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Research Article

Architectural Features of Rehabilitation Environments That Affect Information Processing in Children with Attention-Deficit/Hyperactivity Disorder

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ABSTRACT

Introduction: Numerous studies have demonstrated that physical environments play a critical role in regulating behavior and information processing in children with attention-deficit/hyperactivity disorder (ADHD). This study aims to identify the architectural features of rehabilitation environments and examine their relationship with the information-processing abilities of children with ADHD.

Materials and Methods: A total of 35 children (mean age=7.6 years; range=5-10 years) diagnosed with ADHD from 10 rehabilitation centers in Tehran, Iran, were recruited for this descriptive-analytical study. Data were collected using a researcher-designed questionnaire to evaluate important architectural elements in rehabilitation centers and were validated for content and construct validity (Cronbach α=0.81). A professional architect evaluated the total score and the score for each item of the questionnaire. The sensory improvement of the children was also assessed using the short sensory profile (SSP) questionnaire twice: at baseline and after one month of their treatment. The correlation between each architectural item and the improvement in the children's sensory profiles was assessed using the Pearson correlation test.

Results: A significant positive and moderate correlation between elements such as natural light (r=0.58), calming color schemes (r=0.55), and noise reduction (r=0.49), with improved information processing ability in children with ADHD (P<0.01).

Conclusion: The results suggest that carefully designed and intentional architectural environments can play a significant role in enhancing cognitive performance in children with ADHD. It is recommended that architects and rehabilitation professionals collaborate more closely to meet the perceptual and cognitive needs of these children in the design of their spaces.

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Introduction

Attention deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in children, typically characterized by symptoms such as inattention, hyperactivity, and impulsive behaviors. According to global studies, the prevalence of ADHD in children is estimated to be around 5–10% (American Psychiatric Association [APA], 2013) [1]. A 2021 systematic review of 34 studies found a wide variation in ADHD prevalence, ranging from 3% to 17%, depending on the region, diagnostic tools, and study design [2]. This disorder affects children's academic, social, and familial performance and, if left untreated, can have long-term negative consequences. Health architecture is an interdisciplinary field that combines architecture and health sciences, aiming to improve users' physical and psychological well-being through the design of therapeutic and care environments. This field encompasses spaces such as hospitals, clinics, rehabilitation, and long-term care facilities. It seeks to create efficient, safe, calming, and healing environments by addressing users' physical, mental, and behavioral needs [3]. In recent years, there has been a growing interest in the impact of physical environments on the therapeutic process, rehabilitation, and cognitive information processing in children, particularly those with special needs like ADHD [4].

Children with ADHD face challenges related to attention, information processing, sensory integration, and emotional regulation. These characteristics make them more vulnerable to environmental stimuli, necessitating the careful design of treatment spaces [5]. There are different interventions to treat children with psychological difficulties, such as neurodevelopmental treatment [6], that can improve the functional independence of children with variant disorders in their activities of daily living. In this context, health architecture can play a critical role in optimizing environmental conditions. Factors such as natural lighting, wall color schemes, acoustic insulation, spatial organization, access to natural elements, layout orderliness, and material quality can directly impact children's focus, calmness, and ability to process information [7].

From the perspective of environmental neuroscience, the human brain is highly responsive to environmental stimuli. Specific features of physical spaces can increase or decrease levels of mental stimulation [8]. In children with ADHD, who are overly sensitive to stimuli, a well-designed environment can prevent disruptive behaviors, anxiety, and cognitive fatigue while improving their ability to manage information and learning [9].

This study aims to identify architectural features of rehabilitation environments (such as light, color, sound, spatial layout, and spatial quality) and examine their relationship with the information processing abilities of children with ADHD.

Materials and Methods

A total of 35 children diagnosed with ADHD from 10 rehabilitation centers in Tehran City, Iran, were recruited for this study using an available (convenience) sampling method. According to the inclusion criteria, 35 children were recruited for the study during the 6-month case collection period. The inclusion criteria for the children with ADHD were as follows: Aged between 3 and 12 years, confirmed diagnosis of ADHD by a specialist, providing written informed consent from the child's parents, and the administrative approval from the participating occupational therapy centers, no history of previous rehabilitation treatment, and recently admitted to the center (less than 10 days). The exclusion criteria included the presence of additional neurological disorders, co-occurring psychological disorders, and withdrawal of consent by either the parents or the rehabilitation centers at any stage of the study. After verifying the eligibility criteria, written informed consent was obtained from all parents and center directors of children who met the inclusion requirements. The study was conducted in Tehran in 2024.

To ensure the reliability of the findings while considering practical constraints, the sample size was determined based on power analysis for multiple regression with six predictors, aiming for a medium effect size of 0.15, a statistical power of 0.80, and a significance level of α=0.05. According to established guidelines of Cohen (1988), [1] a minimum of 30–40 participants is sufficient to detect significant effects under these conditions. Moreover, sampling from 10 different centers enhanced the ecological validity of the study by capturing diverse architectural environments and reducing center-specific biases. This multi-site design improves the generalizability of results while maintaining sufficient statistical power for hypothesis testing.

Although the authors were not involved in the treatment interventions and cannot guarantee the complete consistency of the rehabilitation procedures, all the children received standard treatment from senior occupational therapists with at least 15 years of experience working with children with ADHD. The procedures

were relatively consistent and were reviewed and approved by one of the authors, who is a senior therapist and assistant professor of occupational therapy.

To evaluate the physical environment of the rehabilitation centers, a shortened version of a previously developed questionnaire originally designed for children with autism spectrum disorder [10, 11] was adapted and validated for children with ADHD. The original instrument consisted of 30 items assessing architectural and environmental features such as the intensity and quality of natural and artificial lighting, visual access to the outdoors, levels of noise and visual pollution, and the color of interior walls. The face and content validity of the instrument were qualitatively assessed, and the overall reliability was confirmed with a Cronbach α coefficient of 0.81.

The revised questionnaire, comprising 9 items each with 3 subscales, was reviewed by a panel of experts, including three architects specialized in therapeutic and educational environments, three senior occupational therapists, and three parents of children with ADHD. Each item was rated as "essential," "useful," or "not essential." Based on the expert evaluations, 6 items achieved a content validity ratio (CVR) greater than 0.80 and were retained, while three items with CVR values below 0.60 were excluded. The final checklist, therefore, consisted of 6 items, each with 3 subscales (Appendix 1). For further validation, the item-level content validity index (I-CVI) was calculated based on expert ratings on a 4-point Likert scale ("irrelevant" to "highly relevant"). All final items demonstrated I-CVI values above 0.85, confirming their suitability for use.

The finalized architectural evaluation checklist was then used to assess all participating centers. Each center was rated by a qualified architectural expert using a 5-point Likert scale. The final version of the checklist included 18 questions distributed across 6 thematic areas, yielding a total possible score ranging from 18 to 90. Higher scores reflected better architectural conditions that support sensory processing in children with ADHD. Centers scoring 65 or above were classified as "desirable," those scoring between 45 and 65 as "relatively desirable," and those scoring below 45 as "undesirable."

To measure the sensory processing profiles of the participating children, the short sensory profile (SSP) developed by Dunn (2014) was administered. This instrument comprises 34 items that target sensory seeking, sensory avoidance, sensory sensitivity, and sensory registration behaviors, and is designed for children aged 3 to 14 [12]. Responses are recorded on a 6-point Likert scale ranging from "almost always" to "never." The SSP assesses two main domains: sensory processing abilities (14 items) and behaviorally manifested responses to sensory input (20 items).

The 35 participating children were assessed using the SSP by an experienced occupational therapist at two time points: baseline and one month later (α=0.05, β=0.25). During this period, all children continued their regular therapeutic interventions in their respective centers. The changes in SSP scores over the one-month interval were calculated and then statistically analyzed to examine the correlation between the SSP improvement of the children in each center and the total score and the score of each item of the customized architecture questionnaire. This analysis aimed to investigate the most correlated environmental factors that could influence the improvement in sensory processing abilities of children with ADHD in rehabilitation centers.

To assess the collective impact of architectural features on sensory integration in children with ADHD, a multiple linear regression analysis was performed. Six architectural variables (natural light and radiation control, color and spatial contrast, acoustics (sound control), ventilation and indoor air quality, variety of textures and contact surfaces, and access to outdoor space) were entered simultaneously into the model as predictors of sensory integration scores.

Results

A total of 35 children with ADHD (aged 3–12 years; Mean±SD age 7.6±2.1 years; 68.6% male, 31.4% female) from 10 rehabilitation centers in Tehran completed the study. Each child underwent a sensory processing assessment using the SSP at two time points, before and after 1 month of treatment. All children continued to receive standard therapeutic services during this 1-month study period.

Current status of rehabilitation environments

Most respondents rated the current conditions of therapeutic spaces as average or poor. Among various components, natural lighting, diversity of textures, and acoustic control were cited as the weakest features. For example, 68% of participants evaluated natural lighting and glare control as poor, while 59% rated acoustic conditions negatively. Only 18% considered access to outdoor spaces to be relatively satisfactory (Table 1).

According to the architectural checklist, 2 centers (20%) were classified as "desirable" (score above 65), 3 centers (30%) as "relatively desirable" (score between 45 and 65), and 5 centers (50%) as undesirable (score below 45). Checklist scores ranged from 38 to 79 (Mean±SD, 58.2±10.3) (Table 2).

Changes in sensory processing scores

Analysis of SSP scores showed overall improvement in sensory processing profiles across the sample. The mean total SSP score increased significantly (P<0.001) from time 1 (Mean±SD,85.6±9.4) to time 2 (Mean±SD, 91.2±8.1), indicating reduced sensory processing difficulties.

When stratified by center classification, children in "desirable" centers demonstrated the greatest improvement in SSP scores (mean increase of 8.2 points), followed by those in "relatively desirable" centers (mean increase of 5.3 points), and "undesirable" centers (mean increase of 2.1 points). A one-way analysis of variance (ANOVA) revealed a significant effect of center classification on SSP score change (P=0.007) (Figure 1).

This boxplot shows that children in desirable centers had the highest improvements in their SSP scores. The improvements decrease progressively from desirable to undesirable centers.

Correlation between architectural scores and sensory improvement

The Pearson correlation analysis indicated a moderate to strong positive correlation between the centers' architectural scores and the degree of improvement in SSP scores (r=0.61, P<0.001), suggesting that better-designed environments were associated with greater improvements in children's sensory processing abilities (Figure 2).

A positive linear relationship is observed between architectural quality and sensory improvement. This finding supports the hypothesis that better-designed environments have a positive influence on sensory processing outcomes in children with ADHD.

Further exploratory analysis of the architectural checklist subscales revealed that the items most strongly associated with improvements in SSP scores were natural light and radiation control, color and spatial contrast, acoustics (sound control), and ventilation and indoor air quality (Table 3).

These results suggest that specific architectural features within rehabilitation centers play a potentially meaningful role in supporting sensory regulation in children with ADHD.

Multiple linear regression analysis

The overall regression model was statistically significant ($F_{(6, 43)}$=3.73, P=0.004), explaining approximately 48.3% of the variance in sensory integration scores (R^2=0.483, Adjusted R^2=0.351). Among the predictors, only color and spatial contrast demonstrated a statistically significant independent contribution to the model (β=0.48, P=0.027), indicating that environments with higher levels of color differentiation and spatial clarity were associated with better sensory integration outcomes (Table 4).

Although natural light, acoustics, and textures showed moderate correlation values in the preliminary analysis, their effects were not statistically significant in the multivariate context, possibly due to shared variance among predictors.

Discussion

The findings of this study highlight the urgent need to reconsider the architectural design of current rehabilitation environments for children diagnosed with attention-deficit/hyperactivity disorder (ADHD). Across the 3 axes of evaluation (current environmental conditions, sensory needs of children, and the relationship between architectural features and sensory processing), the results reveal a significant gap between existing and optimal conditions.

Current status of rehabilitation environments

Descriptive analyses revealed that sensory-related elements, such as natural lighting, acoustic quality, and tactile variation, were rated as "poor" or "very poor." These findings align with previous studies, including those by Mostafa (2014), which reported that environments characterized by harsh artificial lighting, high noise levels, and uniform textures can increase sensory stress in children with special needs [9].

Among these, controllable natural lighting emerged as a critical factor for improving cognitive functions and emotional regulation in children with ADHD. As also confirmed by Küller et al. [13], moderate-intensity daylight with adjustable features significantly enhances attention and visual focus.

Table 1. Architectural status of the rehabilitation centers

Architectural Elements	Mean Score (of 5)	Status Rating	The Total Score (%)
Natural light and radiation control	2.1	Poor	68
Color and spatial contrast	2.9	average	35
Acoustics (sound control)	2.3	Poor	59
Ventilation and indoor air quality	3.0	average	28
Variety of textures and contact surfaces	2.5	Poor	47
Access to outdoor space	3.2	Above average	18

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Sensory-perceptual needs of children with ADHD

One of the key insights from this study was the emphasis placed by respondents on the necessity of environments that not only reduce distracting stimuli but also provide gradual and targeted sensory inputs. According to Dunn's sensory processing framework [12], children with low sensory thresholds—many of whom are diagnosed with ADHD—experience behavioral disturbances and decreased performance when exposed to overstimulating environments. In this regard, spaces incorporating cool color schemes, adjustable lighting, textured flooring, and flexible movement areas can contribute significantly to enhanced sensory integration. These conclusions are consistent with studies by [14, 15].

No universally agreed-upon threshold for a minimal change in SSP scores definitively indicates clinical significance. Clinicians typically interpret score improvements in the context of category shifts, overall behavioral and functional changes, and the individual's baseline profile. While there is no fixed threshold, a reduction of at least 10-20% in total or domain scores can be viewed as a positive indicator, especially if associated with observed functional gains.

The aim of this study was not to assess the sensory improvement of the children with ADHD. We were looking for any differences between the outcomes of the centers and the correlation between these different therapeutic outcomes and the architectural elements in these centers.

Table 2. Center scores and SSP Results

Center	Architectural Score	SSP Pre	SSP Post	SSP Improvement	Classification
3	79	84	95	11	Desirable
2	74	85	94	9	Desirable
1	65	83	92	9	Relatively desirable
5	63	87	93	6	Relatively desirable
4	60	86	91	5	Relatively desirable
6	44	88	90	2	Undesirable
7	42	86	88	2	Undesirable
8	42	84	85	1	Undesirable
10	40	86	88	2	Undesirable
9	38	85	87	2	Undesirable

SSP: Short sensory profile.

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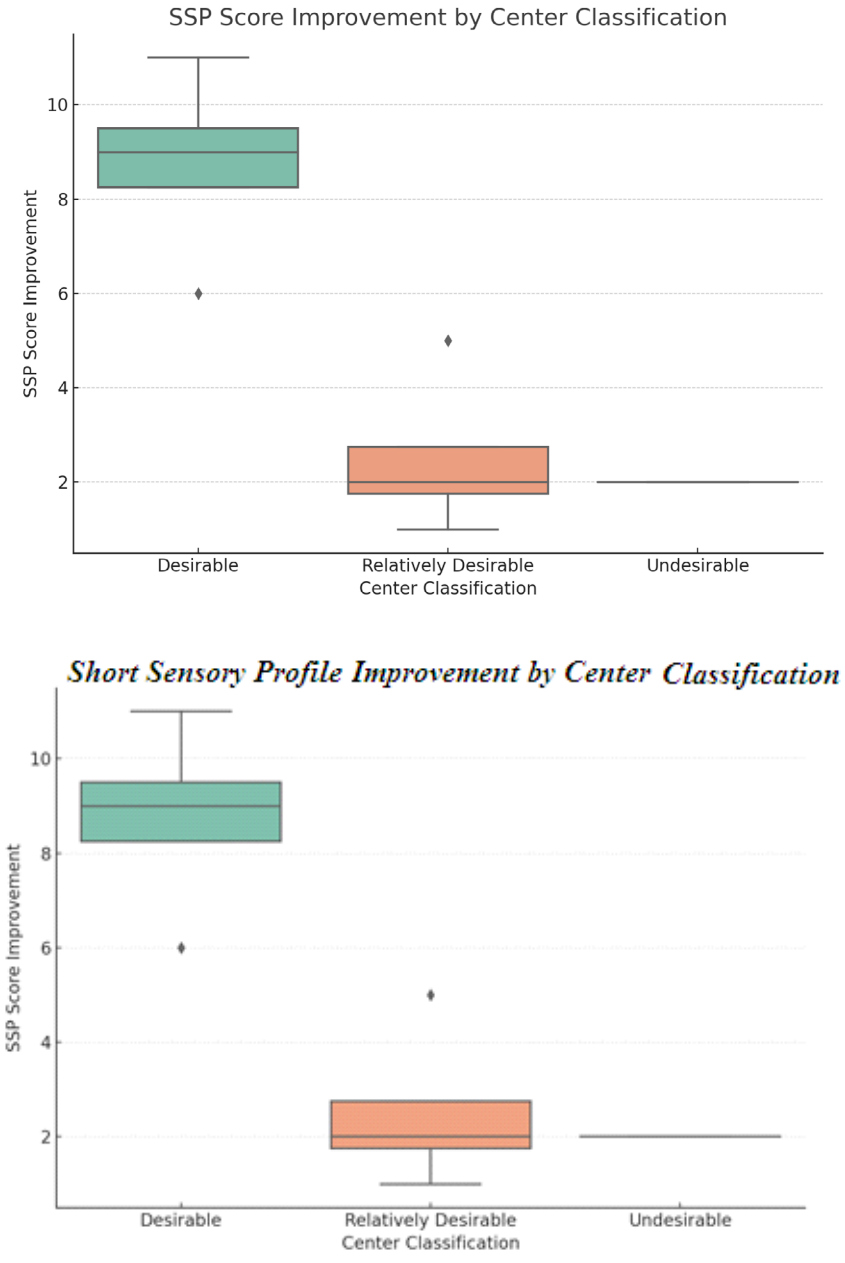

Figure 1. SSP score improvement by center classification

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Impact of architectural features on sensory integration

Correlation analysis

As demonstrated in Table 2, certain architectural components are significantly and positively associated with improved sensory processing abilities in children with ADHD. These components are adjustable, with natural light correlated to enhanced visual focus, cool and gentle color schemes that support emotional regulation, and reduce hyperactivity. Reduced environmental noise contributes to decreased auditory reactivity and aggression, while textural diversity is associated with increased sensory acceptance and reduced anxiety.

These results confirm earlier findings by Unwin et al. [16] and Evans and Wachs [17], emphasizing the importance of consciously designed environments that regulate sensory input—not merely for aesthetic purposes, but as therapeutic tools. Additionally, the higher performance

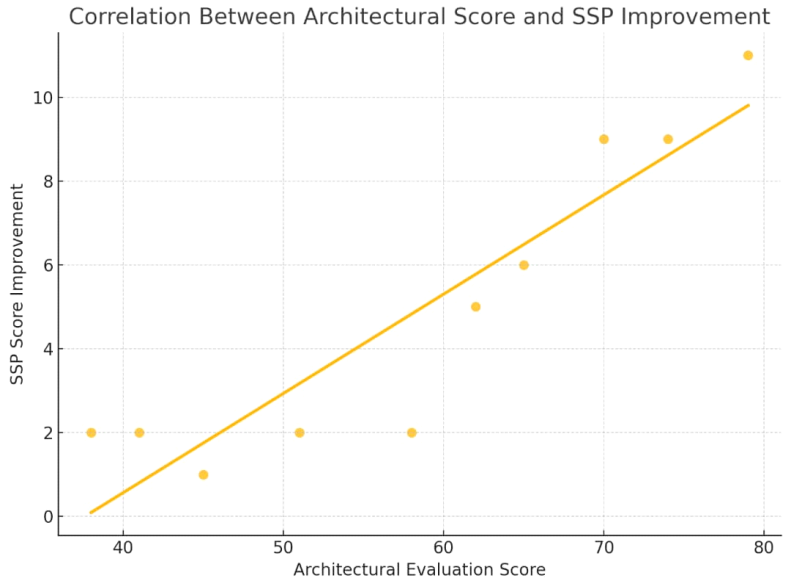

Figure 2. Correlation between architectural score and SSP improvement

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Table 3. Correlation between the architectural checklist subscales of the rehabilitation centers and the SSP improvement of the children with ADHD

Architectural Elements	Correlation Coefficient (r)	Significancy (P)
Natural light and radiation control	0.58	0.001
Color and spatial contrast	0.55	0.002
Acoustics (sound control)	0.49	0.001
Ventilation and indoor air quality	0.41	0.01
Variety of textures and contact surfaces	0.23	0.1
Access to outdoor space	0.15	0.15

P<0.05 is significant.

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Table 4. Multiple regression analysis predicting sensory integration scores from architectural features

Predictor	B	SE	t	P
Constant	6.39	3.27	1.96	0.057
Natural light and radiation control	0.1	0.12	0.81	0.42
Color and spatial control	0.32	0.14	2.3	0.027
Ventilation and indoor air quality	0.01	0.13	0.06	0.951
Variety of textures & surfaces	0.16	0.14	1.1	0.277
Access to outdoor space	0.09	0.19	0.48	0.637

B=Unstandardized coefficient; SE: standard error.

P<0.05 shown in bold.

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and satisfaction reported by parents from centers that made even small architectural adjustments underscores the direct effect of the environment on sensory-cognitive function.

This study aligns with existing research in the field of neurodiverse architecture. For example, [9] introduced the concept by identifying design elements such as daylight, sound insulation, natural materials, and sensory-motor space flexibility as essential for supporting neurological diversity. Similarly, Pfeiffer et al. [18] emphasized the critical role of physical space in facilitating sensory processing and behavioral regulation in children with developmental disorders.

Multiple linear regression analysis

To control the possible confounding effect of the variables, multiple regression analysis was performed. The findings provide empirical support for the role of environmental design in modulating sensory experiences, particularly highlighting color and spatial contrast as a significant independent predictor of improved sensory integration.

While natural light, acoustics, and ventilation exhibited moderate bivariate correlations with sensory integration scores, only color and spatial contrast maintained statistical significance when all variables were analyzed simultaneously. This finding suggests that perceptual clarity, as manifested through well-defined spatial zones, distinct color cues, and visual structure, may play a uniquely vital role in helping children with ADHD process and organize sensory input more effectively. These findings are consistent with prior research emphasizing the importance of visual structure and environmental legibility in reducing cognitive load and enhancing task focus in neurodiverse populations.

Interestingly, natural light and acoustic control, which were previously reported as critical sensory modulators, did not exhibit independent effects in the multivariate model. One possible explanation is that these elements share variance with other predictors, such as ventilation or textures, leading to statistical suppression. Alternatively, their impact might be more context-dependent, varying with factors such as time of day, noise levels, or the nature of therapeutic activities.

The variables "access to outdoor space" and "variety of textures and surfaces" showed weaker and non-significant associations with sensory integration in this study. This finding may reflect a lower relevance of these elements in structured indoor therapeutic settings or the possibility that their benefits are more indirect or long-term.

Overall, the results underscore the importance of incorporating visual-spatial design strategies, such as differentiated zones, clear boundaries, and contrasting colors, into the architectural planning of therapeutic environments for children with ADHD. These modifications are relatively low-cost and easily implemented but may yield meaningful improvements in sensory regulation and functional engagement.

Study limitations

Although this study provided profound insights and data, it is important to acknowledge certain limitations that may affect the generalizability of the findings. First, self-report and observational bias may influence the architectural evaluations and SSP scoring. Second, the research relied on therapeutic outcomes from 10 different rehabilitation centers, making it impossible to ensure consistency in the therapeutic procedures across all centers. Third, the research was geographically limited to Tehran, which may not represent the diversity of architectural and therapeutic settings across different regions. Fourth, the study relied on a researcher-designed questionnaire and did not incorporate standardized psychometric tools directly assessing children's performance, which could have enhanced objectivity. Finally, the study did not employ a mixed-methods or longitudinal design that could have enriched the findings with qualitative insights or long-term outcomes.

Recommendations for future research

For future studies, it is recommended to adopt a mixed-methods approach that combines both quantitative and qualitative methodologies, such as interviews with therapists, in-situ observations of children's behavior, and psychophysiological measurements (e.g. heart rate, eye tracking). Including a broader geographical scope and larger sample size will also strengthen the reliability and applicability of results. In addition, experimental or interventional designs that test specific architectural changes over time could provide stronger causal evidence.

Design-oriented recommendations

Based on the findings of this study, the following design and policy recommendations are suggested to improve rehabilitation environments for children with ADHD.

Architects and spatial designers can maximize the use of natural lighting with adjustable controls, utilize calming color palettes, such as soft greens and blues, avoid glossy surfaces and overly saturated colors, as they may cause overstimulation, clearly define spatial boundaries for different types of activities (e.g. therapy, play, rest) to ensure a seamless transition between them, and provide flexibility in layout and furniture to accommodate a range of therapeutic needs.

Rehabilitation center administrators and policymakers conduct regular assessments of existing environments in terms of noise levels, lighting quality, and color harmony. They invest in acoustic insulation for walls and ceilings to reduce environmental distractions and collaborate with design professionals during renovations or expansions to align spatial features with evidence-based therapeutic principles.

Conclusion

In conclusion, the findings of this study underscore the necessity of rethinking and redesigning rehabilitation environments for children with ADHD. This research underlines the significance of intentional design in clinical environments and highlights' color and spatial contrast' as a potentially impactful intervention point in optimizing rehabilitation outcomes for children with ADHD. Although architectural elements such as natural lighting, acoustic control, and textural diversity can positively influence the sensory integration of children with ADHD, their benefits are more indirect and possibly long-term.

An optimized sensory environment plays a foundational role in supporting improvements in cognitive, emotional, and behavioral functions. By reducing sensory overload and enhancing meaningful sensory input, well-designed spaces can help children manage stimuli more effectively, thus increasing their focus, emotional regulation, and learning capacity.

This research contributes to the growing body of evidence in health architecture and environmental design for neurodiverse populations, offering practical, evidence-based recommendations for both architects and healthcare professionals. Ultimately, it requires greater interdisciplinary collaboration to ensure that the built environment functions not only as a neutral backdrop but as an active, supportive agent in the therapeutic process.

Ethical Considerations

Compliance with ethical guidelines

This research was approved by the Research Ethics Committee of Shahid Beheshti University, Tehran, Iran (Code: IR.SBMU.RETECH.REC.1403.615) and employed an applied, descriptive-analytical design using a survey methodology.

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Appendix 1. The checklist for architectural evaluation

Scoring Guide:

1) Very Poor 2) Poor 3) Moderate 4) Good 5) Excellent

1. Lighting

1. Amount of natural light in the therapy room
2. Ability to control glare and light intensity (curtains, blinds, glass type)
3. Quality and uniformity of artificial lighting (no harsh shadows or glare)

2. Acoustics and Sound

1. Background noise level in the therapy space
2. Presence of sound insulation between rooms (walls, ceilings, doors)
3. Control of echo and elimination of internal disturbing noises (e.g., HVAC sounds)

3. Color and Texture

1. Use of calm, soft colors throughout the space
2. Controlled color diversity (avoiding overly bright or clashing combinations)
3. Use of sensory-friendly tactile textures on walls and floors

4. Layout and Spatial Organization

1. Clarity and order in the spatial functions (play, therapy, waiting)
2. Availability of open space for free movement
3. Ease of navigation for children without confusion or functional overlap

5. Ventilation, Temperature, and Odor

1. Presence of adequate natural or mechanical ventilation
2. Ability to control room temperature across seasons
3. Absence of unpleasant odors (paint, cleaners, moisture)

6. Safety and Child-Friendliness

1. Absence of sharp or dangerous edges in the environment
2. Physical safety measures (lockable doors, restricted access zones)
3. Appropriate scale of furniture and surfaces for child height

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