Research Article

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

Sasan Khademi Kalantari

Department of Architecture, Faculty of Architecture and Urban Planning, Shahid Beheshti University.

***Correspondence author:** Sasan Khademi Kalantari, MSc.
Department of Architecture, Faculty of Architecture and Urban Planning, Shahid Beheshti University
Tel: 09197045689
Email: khademi1374@gmail.com

ORCID ID:
Sasan Khademi Kalantari: https://orcid.org/0000-0002-2533-001X

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Abstract

Background: 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 architectural features of rehabilitation environments and examine their relationship with the information processing abilities of children with ADHD.

Material and Methods: Thirty five children (mean age: 7.6m range: 5-10) diagnosed with ADHD from 10 rehabilitation centers in Tehran were recruited for this descriptive-analytical study. Data was collected via a researcher-designed questionnaire for evaluating important architectural elements in the rehabilitation centers and was validated for content and construct (Cronbach's alpha = 0.81). The total score and the score for each item of the questionnaire were evaluated by a professional architects. The sensory improvement of the children was also evaluated by short sensory profile questionnaire 2 times; at the base line and after 1 month of their treatment. Correlation between each architectural items and the improvement in the children's sensory profiles were assessed by Pearson's correlation tests.

Results: A significant positive and moderate correlation between elements such as natural light (r=0.58), calming color schemes (r=0.55), noise reduction (r=0.49), with improved information processing ability in children with ADHD ($p < 0.01$).
Conclusions: The results indicate that careful and intentional architectural design of rehabilitation environments can play an effective 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 space design.
Keywords: Attention-Deficit-Hyperactivity Disorder; Architecture; Rehabilitation; Information processing

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, 2013) [1]. A 2021 systematic review of 34 studies found wide variation in ADHD prevalence, from roughly 3% up 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 between architecture and health sciences aimed at improving 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, and 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, orderliness in layout, 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 Attention-Deficit/Hyperactivity Disorder from 10 rehabilitation centers in Tehran were recruited for this study using an available (convenience) sampling method. According to inclusion criteria during 6 month case collecting period, 35 children were recruited for the study. The inclusion criteria for the children with ADHD were: (1) age between 3 and 12 years, (2) confirmed diagnosis of ADHD by a specialist, and (3) written informed consent obtained from the child's parents and the administrative approval from the participating occupational therapy centers (4) no history of previous rehabilitation treatment (5) recently admitted to the center (less than 10 days). Exclusion criteria included: (1) the presence of additional neurological disorders, (2) co-occurring psychological disorders, and (3) 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. This research was approved by ethical committee (Code: IR.SBMU.RETECH.REC.1403.615) and employed an applied, descriptive-analytical design using a survey methodology and 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 ($f^2 = 0.15$), a statistical power of 0.80, and a significance level of $\alpha = 0.05$. According to established guidelines of Cohen (1988), a minimum of 30–40 participants is sufficient to detect meaningful 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's alpha 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, six 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 six items, each with three subscales (Figure 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 six thematic areas, yielding a total possible score ranging from 18 to 90. Higher scores reflected better architectural conditions with regard to supporting 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”.

چک لیست مراکز کاردرمانی کودکان (ADHD)

راهنمای امتیازدهی:

(1خیلی ضعیف 2) ضعیف 3) متوسط 4) خوب 5) عالی

1- روشنایی

1-1- میزان نور طبیعی در اتاق درمان

1-2- توانایی کنترل خیرگی و شدت نور (پرده، کرکره، نوع شیشه)

1-3- کیفیت و یکنواختی نور مصنوعی (بدون سایه یا خیرگی شدید)

2- آکوستیک و صدا

2-4- سطح نویز زمینه در فضای درمانی

2-5- وجود عایق صدا بین اتاق‌ها (دیوارها، سقف‌ها، درها)

2-6- کنترل پژواک و حذف صداهای مزاحم داخلی (مانند صداهای سیستم تهویه مطبوع)

3- رنگ و بافت

3-7- استفاده از رنگ‌های آرام و ملایم در سراسر فضا

3-8- تنوع رنگ کنترل شده (اجتناب از ترکیب‌های بیش از حد روشن یا متضاد)

3-9- استفاده از رنگ‌های سازگار با حس بافت‌های لمسی روی دیوارها و کف‌ها

4- چیدمان و سازماندهی فضای

4-10- وضوح و نظم در عملکردهای فضایی (بازی، درمان، انتظار

4-11- وجود فضای باز برای حرکت آزاد

4-12- سهولت پیمایش برای کودکان بدون سردرگمی یا تداخل عملکردی

5- تهویه، دما و بو

5- 13- وجود تهویه طبیعی یا مکانیکی کافی

5- 14- توانایی کنترل دمای اتاق در فصول مختلف

6-15- عدم وجود بوهای نامطبوع (رنگ، مواد شوینده، رطوبت)

6- ایمنی و مناسب بودن برای کودکان

6-16 - عدم وجود لبه‌های تیز یا خطرناک در محیط

6-17- اقدامات ایمنی فیزیکی (درهای قفل‌دار، مناطق دسترسی محدود(

6-18- مقیاس مناسب مبلمان و سطوح برای قد کودک

Figure 1. The check list for architectural evaluatation

To measure the sensory processing profiles of the participating children, the Short Sensory Profile (SSP) developed by Dunn (2014) was administered. This instrument includes 34 items targeting 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, at the base line 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 was calculated and were 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 items of the customized architecture questionier. This analysis aimed to investigate the most correlated environmental factors that could influence the improvement in sensory processing abilities of the ADHD children in the 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 age = 7.6 years, SD = 2.1; 68.6% male, 31.4% female) from 10 rehabilitation centers in Tehran completed the study. Each child underwent sensory processing assessment using the Short Sensory Profile (SSP) at two time points between assessments; before and after 1 month of treatment. All children continued receiving 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).

Table 1. Architectural status of the rehabilitation centers

Architectural Elements	**Mean Score (of 5)**	**Status Rating**	**The Total Score (of 100%)**
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%

According to the architectural checklist, two centers (20%) were classified as “desirable” (score above 65), three centers (30%) as “Relatively desirable” (score between 45 and 65) and five centers (50%) as undesirable (score bellow 45). Checklist scores ranged from 38 to 79 (mean = 58.2, SD = 10.3). (Table 2)

Table 2. Center Scores and Short Sensory Profile Results

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

SSP= Short Sensory Profile

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 ($M = 85.6 \pm 9.4$) to Time 2 ($M = 91.2 \pm 8.1$), indicating reduced sensory processing difficulties.
When stratified by center classification, children in “desirable” centers demonstrated the greatest improvement in SSP scores (mean increase = 8.2 points), followed by those in “relatively desirable” centers (mean increase = 5.3 points), and “undesirable” centers (mean increase = 2.1 points). A one-way ANOVA revealed a significant effect of center classification on SSP score change, ($p= 0.007$). (Figure 2)

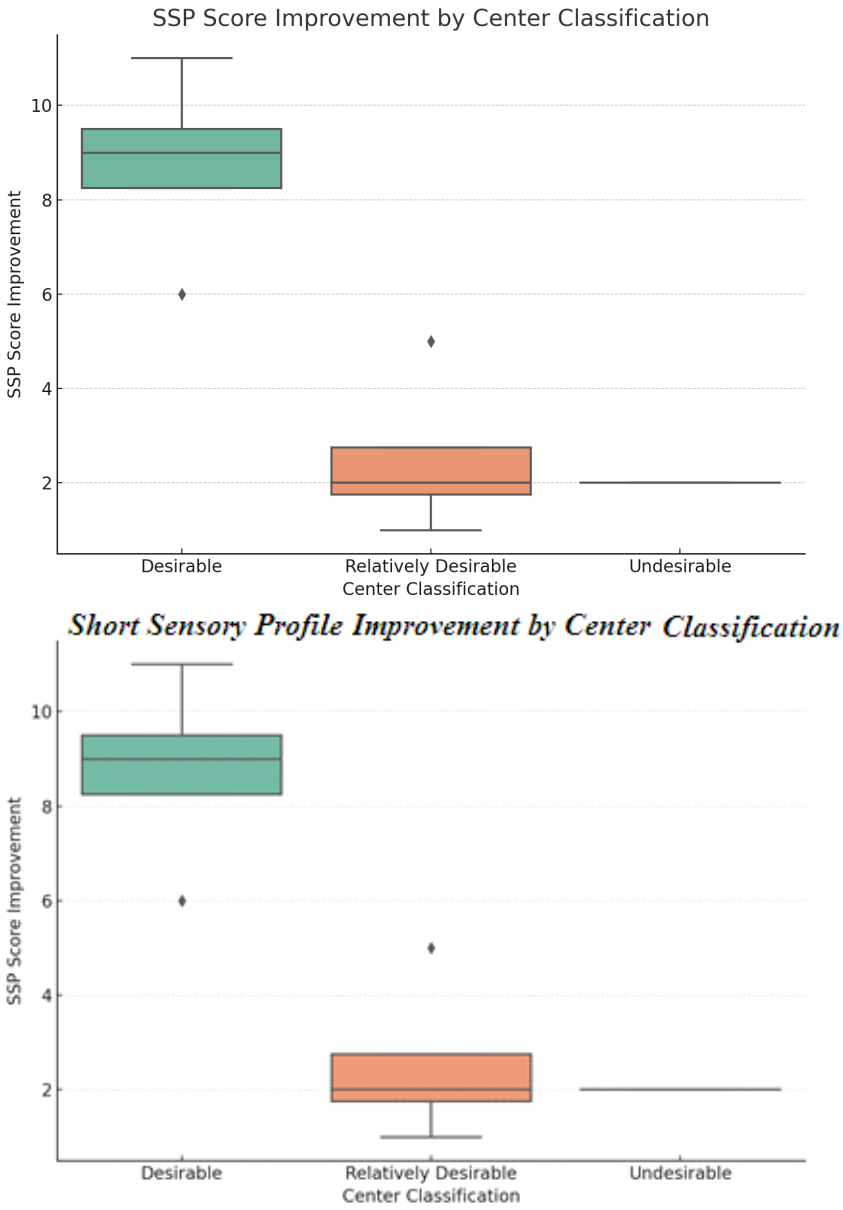

Figure 2. SSP Score Improvement by Center Classification. (SSP= Short Sensory Profile)

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

Correlation Between Architectural Scores and Sensory Improvement:
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 3)

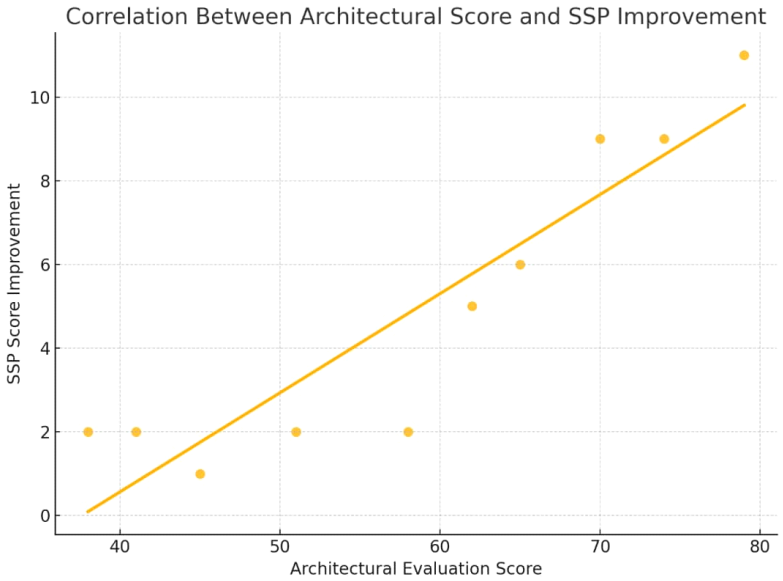

Figure 3. Correlation Between Architectural Score and SSP Improvement. (ssp= Short Sensory Profile)

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

Further exploratory analysis of the architectural checklist subscales revealed that the items most strongly associated with SSP score improvements were: Natural light and radiation control, Color and spatial contrast, Acoustics (sound control), Ventilation and indoor air quality. (Table 3)

Table 3. Correlation Between the architectural checklist subscales of the rehabilitation centers and the Short Sensory Profile improvement of the children with Attention-Deficit/Hyperactivity Disorder

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

Note: $p < 0.05$ shown in bold

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 ($\beta = 0.48$, $p = 0.027$), indicating that environments with higher levels of color differentiation and spatial clarity were associated with better sensory integration outcomes.

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.

Table 1. Multiple Regression Analysis Predicting Sensory Integration Scores from Architectural Features

Predictor	B	SE	t	P-value
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 texture & surfaces	0.16	0.14	1.1	0.277
Access to outdoor space	0.09	0.19	0.48	0.637

Note: B = unstandardized coefficient; SE = standard error; $p < 0.05$ shown in bold.

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. Across the three 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 showed that sensory-related elements such as natural lighting, acoustic quality, and tactile variation as “poor” or “very poor.” These findings align with previous studies, including those by Mostaafa (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.

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 meaningfully to enhanced sensory integration. These conclusions are consistent with studies by [14,15].

There is no universally agreed-upon minimal change in SSP scores that 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's 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 difference between the outcome of the centers and the correlation between these different therapeutic outcomes and the architectural elements in these centers.

Impact of Architectural Features on Sensory Integration:

Correlation analysis:

As demonstrated in Table 2, certain architectural components were found to be significantly and positively associated with improved sensory processing abilities in children with ADHD. Specifically:

- Adjustable natural light correlated with enhanced visual focus
- Cool, gentle color schemes supported emotional regulation and reduced hyperactivity
- Reduced environmental noise contributed to decreased auditory reactivity and aggression
- Textural diversity was associated with increased sensory acceptance and reduced anxiety

These results affirm earlier findings by Unwin [16] and Evans & Wachs [17], emphasizing the importance of consciously designed environments that regulate sensory input—not merely for aesthetics, but as therapeutic tools. Additionally, the higher performance 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 suggests that perceptual clarity 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, while previously reported as critical sensory modulators, did not show 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 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 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 uch 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.

Limitations and Recommendations

Although this study provided meaningful 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 was relied on the therapeutic outcome from 10 different rehabilitaton centers and it was impossible to assure the consistency of the therapeutic procedures in all centers. Third, the research was geographically limited to the city of 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:

For architects and spatial designers:
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 that may cause overstimulation.
Clearly define spatial boundaries for different types of activities (e.g., therapy, play, rest).
Ensure flexibility in layout and furniture to accommodate varied therapeutic needs.

For rehabilitation center administrators and policy-makers:
Conduct regular assessments of existing environments in terms of noise levels, lighting quality, and color harmony.
Invest in acoustic insulation for walls and ceilings to reduce environmental distractions.
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 Attention-Deficit/Hyperactivity Disorder (ADHD). This research reinforces 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, but their benefits are more indirect and possibility 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 capacity for learning.

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 calls for greater interdisciplinary collaboration to ensure that the built environment functions not only as a neutral background 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 the physiotherapy research center SBMU, Code: IR.SBMU.RETECH.REC.1403.615.

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Conflict of interest

The authors declared no conflict of interest.

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Authors' contributions

Conceptualization and Supervision: Sasan Khademi Kalantari
Methodology: Sasan Khademi Kalantari
Data collection: Sasan Khademi Kalantari
Data analysis: Sasan Khademi Kalantari
Writing: Sasan Khademi Kalantari

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