus control and restriction strategies, serving as anchors for behavioral conditioning or lowering

dropout rates. Because environmental consistency is a vital determinant of compliance, this synergy is particularly useful for individuals with sensory hyper-responsivity, such as children with autism or adults with sensory processing sensitivities.

7.2 Cognitive Restructuring and Sensory Reassurance

Maladaptive beliefs about sleep, such as catastrophizing over not sleeping, are another common roadblock in insomnia. Cognitive restructuring, which addresses these negative thoughts by promoting healthier thinking, is one of the primary components of CBT-I. Sensory interventions can play a significant role in this process because they provide a tangible assurance that non-pharmacological, evidence-based strategies can contribute positively to sleep. For example, clinicians may recommend sensory-oriented techniques when patients express fear that one night of insomnia will have severe health consequences. Interventions such as consistent morning light exposure, evening dim light, or regulated soundscapes demonstrate the connection between peripheral sensory cues, circadian rhythms, and relaxation processes.[42] These approaches not only support treatment adherence but also reduce reliance on maladaptive coping strategies like alcohol use or late-night screen time. By tailoring sensory plans to emphasize controllable elements and reduce focus on uncontrollable ones, cognitive restructuring enhances patients' sense of agency. Sensory reassurance thus becomes a key part of CBT-I, helping to correct maladaptive thinking while simultaneously curbing anticipatory anxiety—a frequent contributor to chronic insomnia.

7.3 Relaxation Training and Sequential Integration of Sensory Cues

Relaxation training is the final element of CBT-I and is most closely linked to sensory-based strategies. The goal is to reduce physiological arousal and promote parasympathetic activation before and during sleep. Sensory approaches provide direct access to relaxation: pre-sleep cooling, warm showers followed by a cool bedroom climate, and other natural thermoregulatory processes help the body transition to sleep. Similarly, predictable auditory inputs (e.g., white noise, pink noise) foster parasympathetic regulation and reduce hyperarousal.[43] [44]

To formalize this integration, a stepwise algorithm has been proposed to guide clinicians in combining relaxation and sensory-based practices within CBT-I protocols.[45] This structured approach allows therapists to systematically align sensory strategies with relaxation goals, improving both adherence and clinical outcomes.

- **Step 1:** Deliver standard CBT-I modules.
- **Step 2:** Introduce targeted sensory adjustments (light, sound, or temperature) when progress stalls.
- **Step 3:** Tailor sensory interventions to the patient's unique sensory profile, assessed via occupational therapy tools.
- **Step 4:** Embed these strategies into daily occupational routines, ensuring consistency and generalization.

This is because the sense inputs are between-layered so that the sensations are not the supplements but reinforcers as in the CBT-I models. It needs to be noted that this strategy does not provide any sensory cues as the alternative to CBT-I and these can be used as the environmental enhancers that make the latter more sticky and adhesive. The patients who have a high risk of night hyperarousality, and who experience cognitive restlessness may be ideally served by exposure to low frequency sounds and to low intensity warm spectrophotometric light signals of sleeping respectively. These individualized therapies in combination with the relaxation aspects of CBT-I will provide an inter-sensory buffer to arousal; such will render the entire treatment to be more successful.

Once sensory-premised interventions are added to CBT-I, a predominantly cognitive-behavioral intervention becomes a multimodal, holistic intervention. Cognitive restructuring besides light, sound and temperature notifications integrated within the stimulus control process will promote environmental endorsement within the processes of compliance and therefore the future results (Clinicians). This strategy takes into consideration that sleep is not merely behavior but is cognitive and is also a sensory experience. Finally, sensory interventions should be introduced into CBT-I as they give the patients effective non-hazardous, practical, and viable methods of the enhancement of the efficacy of the gold-standard insomnia treatment.

8. Populations & Settings

Application of sensory-based interventions under CBT-I varies greatly, depending on age groups and situations. In children sensory processing difference takes the form of excessive sensitivity to light or sound or intolerance of hot or cold. These sensitivities worsen sleep fragmentation, and lead to impairment in daytime functioning, including learning and daytime mood. Included in this category of interventions are focus on routine-building, auditory predictability, and

caregiver coaching. Adolescents have the same strategies targeting social and behavioral factors of determinants, namely late infobox exposure to screens, and inconsistent routines. The insomnia in adults normally indicates poorly adjusted colonial patterns to which CBI coupled with sensory cues is helpful in reinforcing compliance. Reduced circadian amplitude and comorbidities (e.g., chronic pain or dementia) in the elderly population calls for high levels of individualizing interventions. Adaptations of room temperature and the incorporation of light signals are the most suitable to these settings.

Special attention should be paid to the neurodiverse groups of people, including those with autism spectrum disorder and fetal alcohol spectrum disorder, who experience abnormal sensory processing and are highly likely to have sleeping problems. Inpatient units and long-term care arrangements are more difficult across settings since they share spaces and have the institutional lighting. Even in the portable sound appliances and customized lighting regimens can offer familiarity. During telehealth coaching, the therapist may also be able to direct families to use sensory routines remotely. In the case of low-resource settings, low cost options like blackout curtains, fan created noise, or breathable bedding, can guarantee access.

9. Safety, Contraindications, and Equity

Sensory-based interventions present few risks, but safety remains a heightening priority. Light therapy should not be administered to those with photosensitive epilepsy, in specific ocular disorders, and those individuals who may be susceptible to manic episodes because of the increased risk of worsening these conditions due to bright-light exposure. There should also be hearing safety in sound interventions: Devices should not be used at decibel levels that are dangerous and cords should not be used in the sleep environment of infants, as well as those affected by hyperacusis and closely monitored. The temperature-based approaches risk the perils of burns due to heating machines, frostbite due to drastic cooling and the risks of dehydration in hot weather. Equity issues need to be handled also Low-income or resource-limited families may not be able to have access to air conditioning, very good noise machines or special lighting. For those on low-income, cost-sensitive measures can include open-window ventilation, cheap blackout curtains, or the use of noise applications using a phone can help bridge this gap. With such policies, clinicians will feel secure and safe in sensory intervention, and this promotes both

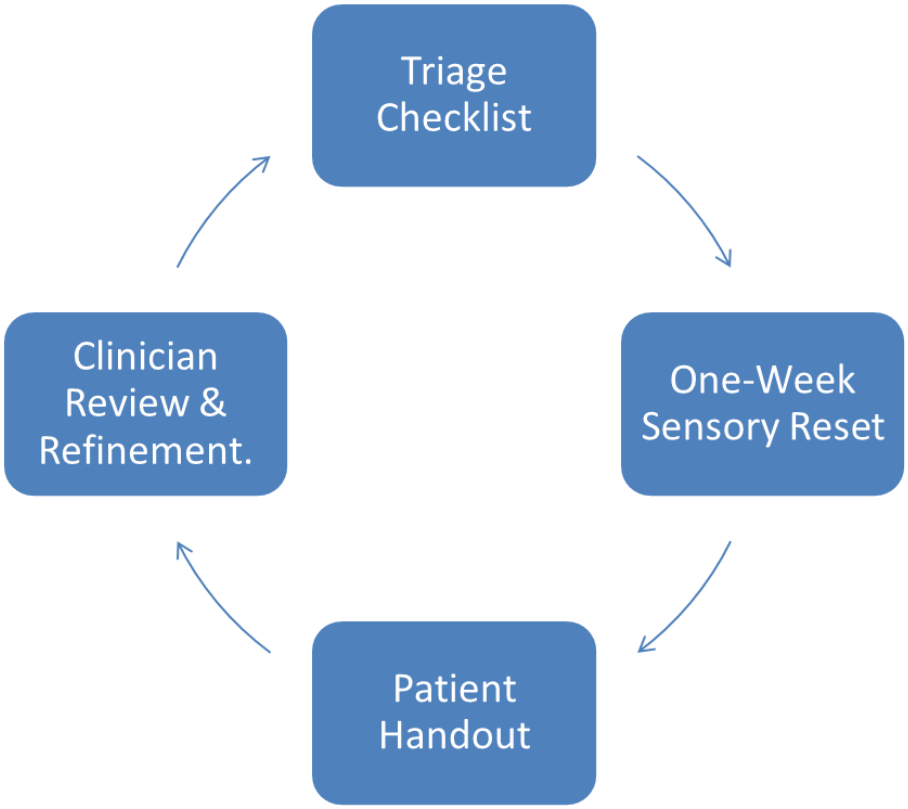
inclusivity and practicality in such interventions that are also ethically friendly among diverse groups.

10. Implementation Toolkit (Practice-Ready)

To move from theory into practice, clinicians need straightforward, actionable tools for implementing sensory-based sleep interventions. Below are core elements that can be adapted for individual needs.

Triage Checklist (10 Key Items)

- **Room lighting**: Are blackout curtains or dimming strategies available?
- **Evening device use**: Is there consistent use of blue-light filters or curfews?
- **Morning light**: Does the patient receive natural light exposure within one hour of waking?
- **Bedtime routine**: Is there a consistent, calming pre-sleep sequence?
- **Sound environment**: Are external noises controlled or masked?
- **Decibel estimate**: Is white/pink/brown noise used at safe levels (<50 dB)?
- **Thermal comfort**: Is room maintained between 18–21°C?
- **Bedding and sleepwear**: Are breathable, adaptive materials used?
- **Household context**: Are family/roommates aware of the patient's sensory needs?
- **Safety risks**: Are electrical devices, cords, or heating/cooling products used safely?



One-Week Sensory Reset Plan

- **Morning (Day 1–7):** 15–30 min light walk outdoors or near bright window.
- **Evening (Day 1–7):** Dimming lights two hours before bed; switch to warm-spectrum bulbs.
- **Night (Day 1–7):** Establish sound routine (white/pink noise machine or calming music) set to timer.
- **Thermal ritual:** Warm shower or foot soak 60 minutes before bed, followed by breathable bedding setup.
- **Weekly review:** Clinician checks adherence, logs barriers, and refines plan.

Patient Handout (Adherence Bullets)

- Keep bedtime and wake time consistent—even on weekends.
- Dim lights and avoid screens one hour before bed.
- Use consistent sound each night; volume low and steady.
- Adjust bedding and clothing to maintain comfort.

- Track your sleep diary and note improvements weekly.

Clinician Speaking Points

- "These strategies are **tools, not cures**—success comes from consistency."
- "Think of sensory cues as **signals to your brain** that it's time for rest."
- "Adjustments must fit your life—low-cost and realistic changes often work best."

11. Research Gaps & Future Directions

Notwithstanding positive evidence, there are still quite large evidence gaps regarding sensory-based sleep interventions. The first limitation lies in the heterogeneity of trials: the populations, outcome measures, and intervention integrity may be very different and thus it is hard to combine results. In addition, many studies center on short-term efficacy with little research on long-term adherence and long-term distribution of benefits. Variability of sensory processing is another issue. Though white noise may appear good to some, it may be distracting to others, and that even the perfect temperature depends on age and health status and culture. Comparison of types of noise or thermal protocols can never be much and yet these comparisons must be made to improve thermal routines. The connection of modalities of light and temperature to sound, and of sound to light and temperature is currently unknown and how it affects sleep has its ignorance. It is highly desirable that practical trials should be carried out to evaluate multimodal interventions in practice. And finally, more equity-based research, investigating cost-effective relationships with low resource groups, is required. Their bridging will make clinical confidence greater, protocols consistent, and interventions comprehensive and extendable.

12. Conclusion

Treatments involving sensory modalities -light, sound and temperature offer non-invasive, readily available and adaptable promoters of sleep health. Used in combination in the Cognitive Behavioral Therapy of Insomnia (CBT-I), they serve as environmental prompting behavior to aid in reminding to adhere, arousal level and self-management. These techniques comprise of dimming evening light, establishing daily sound schedules, reducing the body temperature when asleep, and controlling thermal comfort so that persons can shape their sensory spaces in ways

that permit them to sleep serenely. What makes them practical is that they can be customized throughout the age spectrum, and also to cohorts of neurodiverse people, and applicable in a range of settings, including homes, and long-term care homes. The unique thing about that is that they are non-pharmacological and therefore they inject a lot of attractiveness in circumstances where the medicine is not allowed or in the case of the less effective choice.

Sensory interventions are not necessarily the solitary source to solution. They are safe and can be used in the general context of treatment because they work better when they are individualized and followed by clinicians. Further studies are needed to better inform the clinical guidelines; this requires more pragmatic head-to-head studies of longer term outcomes and multimodal outcomes. Generally, it will matter that interested parties on sensory-based sleep interventions discover effective uses as it lie between the two better-established wells of environmental modification and behavioral therapy.

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