Smart ADHD-friendly university educational spaces -the synergy of architecture-design-digital assistive technologies in supporting the performance of students with attention deficit/hyperactivity disorder-

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Abstract

Objectives: Hidden or invisible disabilities are often overlooked in the design of higher education spaces. ADHD is a neurodevelopmental disorder that persists in adults in a significant percentage of cases, with defining symptoms such as attention difficulties, mental and physical hyperactivity, impulsivity. The paper investigates the ways in which architecture and design of contemporary university educational spaces, in synergy with digital technologies, can intelligently support the performance of students with ADHD, in the spirit of an inclusive and resilient academic community. Prior work: In the university environment, students with ADHD frequently face difficulties caused by attention deficits, mental hyperactivity, executive function deficits and the presence of ADHD-related mental disorders. Research in the field of ADHD-friendly architecture is still in its infancy, the present work starts from existing concepts such as: user-centered design, accessibility, inclusivity, bringing into discussion aspects related to optimization through digital technologies. Approach: The research is a narrative review and investigates, interdisciplinary, the types of interventions on the physical environment, including digital technologies - in relation to educational interventions - that support the good results of students with ADHD. Case studies are used, examples of good practices for ADHD-friendly educational spaces. Results: Therapeutic behavior in young adults with ADHD involves drug treatment, psychological interventions and environmental adaptations, for which strategies were identified for an ADHD-friendly university educational space, with an emphasis on architecture, formulating eleven principles: 1. Providing a "calm" environment, in soothing colors, without unnecessary decorations or visual and auditory distractions, to improve concentration; 2. Possibility of adjusting the degree of illumination, both natural and artificial; 3. Designing enclosed, soundproof spaces, avoiding distracting elements; 4. Maintaining a spatial routine and minimizing surprises; 5. Specific configuration of classrooms, laboratories and seminars for focused attention; 6. Using materials that provide a neat and tidy appearance; 7. Using organizational, ergonomic, comfortable furniture in spaces dedicated to practical work, seminars; 8. Inclusion of a quiet space / quiet room in the planimetric-functional configuration of the educational building; 9. Ensuring thermal comfort and the possibility of easily adjusting the temperature; 10. Encouraging spending time outdoors for both learning and relaxation; 11. An ADHD-friendly architecture is an inclusive architecture, friendly for all users. Currently there are few examples of ADHD-friendly universities in terms of physical environment, most of them responding rather to special educational requirements. The architecture can intelligently include natural and interactive interfaces, monitoring and regulation technologies (e.g. smart furniture with sensors, soundproof rooms equipped with BCI technologies), Information and Communication Technologies (ICT), digital play/training areas. Implications: The management of ADHD in students requires a multidisciplinary and personalized approach, involving pharmacological treatment, psychological interventions and environmental adaptations / accommodations. An ADHD-friendly university space effectively supports the transition period from adolescent to adult, is inclusive, supportive, using architectural tools and assistive digital technologies harmoniously and intelligently, in order to facilitate the performance and well-being of all users. Value: The work integrates architectural and clinical expertise, giving the study an optimized interdisciplinary value on the subject of ADHD-friendly university environments.

Keywords: ADHD-friendly architecture, university educational space, user-centered design, interdisciplinarity.

1. Introduction

Hidden or invisible disabilities -those without visible supports such as wheelchairs or sign language- are often overlooked in the design of higher education spaces [1]. Examples range from Autism Spectrum Disorder (ASD), depression to Attention Deficit / Hyperactivity Disorder (ADHD) [2].

ADHD is a neurodevelopmental disorder that persists into adulthood in a significant percentage of cases. The worldwide prevalence of ADHD is estimated at 7.3% among children [3] and between 2.5%–6.7% among adults [4]. The defining symptoms of ADHD are attention difficulties (for sustained attention, focused attention, distractibility), mental and physical hyperactivity and impulsivity. In addition, most adults with ADHD have executive dysfunctions: poor time management, procrastination, difficulties in self-organization and problem-solving, low motivation or difficulty in self-regulation of emotions [5, 6]. In the case of students, we must take into account the evolution of ADHD symptoms in adults, which involves a decrease in motor hyperactivity symptoms but an increase in mental hyperactivity symptoms and the impact of executive dysfunctions. This change is due to the maturation of young adults on the one hand, but at the same time, students must cope with the increase in the complexity of educational requirements, the complexity of the information needed to be assimilated at a higher level, the overlap of educational requirements [7].

In addition to drug treatment and psychotherapy, architecture and interior design can significantly contribute to the performance of students with ADHD [8, 9].

2. Objectives

ADHD is associated with significant underachievement among university populations [10]. Most studies focus on the population of children and adolescents with ADHD, where their performance is clearly shown to be significantly lower than that of peers without ADHD [11]. These studies highlight the need for early adaptations of both the teaching method and the physical environment [10]. While ADHD may improve in adulthood, a significant percentage of individuals experience persistent ADHD symptoms.

Increasingly, young people are diagnosed with ADHD only in adulthood, many of them being students who exert considerable effort to meet the complex demands of higher education.

The paper investigates the ways in which architecture and design of contemporary university educational spaces can intelligently support the performance of students with ADHD in the spirit of an inclusive and resilient academic community.

3. Prior work

In the university environment, students with ADHD frequently face difficulties caused by attention deficits, mental hyperactivity, executive function deficits and the presence of other mental disorders. In the absence of an adequate support system, these students quickly become overwhelmed, leading to a repetitive cycle of frustration and failure [5, 6].

Research in the field of ADHD-friendly architecture is still in its infancy, especially in young adults users, the present work starts from existing concepts such as: user-centered design, accessibility, inclusivity.

The article of Thomas et al. (2015) [12] provides an essential overview of the global prevalence of ADHD, establishing a combined estimate of approximately 7.2% among children and adolescents. The relevance for higher education (universities) is that this high prevalence, which also extends to the young adult population, fully justifies the adoption of a Universal and Smart Design approach. The figures validate the strategic need for universities to invest in adaptive smart educational spaces that support a large number of students with neurodevelopmental disorders in order to improve concentration and academic performance.

Another paper of Alqahtani (2015) [13] argues that space design is an essential therapeutic tool for people with hyperactivity and attention disorders. Integrating sustainability principles (especially the choice of natural, recycled and local materials) not only complies with ecological standards, but also contributes to a calming and simplified indoor environment. The design should be flexible, informal and simple, using pastel colors and clear lines to reduce complex visual stimuli and facilitate self-control and concentration, aspects vital for the performance of students with ADHD.

A dissertation study of Winterhalter (2016) [14] reveals that college environments exacerbate academic challenges for students with ADHD due to reduced structure, increased distractions, and heightened demands on executive functioning. Inattention—rather than hyperactivity—emerges as the primary predictor of poor academic adjustment, study skills, and self-efficacy. Deficits in time management, organization, and information processing further hinder adaptation to university life. For architectural design, these findings underscore the necessity of structured, distraction-minimized, and cognitively supportive learning spaces that enhance focus, reduce cognitive overload, and accommodate diverse attentional needs. The concept of the *Physical Learning Environment* has evolved from a narrow focus on classroom structure to a multidimensional understanding of the diverse physical, social, and technological spaces where learning occurs. Research shows that spatial and sensory elements—noise, lighting, temperature, and organization—significantly shape cognitive and emotional performance. For students with ADHD, who are particularly sensitive to environmental stimuli, defining and designing the physical learning environment becomes critical. Adaptive, structured, and low-distraction spaces can support sustained attention, cognitive processing, and academic engagement.

The volume "Design for the mind - Neurodiversity and the built environment - " (2021) provides an essential framework for designing built environments that are inclusive for people with neurodevelopmental disorders. The guide starts from the premise that sensory overload (caused by noise, light, colors, patterns or crowded spaces) creates stress and anxiety, being a significant barrier for many users. Therefore, the guide provides detailed design and management recommendations aimed at reducing visual and auditory noise, optimizing acoustics and lighting and creating clear wayfinding solutions. A central element of the guide is the encouragement of quiet and restorative spaces in all types of buildings, providing a place of recovery when users feel overwhelmed. The ultimate goal is to create attentive and intuitive environments that allow everyone to thrive, regardless of their mental profile [15].

Moriña (2022) [2] explores the major challenges faced by students with invisible disabilities, such as ADHD, in higher education. The central idea is that the invisibility of the condition creates barriers to disclosure and access to support, as it is often assumed that "unseen" problems do not exist. The article emphasizes that effective support must go beyond simple academic accommodation and include staff awareness, a culture of inclusion, and, implicitly, the Universal Design of the physical and technological environment. Thus, by eliminating stigma and through proactive adaptations (such as ADHD-friendly smart spaces), universities can ensure equity and improve the performance of these students.

A very recent research of Kalantari (2025) [16] empirically demonstrates that the intentional architectural design of rehabilitative environments directly influences the processing of sensory information in children with ADHD, providing a solid basis for adapting academic spaces. The study identified also significant positive and moderate correlations between elements such as natural light, calming color schemes, and noise reduction and improving the sensory profile of children. Although multivariate analysis highlighted color and spatial contrast as key independent predictors, the conclusion is that the built environment—through optimal adjustment of stimuli—is not just a backdrop, but an active therapeutic tool that supports cognitive performance and emotional regulation, essential principles for creating smart ADHD-friendly academic spaces.

While extensive research exists on physical learning environments—from classroom ecology to technology-enhanced and evaluative studies—most prior work focuses on general student populations and traditional learning spaces. These studies predominantly employ quantitative methods and rarely address learners with attention or executive function challenges. The key gap identified is the lack of research on how *physical learning environments* affect college students with ADHD. Specifically, there is limited understanding of how spatial attributes influence cognitive load-either supporting learning or creating distractions. This highlights the need for architecture and design research that integrates cognitive and mental health perspectives.

4. Approach

This research employs a narrative review and investigates, interdisciplinary, thorough the lense of architecture and mental health, various types of physical environment

interventions, including digital technologies - in relation to educational interventions - that enhance academic outcomes for students with ADHD. Case studies are used, examples of best practices, to illustrate the design of ADHD-friendly educational spaces.

The significance of the built environment is evident from the definition of the disability, which can manifest itself in relation to interaction within it. Disability refers to the limitations that people with physical, mental, sensory and intellectual abilities, different from typical ones, encounter in their interaction with the built environment, with the way information is transmitted and with societal attitudes, limitations that prevent them from participating on equal terms with their peers in all spheres of life [17, 18].

It is widely recognized that a wheelchair user cannot achieve a comfortable quality of life if there is no accessible built environment featuring ramps and elevators, in this case the person's situation is visible and recognizable, through the walking aids used. In contrast, the neurodevelopmental disorders such as ADHD or ASD (Autism spectrum disorder) can affect the way these people interact with the world, how they process sensory information, yet they are less visible to those around them. An inappropriate physical environment can be an obstacle in achieving personal goals, whether related to learning, practicing a profession or being patient in a therapeutic space. Conversely, a built environment that supports personal needs can significantly improve outcomes [19].

5. Results

Therapeutic behavior in young adults with ADHD involves drug treatment, psychological interventions and environmental adaptations / accomodations [5].

Drug treatment is the most effective in controlling symptoms and includes stimulants and non-stimulants [20]. Psychological interventions are based on the principles of cognitive-behavioral psychotherapy [21].

In contemporary scholarship, the Physical Learning Environment (PLE) could be understood as a multidimensional construct integrating spatial, sensory, technological, and social dimensions that shape learning behavior and cognition [22]. Current definitions move beyond traditional classroom architecture to include hybrid and flexible spaces that promote collaboration, inclusivity and well-being [23]. Recent research emphasizes sensory ergonomics - lighting, acoustics, and spatial layout - as determinants of attention, engagement, and cognitive performance [16]. For learners with neurocognitive disorder, particularly students with ADHD, the PLE plays a critical compensatory role. Environments that minimize sensory overload, provide structured flexibility and incorporate restorative zones, enhance executive functioning and self regulation [24]. There are recent studies that show that the emphasis in education, in the context of the unprecedented development of digital technologies, should be placed on the central role of cognitive aspects in student behavior, suggesting that the physical environment is not the main barrier [25].

In conclusion, contemporary definitions of the PLE highlight inclusivity and adaptability as central. Designing ADHD-friendly university spaces requires evidence-based

architectural strategies that balance stimulation and calm, optimize sensory input and support focus through spatial clarity and flexible, technology-integrated layouts.

The challenges of the physical environment for students with ADHD in university spaces involve various aspects that architects must take into account. Sensory overload, which can involve constant or sudden background noises, bright or cold lights, can cause rapid distraction. Open and crowded spaces - such as foyers, wide hallways or completely open courtyards, without retreat areas - can cause difficulty concentrating and increase stress levels. The lack of visual structure - landmarks, color coding, spatial predictability - can lead to disorientation and a feeling of mental chaos. Intense artificial lighting, at the expense of facilitating natural light, can cause visual fatigue and disruption of the circadian rhythm. Thermal discomfort - temperatures that are too high or, conversely, too low - can diminish the ability to concentrate. The lack of retreat areas can lead to the impossibility of emotional and sensory self-regulation [26].

Regarding accommodations / environmental adaptations, strategies for an ADHD-friendly university educational space were identified, highlighting the role of architecture and design. These strategies can be described according to different dimensions: the organizational context (preferential seats, reduction of distractions, sound control, working in small groups), the way of presenting information (halls equipped with assistive technologies), time management (break spaces relaxing, furnishing lecture and seminar rooms with clocks), comfort (organized, functional and ergonomic furniture - chairs and tables, optimal lighting, soothing colors, pleasant textures that give a neat appearance, sound insulation adapted to the purpose of the space) and various other details [27].

Adaptations in educational spaces based on ADHD-friendly principles have a significant role [28], recognized by specialists. Thus, eight principles were formulated for an ADHD-friendly educational space [29, 30].

Thus, 11 ADHD-friendly design principles were formulated for university educational spaces.

5.1. Providing a "calm" environment, in soothing colors, without unnecessary decorations or visual and auditory distractions, to improve concentration

Strategic selection of color schemes is essential in the design of academic spaces to alleviate the symptoms of inattention and hyperactivity, characteristic of ADHD. Good practice examples recommend implementing calm, muted colors, such as light blues, greens, and pastels, to alleviate anxiety and promote sustained concentration [31]. In contrast, bright, intense hues (e.g., red, orange) should be avoided, according to some studies, due to their potential to induce overstimulation and agitation [32]. The use of simple, consistent color schemes and neutral backgrounds with controlled color accents minimize visual clutter [33, 34], favoring an environment conducive to concentration. Additionally, color zoning can be used to delineate functional areas, thereby reducing confusion and increasing spatial predictability [35].

Earthy, bright, relaxing shades are recommended, to which it can be added shades of blue and green. Shades of blue increase productivity, help with organization, support cognitive processes, and green supports focus, motivates, and reduces stress [36, 37].

5.2. Possibility of adjusting the degree of illumination, both natural and artificial

To reduce sensory stimuli and anxiety in transition areas, it is recommended that lighting levels be lower than in educational areas, and that lighting be indirect.

We can talk about inclusive lighting strategies. This can involve adjustable light control, so that the intensity and color temperature can be adjusted (dimmer, adjustable white light, smart systems). Educational spaces should be generously lit naturally, exposure to natural light supports mental health and reduces dependence on artificial sources. Lighting should be diverse, multi-layered, both ambient and task or accent lighting, all of which flexibly and optimally support a variety of educational activities. It is also recommended to pay attention to the choice of lighting sources, which should prevent unwanted effects such as glare or flickering. In this regard, it is recommended to use matte surfaces instead of glossy ones and flicker-free LED sources, as an additional protection measure for students with sensory hypersensitivity [36, 38].

Warm tones (2700k-3000k) can also have beneficial effects, generating comfort. Cool tones (4000k-5000k) stimulate energy [38]. The color temperature of lighting (cool white vs. warm white lighting) has a measurable impact on cognitive performance and emotional state, specifically influencing memory (long and short term) and the overall perception of the learning environment [39].

When we talk about smart technologies, Smart Lighting systems allow students with ADHD to finely and individually adjust, through a mobile application, the color temperature and intensity of the light at their desk.

5.3. Designing enclosed, soundproof spaces, avoiding distracting elements

Open, flexible spaces have qualities in multifunctional use, however, they can be unpleasant when they do not offer alternatives for withdrawal. The choice is crucial, it is recommended to design clearly defined areas that adapt to a variety of preferences regarding sound levels and comfort zones, which will contribute to creating a more inclusive work environment. Seminar, practical work rooms, on a smaller scale offer comfort, privacy, safety especially for students who have concentration problems or suffer from anxiety. In the case of compartmentalized spaces, sound proof can be achieved more easily [39]. Partitions can be improved with sound-insulating/sound-absorbing materials, depending on the desired effect. Acoustic design can minimize reverberation, reduce noise transmission from adjacent spaces, take into account sudden loud noises (such as alarms) and omit repetitive background noise, where possible. For students with ADHD, it is recommended to design hyper-concentration areas.

Spatial and behavioral design can work together to indicate a person's willingness to be interrupted, supporting each other synergistically. Signage can complement the design, in this sense, specially designated areas for concentration, study can be accompanied by a

message such as "Do not disturb", where everyone is aware of the function of the space, for example in a library [40, 41].

Access to soundproof spaces can be managed digitally through real-time reservation systems, eliminating the surprises and frustration present in ADHD and guaranteeing the availability of concentration space.

5.4. Maintaining a spatial routine and minimizing surprises

It is not necessarily about maintaining a spatial routine, although this can provide comfort to students with ADHD. It is rather about personalizing spaces through color, materiality, using a certain coding through the specific use of architectural tools such as color and texture.

Spatial orientation is a significant challenge for people with ADHD, influencing how they perceive, navigate, and use educational spaces. Studies show that difficulties in processing visual-spatial information can lead to disorientation, anxiety, and decreased performance in complex or chaotic environments [42]. An intelligent and coherent architectural design, with clear circulation routes, consistent visual landmarks, and well-defined transition areas, can reduce cognitive overload and support attentional self-regulation. In addition, the integration of assistive digital technologies - such as indoor navigation applications, dynamic signage, or tactile maps - enhances the ability of students with ADHD to interact effectively with the university educational space. Thus, the synergistic use of architecture-interior design-intelligent digital technologies can transform universities into inclusive environments, capable of supporting the orientation, autonomy, and academic performance of all students.

For example, the BBC's new headquarters in Cardiff, Wales, employs a color-coded floor system visible from a central atrium to intuitively guide navigation and promote spatial clarity—an approach that supports focus and autonomy in dynamic environments [36]. Similarly, the *Special Education School in Heyuan, China*, integrates chromatic zoning and light modulation to distinguish functional areas and foster a sense of safety and predictability for students with diverse sensory and attentional needs [43]. These architectural solutions demonstrate how visual coding and sensory design principles can make educational and workplace spaces more inclusive and ADHD-friendly.

There are mobile navigation and real-time applications that can overlay visual information about route or schedule changes, providing increased control over the physical environment.

5.5. Specific configuration of classrooms, laboratories and seminars for focused attention

The literature, particularly for children, emphasizes the need for a structured and predictable learning environment to support students with ADHD. Key interventions include arranging classrooms in the traditional row-seating model, which provides essential spatial predictability [44].

A crucial aspect is strategic placement: students are positioned at the front of the room and near the teacher's desk to minimize lateral distractions and allow for immediate feedback from the teacher [45]. Further optimization requires moving students away from major sources of distraction, such as windows and doors [44]. These considerations may also apply to college students.

Furthermore, strategic seating arrangements significantly modulate student participation and engagement, particularly for learners with ADHD. Research indicates that in seminar settings utilizing square or U-shaped table configurations, students seated directly opposite the instructor demonstrate higher rates of participation compared to those in peripheral positions. Similarly, in laboratory rooms with fixed rows, optimal participation is observed in the center and side front rows. While the direct impact of seating location can sometimes be confounded by individual student preferences and initial choice - as those who voluntarily select front seats are often intrinsically more motivated - these findings underscore the importance of minimizing peripheral seating and maximizing direct visual access to the instructor to enhance focus and involvement in learning activities [39].

Other effective strategies involve implementing enclosed classrooms (with walls and doors) to mitigate the intrusion of external noise. Although the impact on performance between open and closed environments may vary [39], the provision of flexible furniture and cubicles allows for spatial adjustment tailored to tasks that require intense attention, promoting an adaptable and functional university architecture. In the case of university spaces, the trend toward open and flexible design - more prevalent than in pre-university education - should be nuanced to take into account the needs of students with neurodevelopmental disorders. Supporting their performance in this way contributes to the formation of more resilient, inclusive, and functional generations.

Digital equipment (such as interactive whiteboards and flexible screens) can facilitate rapid changes in teaching mode (e.g. from focus to brainstorming) without requiring major physical reconfigurations, maintaining attention through controlled variety.

5.6. Using materials that provide a neat and tidy appearance

The visual orderliness of university learning environments plays a decisive role in supporting the cognitive and emotional balance of students with ADHD. Recent research in neuroarchitecture emphasizes that tidy, visually coherent spaces reduce cognitive overload and help sustain attention by minimizing peripheral distractions [46, 47]. Using materials and furniture that reinforce a sense of order - such as smooth matte surfaces, built-in cabinetry, concealed wiring systems, and modular desks with integrated storage - can significantly improve spatial clarity. For example, furniture with flush finishes, rounded edges, and consistent color tones (e.g., pale wood, muted gray, or white) helps avoid visual clutter while maintaining warmth and comfort. Open shelving should be limited or enclosed with translucent panels to preserve both accessibility and neatness. In ADHD-friendly university design, material choices and furniture composition act as subtle behavioral cues, promoting organization, calmness, and focus through an aesthetic of simplicity and coherence.

Physical order can be complemented by centralized cloud storage systems and digital homework delivery, reducing clutter on work surfaces (table, desk) and supporting executive functions.

5.7. Using organizational, ergonomic, comfortable furniture in spaces dedicated to practical work, seminars

Contemporary pedagogy requires tutors to understand the different needs of students and is embodied in their willingness to adapt courses and practical work to encourage performance and well-being. By prioritizing diverse needs, professors promote the success of all students. When designing educational spaces, architects consider providing comfort, stimulating engagement, and generating inclusive spaces. Classrooms/seminars with furniture adapted to people with ADHD provide students with a private and supportive space where they can focus on tasks and interact in a comfortable and empowering manner.

Configuring educational spaces according to ADHD-friendly requirements requires the integration of furniture systems with a high degree of modularity and functional flexibility [48], adaptable to individual needs [49, 50]. Ergonomic chairs are very important, which optimize static comfort and facilitate sustained attention.

The design of chairs must include a series of essential technical attributes, in order to promote a correct and constant posture: high-performance, breathable upholstery with adequate cushioning, adjustable support elements (lumbar support, armrests, height and tilt angle adjustment) that allow the personalization of the human-furniture interface. Furthermore, the inclusion of specialized seating solutions that allow for dynamic movement and postural changes can significantly benefit students with ADHD by helping them regulate their energy levels and maintain focus during academic tasks.

These specifications are fundamental to ensure kinesthetic stability, significantly reducing the need for motor self-regulation (fidgeting) and position change – behaviors associated with sensory regulation difficulties in ADHD [51]. By providing effective physical anchoring, proprioceptive distractions are minimized and cognitive resources are supported for the primary task.

In addition to ergonomics, design interventions integrate elements that provide sensory protection and visual-auditory limitation [49]. It is recommended to use additional panels, such as a curved screen with a textile finish (sound-absorbing), integrated behind the seating unit. This element functions as a micro-spatial barrier like a concentration niche. These screens can restrict the peripheral visual field, reducing the cognitive load generated by environmental movement. They can attenuate sound waves through the absorption properties of the material, reducing auditory intrusions. Finally, they can provide a sense of shelter and territorial control, essential in alleviating the hypersensitivity and anxiety associated with neurodevelopmental disorders [52].

Ergonomic chairs designed to increase comfort and concentration have multiple features and additions that promote better posture and make it easier to focus by eliminating the need to shift positions or fidget in the seat. These ADHD-friendly chairs have features-

padded and breathable seats, armrests, adjustable heights, lumbar support, and more [53, 54].

In ADHD-friendly university environments, current interior design trends emphasize organizational furniture systems that incorporate predominantly closed storage areas. This approach not only prevents dust accumulation but also sustains a tidy, minimalist, and visually calm atmosphere, essential characteristics for supporting attentional stability in students with ADHD. Studies on spatial organization and neuroinclusive design demonstrate that clutter-free, coherent environments enhance concentration and emotional regulation [55, 56]. In practice, such furniture may include bookstores or shelving units with alternating closed doors and small open niches, or desks with drawers that maintain accessibility while preserving visual order. Combining closed elements with selective open areas provides both functionality and aesthetic balance. Neutral color schemes - such as whites, grays, or light wood tones - enriched with soft green or blue accents, have been shown to promote calmness and cognitive comfort [57]. Consequently, organizational and ergonomic furniture serves as both a practical and therapeutic design tool within ADHD-friendly university architecture.

Ergonomic chairs and desks can be integrated with posture sensors or smart charging stations (DAT), turning the furniture into a digital assistant that encourages movement or reminds you to take breaks.

5.8. Inclusion of a quiet space / quiet room in the planimetric-functional configuration of the educational building

Given that studies using EEG (electroencephalogram) indicate individuals with ADHD may possess a lacking or slow neural defense system against uncomfortable sensory input, particularly acoustic discomfort, it is crucial for universities to design adaptive and neuro-inclusive smart buildings. These spaces must be capable of actively modulating the acoustic environment to accommodate diverse sensory responses, thereby ensuring optimal concentration and equitable learning conditions for all students [58].

Quiet-room spaces are recommended in therapeutic design for different types of users. For example, these are recommended for elderly people with neurocognitive disorders (NCDs), for example from the Alzheimer's spectrum [59, 60]. A similar type of space that provides relaxation in addition to quiet, which reduces stimuli is also recommended in office buildings, to combat overwork and burnout. In the case of students with ADHD, we talk about these spaces with the role of providing peace and quiet, a sense of privacy and solitude, helping relax and prevent or combat anxiety. These spaces can be private cubicles, individual study spaces, "nest" furniture pieces, comfortable armchairs and/or chairs with soft surfaces, with protective zones that give you the feeling of relaxation. Chromatics can contribute to the effect of these quiet spaces [61].

Recent research indicates that total sensory deprivation may be counterproductive, as certain stimuli can aid concentration. For instance, natural/green spaces resulted in milder ADHD symptoms, but studies also found that white noise can improve cognitive performance due to stochastic resonance. Moreover, dynamic seating was effective in

increasing attention capacity, showing that controlled movement or stimulation, not just calmness, is beneficial [14].

Quiet spaces, zones or boxes can be equipped with virtual reality technology or digital biofeedback tools, which provide guided calming exercises, supporting the physical space to transform into an assisted self-regulating environment.

5.9. Ensuring thermal comfort and the possibility of easily adjusting the temperature

Thermal comfort is a significant component of indoor environmental quality, according to some researchers, even critical and yet often overlooked, which can significantly affect the performance and well-being of both children and young adults, schoolchildren and students with ADHD. The scientific literature suggests that thermal discomfort, especially excessive heat, can exacerbate core symptoms of ADHD, such as inattention, restlessness and irritability, making it much more difficult to maintain focus on academic tasks [62, 63]. Recent research indicates that for children—a finding often extended to young adults with ADHD who are more sensitive to environmental stimuli—thermal comfort contributes to symptom severity, with air quality and temperature predicting variation in the severity of inattention. Furthermore, some studies suggest that individuals with ADHD may report feeling hot even when other users are comfortable, highlighting a potential heightened thermal sensitivity [62]. Therefore, ADHD-friendly design should prioritize thermal flexibility, giving students the ability to customize their microenvironment through adaptive controls, such as adjustable seating near windows, personal fans, or localized temperature regulation, to create an optimal zone for cognitive function.

Smart HVAC (heating, ventilation, air conditioning) systems can allow local temperature adjustment through the digital interface right from the work table, preventing thermal discomfort that can quickly lead to distraction or sensory crisis.

5.10. Encouraging spending time outdoors for both learning and relaxation

Spending time outdoors during the week can be very limited due to lack of time, for students, which could have an impact on both their well-being and performance. Moreover, students with ADHD feel the need to move, to have diverse possibilities for studying, not to be conditioned by a fixed and sometimes tiring framework. Studying models already used in the West, especially in pre-university education, where more importance is given to the need for children to move, certainly for students with ADHD, using outdoor spaces as extensions of the course rooms would bring added value. Universities can contribute to promoting a culture of continuous learning, by transforming courtyards and other informal learning spaces into captivating and stimulating intellectual spaces.

Outdoor learning areas should offer accessibility throughout the activity, with a wide range of spaces, from quiet corners for reflection to sports fields for energy consumption.

Contact with nature is very important for well-being and this has been especially evident during the Covid-19 pandemic. One can think of green lecture halls and open amphitheaters, as extensions of university buildings.

It may be considered installing pergolas or canopies, which can provide both sun and rain protection, transforming open areas into spaces that can be used all year round [64]. It is recommended to use modular and weatherproof furniture, the use of mobile chairs and tables, with integrated outdoor sockets and secure Wi-Fi access, thus allowing students to configure their own working environment, similar to an outdoor office. Acoustic niches can also be designed in outdoor spaces, by using landscape elements (hedges, short walls, artesian fountains), areas with a reduced noise level can be created, essential for the concentration of students with ADHD or for individual study [65].

Geo-located mobile apps can guide students to optimized outdoor study areas and offer mindfulness or learning tasks based on proximity to natural elements.

5.11. An ADHD-friendly architecture is an inclusive architecture, friendly for all users

Although the solutions implemented – from ensuring a calm and distraction-free environment, soundproofing and spatial routine, to the inclusion of a quiet space – are designed to manage the challenges of executive functions specific to ADHD, their impact goes beyond the clinical sphere. The resulting university educational environment, optimized for concentration, cognitive comfort and sensory regulation (through adjustable lighting, ergonomic furniture and thermal comfort), becomes a model of Universal Design. Thus, the premise is confirmed that a design made with meticulous attention to the needs of a specific group on the spectrum of neurodevelopmental disorders raises the quality standard of the entire space, reinforcing the fundamental idea, design for all is just good design [66, 67].

Digital adaptability is essential, architecture provides the physical framework, and customizable assistive technologies can ensure that every student with neurodevelopmental disorders (and others than ADHD) can calibrate their environment exactly according to their unique needs, because, ultimately, an inclusive society ensures its sustainability by taking care of the most efficient education for all its members.

6. Discussions

6.1. Prioritizing design to support people with disabilities

Recent buildings that have prioritized design to support users with disabilities associated with neurodevelopmental disorders include the new headquarters of the British Broadcasting Corporation (BBC) for Wales (master planning and interior architecture by Sheppard Robson, basic architecture by Foster+Partners).

The BBC Wales headquarters serves as a demonstration model of neuro-inclusive design, the strategies of which can be directly applied in university spaces. Wayfinding is optimized through the use of distinct color coding of different functional areas, the spatial legibility of which is ensured from the central atrium. This clear visual organization reduces cognitive load and supports executive functions of planning and routine. A crucial functional element is the diversity of spatial typologies. The inclusion of private cubicles and concentration spaces offers users with ADHD the possibility of sensory self-regulation, allowing the choice of a work environment with controlled stimulation, essential for maintaining sustained attention [68].

The perception of sensory stimulation is an individualized process within the human population, with each individual processing external information in a unique way. In the clinical context, neurodevelopmental disorders epresent a broad category of conditions characterized by functional impairments in critical domains such as physical, cognitive, language, and behavioral. The global prevalence of these neurodevelopmental disorders is estimated to range significantly from 16.2% to 17.8% [69, 70].

6.2. Learning environment for all, including students with ADHD

Implementing a superior learning environment that supports students with neurodevelopmental disorders, including ADHD, requires a systemic approach that encompasses both architectural interventions and institutional strategies.

Adopting Universal Design for Learning involves using the Universal Design for Learning Principles that advocate for designing flexible learning environments that maximize cognitive and functional accessibility. This paradigm ensures that architectural solutions address a wide range of curricular and sensory needs, benefiting all learners, beyond a strict focus on disability adaptations [71].

Given that for many young adults with ADHD, sensory stimuli can be either distracting or hyper-focused, university spaces need to be designed as sensory-friendly environments [72], optimizing the sensory environment and stimulus mitigation is recommended. Interventions focus on reducing ambient noise and visual clutter, providing controlled stimulation / quiet study areas. It is essential that lighting systems and classroom design are adjustable to optimally support concentration efforts.

Beyond physical adaptations and the application of the principles of Universal Design for Learning, it is imperative to develop and provide specific individualized supports. Students with ADHD particularly benefit from resources and accommodations tailored to their specific needs, which may include assistive technology, specialized mentoring, and flexible schedules. This complementary approach ensures that the built environment and pedagogical support work synergistically [71].

Going beyond strictly architectural aspects, it is necessary to create an ADHD-friendly institutional culture, which involves a concerted effort to raise awareness and training among all personnel (faculty, administrative staff, and students). Relevant ADHD education transforms the social and academic environment in an inclusive way. Adopting this vision promises not only to support the performance and well-being of students with ADHD, but also to improve the quality of the learning experience for the entire university population.

The integration of ADHD-friendly architecture and design principles is observed in kindergartens and schools and much less in universities, although the percentage of adults with ADHD is on average 5%.

Westmark Elementary School (NBBJ, Encino, California, 2024) is a model of good practice in this regard, being explicitly designed to reduce anxiety and stress in students with specific learning difficulties (dyslexia, dysgraphia) [73].

The project, with an area of 1,440 m2, is conceived as a "prototype" of design that supports distinct learning styles by including inclusive and natural elements. Formally, the building adopts a "U"-shaped plan, organized on two levels around a central interior courtyard. This open perimeter space is vital, as it hosts circular gardens and relaxation areas. The geometric configuration and integration of nature facilitate wayfinding and provide students with controlled opportunities for sensory regulation and emotional de-escalation, aligning directly with the need for a quiet space and an environment that minimizes cognitive overload.

Currently, there are very few examples of ADHD-friendly universities in terms of physical environment, most of them responding rather to special educational requirements. Two ADHD-friendly universities were identified, models of good practice, but rather at a declarative level.

6.3. Universities ADHD-friendly good practice examples

Currently there are few examples of ADHD-friendly universities from the point of view of the physical environment, most of them responding rather to special educational requirements / accomodations. Two ADHD-friendly universities were identified, models of good practice such as: University of Illinois- expansion and renovation of Turner Hall [1] and Shannon University of Technology (TUS)-Ireland [74].

The Turner Hall expansion from University of Illinois and renovation project, by Legat Architects (2020), is an effort to integrate design elements that are accessible to people with neurodevelopmental disorders into the university environment. The newly created spaces provide a high degree of visual order and utilize calm and balanced color palettes. These attributes help reduce excessive visual stimulation and support concentration [75]. However, from the analysis of the available data, it is observed that these spaces do not appear to be configured as completely enclosed or soundproof units. This architectural limitation contradicts the requirements of the enclosed/soundproof spaces principle, which is essential for minimizing peripheral auditory and visual distractions for students with ADHD.

Shannon University of Technology (TUS) has achieved notable recognition by being officially designated as an ADHD-friendly university by ADHD Ireland (2024). This achievement stems from the implementation of an ADHD-Friendly University Program that focuses primarily on awareness, understanding and practical strategies (programmatic support and accommodations) for students with neurodevelopmental disorders. Although TUS recently opened its new Coonagh campus, a 5500 square meters state-of-the-art engineering building, a detailed review of these facilities suggests that there is no extensive and explicit implementation of ADHD-friendly architectural principles in the physical design. Thus, the TUS model is a benchmark for institutional and pedagogical inclusion,

but it reflects the persistent challenge of translating physical design principles (as applied in pre-university education) into the complex university environment [76, 77, 78].

6.4. Neuro-arhi lab: the future of neuroarchitectural research in the context of neurodevelopmental disorders

In the context of the need to scientifically substantiate design solutions adapted to Neurodevelopmental Disorders, including ADHD, by understanding how the built environment influences cognitive performance, Neuro-Arhi Lab (NAL) is positioning itself as an essential research structure in Romania. Recently launched, in October 2024, within the "Ion Mincu" University of Architecture and Urbanism (UAUIM), NAL is an Applied Research Laboratory (Applied R+D).

The fundamental goal of NAL is to study the relationship between neuroscience and architecture/urbanism, focusing on how parameters such as light, space, shape, color and texture influence brain functioning, psycho-emotional state and human behavior [79].

This research direction is crucial for the development of ADHD-friendly spaces. The NAL structure is deeply interdisciplinary, being composed of architects alongside specialists from related fields, such as medicine, cinema and theather, mathematics, computer science and biophysics. This multidisciplinary composition gives the laboratory the capacity to generate validated knowledge and pertinent tools necessary for space creators to design environments that promote well-being, comfort and cognitive performance, including for populations with specific sensory requirements [80].

7. Implications

An ADHD-friendly educational space supports the management of symptoms of attention deficit, hyperactivity-impulsivity, and executive dysfunction in students with ADHD. Multisensory design helps support students with ADHD in completing tasks within curricular activities.

Specialized studies that involved dialogue with students with ADHD [81] highlight their needs in terms of adaptations to the physical environment, such as: improved lighting, workspaces without distracting elements, quiet areas, noise control, less crowded and overstimulating outdoor spaces on campus, furniture with sensors, diverse study spaces and not just positioned in the library, comfortable chairs so as to allow for a change of position and, possibly, mobility [68].

The management of ADHD in students requires a multidisciplinary and personalized approach, involving pharmacological treatment, psychological interventions and environmental adaptations. An ADHD-friendly university space effectively supports the transition period from adolescent to adult, is inclusive, supportive, using architectural tools and assistive technologies harmoniously and intelligently, in order to facilitate the performance and well-being of all users.

8.Value and conclusions

The management of ADHD in students requires a multidisciplinary and personalized approach [6], involving pharmacological treatment, psychological interventions and adaptations of the environment (accommodations). An ADHD-friendly university space effectively supports the transition period from adolescent to adult. To generate an ADHD-friendly educational environment- both for existing university buildings and for building ab initio)- the architect must collaborate with health professionals-psychiatrist, general practioner, psychologist, in addition to technical specialties. Students can be the best source of information for their needs, so architects must be open to the needs identified from discussions with students with ADHD and their parents, in a co-participatory design. An ADHD-friendly educational environment is inclusive, supportive, harmoniously and intelligently using architectural tools - light, shape, color, texture, sound - and assistive technologies, in order to facilitate the performance and well-being of all users.

Implementing a comprehensive vision of a "Smart ADHD-friendly university" (which combines architectural principles and inclusive design with digital assistive technologies), although essential for the academic performance of students with neurodevelopmental disorders (in this case, ADHD), represents a complex and sometimes costly challenge, especially in the context of Romanian institutions.

Internationally, universities with solid funding can allocate funds for architectural adaptations such as specialized ergonomic furniture, the integration of Smart HVAC systems and digital space management solutions, but in Romania, initiatives focus, for now, mainly on accessibility for physical disabilities and on counseling services.

Therefore, the transformation that also includes the high costs of integrating personalized Digital Assistive Technologies (DAT) and reconfiguring spaces requires not only a firm institutional commitment, but also complementary funding, being a significant challenge for the resources allocated from the current core funding of universities.

However, things must always be started in a hierarchical manner, priorities must be established and adaptations must be initiated in stages, according to the resources available. These adaptations should, however, be part of long-term university development strategies, inclusive universities, friendly to students with diverse abilities, both physical and mental.
The work has a pioneering character, addressing the interdisciplinary architecture-medicine topic of ADHD-friendly architecture.

Conflicts of interests

Authors have no conflicts of interest to declare.

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