Optimizing the Built Environment for Mental Health

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Abstract

Features of the built environment have the potential to either improve or worsen mental health. Here we review the research on how the built environment can promote this positive impact, organizing key principles into three categories, 1) User Experience, 2) Building Performance, and 3) Smart Systems. User Experience that enhances safety, community, and empowerment can improve mental health. Building Performance elements that support mental health include implementation of lighting, acoustics, and other features related to environmental comfort, while adhering to standards of health, safety, and energy efficiency. Smart Systems include the use of real-time monitoring and artificial intelligence (AI) interventions. For specialized mental health facilities, adaptive features are discussed, along with evaluation metrics. We also provide a brief outline of our pattern language, *La'i Community Standards*, formatting these features to ease implementation by the architect.

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1. Background

American Architect Shea Trahan said, "As architects, we design buildings that are de facto instruments". As instruments, he is referring to the impact of the building's design on its inhabitants. The built environment influences both physical and mental health (Beauchemin, K.M., & Hays, P. 1996, Even et al, 2008). This has been known for thousands of years, reflected in the Chinese concept of Feng Shui (*feng* 風 meaning "wind" and *shui* 水 meaning "water"). Feng Shui uses the arrangement of space to produce balance with the natural world.

Several features of the built environment may produce negative mental health outcomes, shown in a review of studies by Singh et al. (2019), with detrimental features relating to 1) negative perceptions of the physical space and 2) housing instability. Negative perceptions included experiencing reductions in physical space, exteriors with poor cleanliness or clutter, and general perceptions of poor housing quality. These were associated with depression and anxiety in adults and with aggression in children. Housing instability was described as fear of mortgage delinquency or eviction and was associated with increased mental strain, depression, and poor physical health.

In contrast, the features of a mentally healthy environment include elements that evoke a sense of safety and privacy (Pearson et al., 2021; Taylor et al., 2021; Zhang et al., 2022; Al Jowf et al., 2023). Mental health symptoms are also influenced by surface colors and patterns (Fisher et al., 2023; Montoya et al., 2023; Subramanian, 2023), the amount of relative natural light (Evans, 2003; Facer-Childs et al., 2019; Bertani et al., 2021), pleasant acous-

tic elements (Yang & Kang, 2005; Axelsson et al., 2010), and environmental comfort (Poortinga et al., 2017; Bernal, 2020; Engineer et al., 2021). The social aspects of community and equity also contribute to the occupant's perception of a space, along with relative ease of use (Evans, 2019; Fogle et al., 2020). Building performance, such as air quality and drinking water purity can also have effects on mental health (Wilson & Boehland, 2005; Wargocki & Wyon, 2007; Li, 2010; Jones, 2011).

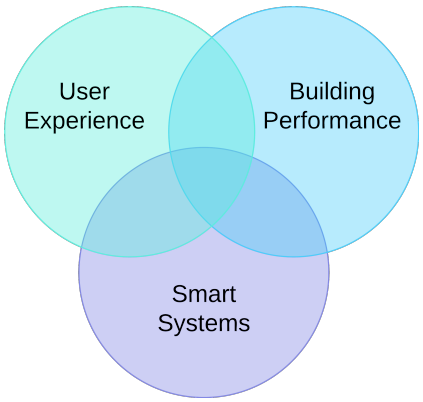

Figure 1: Conceptualization of the components impacting mental health in the built environment

In the pursuit of creating an optimal living space that supports mental well being, we have categorized the necessary spatial and supportive implementation strategies into three categories: 1) User Experience, 2) Building Performance, and 3) Smart Systems to monitor well-being and deliver effective interventions to maintain wellness. We also discuss modifications for special populations, such as those in mental health facilities, and include the evaluation of these spaces. We then conclude with an outline of our pattern language, *La'i Community Standards*, to give a general sense of the types of

patterns contained therein, although we must emphasize this is only an outline, so we refer the reader to the full *La'i Community Standards* document for implementation.

2. User Experience

User Experience relates to features of built environment that affect the feelings of the inhabitants in their day-to-day life. These include elements of safety, privacy, a sense of community, equity and empowerment, influence of the natural environment, and choice of surface patterns and colors. With thoughtful design, a home can serve as a retreat that promotes self-regulation and reduces anxiety.

2.1. Space, Safety, and Privacy

The experiences of space and spatial context have both conscious and unconscious effects on the human mind. One stark example is the *neighborhood deprivation effect*, which occurs in disadvantaged areas often characterized by poorly maintained housing and infrastructure and limited green spaces. These are generally urban spaces with higher levels of environmental noise, greater barriers to housing, and higher crime rates. Individuals living in these areas have poorer health outcomes, lower levels of mental well-being, and overall lower quality of life when controlling for other factors (Visser et al., 2021; Conley et al., 2023).

One's sense of safety in their environment, such as the perception of safety when walking during daytime hours, is a critical factor in both physical and mental health outcomes (Pearson et al., 2021; Zhang et al., 2022). This is especially true for those with a history of post-traumatic stress disorder

(PTSD) or other mental health problems, necessitating private, secure spaces in the built environment (Taylor et al, 2021; Al Jowf et al., 2023). Safety is a key feature of *trauma-informed design* which focuses on mentally healthy approaches to creating environments that enchance recovery. (SAMHSA, 2014; Owen & Crane, 2022). This is discussed in more detail in Section 5.1.

Principles of a Trauma-Informed Approach
1. Safety
2. Trustworthiness and Transparency
3. Peer Support
4. Collaboration and Mutuality
5. Empowerment, Voice, and Choice
6. Cultural, Historical, and Gender Issues

Table 1: SAMHSA's Trauma-Informed Approach (SAMHSA, 2014)

2.2. Community

A sense of community has significant psychological benefits, including reducing feelings of isolation, enhancing social support, and improving overall mental well-being (Evans, 2019; Fogle et al., 2020). Social settings offer opportunities for individuals to engage in meaningful interpersonal interactions, build relationships, and develop a sense of community (Joye, 2007). The presence of communal spaces in residential environments has been associated with increased life satisfaction, reduced stress levels, and improvement in other mental health outcomes (O'Brien & Godschalk, 2016). Such spaces also provide a platform for the implementation of various therapeutic

activities, group interventions, and social programs that promote resilience and support recovery (Gehl, 2013). By designing and incorporating well-designed communal spaces, residential settings can create environments that contribute to overall well-being.

2.3. Equity and Ease of Use

Recent studies indicate that principles of equity and ease of use can have significant effects on mental and physical wellness (Rollings & Bollo, 2021; Barnett et al., 2022). Equity in residential design goes beyond mere *accessibility* to encompass a broader range of inclusivity, ensuring that people of all ages, abilities, and backgrounds can comfortably inhabit a space (Angus et al., 2021; Krieger & Higgins, 2002). Strategies like Universal Design, community engagement, and affordable housing options can make homes more equitable, thereby promoting better mental health outcomes (Evans, Wells, & Moch, 2003; Manzo & Perkins, 2006; Steinfeld & Maisel, 2012). *Ease of use* focuses on the efficiency and intuitiveness of residential layouts and features, which can promote stress reduction (Guite, Clark, & Ackrill, 2006). Ergonomic design elements can minimize physical and mental strain, which can be seen via physiological measurements (Miles & Perrwé, 2011; Purnawati et al., 2016).

2.4. The Natural Environment

Research findings consistently support the preference for natural settings over hardscape, with reduction in perceived stress and and improved cognitive function (Stigsdotter et al., 2010; MacKerron & Mourato, 2013; Beyer et al., 2014; Bratman et al., 2015). Multiple researchers have investigated

the relationship between exposure to natural settings and cortisol, a human hormone associated with stress (Thompson et al., 2012; Roe et al., 2013; Gidlow et al., 2015; Kobayashi et al., 2017). Results have shown a significant inverse correlation, with cortisol levels declining throughout the day when individuals in urban settings are introduced to more greenspace. Even virtual representations of nature have been shown to reduce psychological stress (Hedblom et al., 2019).

The diminishing presence of green space in inner-city areas, replaced by hardscape, has produced challenges for urban planners and has shown increased performance errors, social incivility, and irritability (Kaplan, 1995). As a result, the World Health Organisation (WHO) has called on cities to create urban green spaces as a "necessary component for delivering healthy, sustainable, liveable conditions." (World Health Organization, 2016)

Technology-rich urban environments may incur cognitive costs that are more significant when there is limited exposure to natural green spaces (Thomée et. al, 2011, Berg-Beckhoff, 2017, Islam et al., 2022). This is especially true to groups of disadvantaged socioeconomic status (Maas et al., 2009). In a study conducted in Barcelona, Spain, Dadvand et al. (2015) investigated the impact of greenery on the cognitive abilities of 7- to 10-year-old school children. The study found that children exposed to more greenery, particularly in school environments and along their route to school, had better attentiveness and superior working memory on tasks. This group also found an association between greenspace near the home and perceived social support (Dadvand et al., 2016). However, the presence of greenery around the home may not be as influential as exposure to greenery within the school

or during commutes (Mooney, 2015).

2.5. Surface Patterns, Texture, and Color

Our sense of vision relies heavily on the characteristics of the surfaces that surround us. By reflecting light in different ways, surface textures and colors present their own reality to human perception. These differences serve as signals to our sense of vision, informing our interpretation of the world around us.

2.5.1. The Influence of Surface Patterns

Patterns have the ability to deceive our minds, as evidenced by optical illusions. Moreover, certain regular patterns can cause cognitive difficulties. Research suggests that highly repetitive patterns appearing with high regularity tend to capture our attention and consume significant cognitive capacity (Wilkins, 1995, 2018; Fisher et al., 2023; Montoya et al., 2023; Subramanian, 2023).

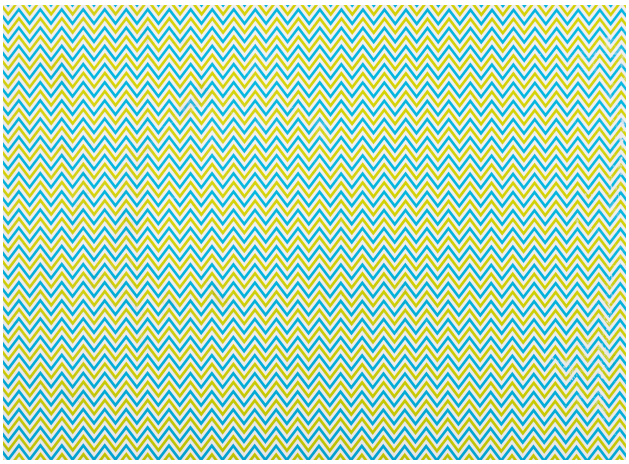

Figure 2: Repeating patterns can cause cognitive “noise”

A pattern that repeats three times within a single degree of our visual field has the highest potential to be perceived as unwanted noise. This is the equivalent of about 1.8 cm in width when viewed from 1 meter. Additionally, patterns with higher color or tone contrast are even more likely to be perceived as having visual noise. Avoiding highly repetitive visual patterns is therefore an important consideration in the design of built spaces.

2.5.2. Color

While the exact effects of different colors are still a subject of debate, there is evidence that certain pallettes have an impact on mental health. In a study across of over 4000 individuals, representing 30 different countries and 22 languages, Jonauskaite et al. (2020) showed the universal impact of color on mood, with similarity among emotions and colors, although there is variation by region.

Red	68% associated red with love
Yellow	52% associated yellow with joy
Black	51% associated black with sadness
Pink	50% associated pink with love
Orange	44% associated orange with joy
White	43% associated white with relief
Green	39% associated green with contentment
Brown	36% associated brown with disgust
Blue	35% associated blue with relief

Table 2: Color Associations with Mood (Jonauskaite et al. 2020)

In other studies, vibrant reds and yellows are often associated with danger

and have been associated with greater intensity of motor responses (Elliot et al, 2011). The stress-inducing properties of the color red have also been associated with a 20% decrease in IQ test performance (Elliot et al., 2007). Green and blue are abundant in areas where human populations tend to congregate and have demonstrated positive impacts on mood compared to reds and grays (Akers et al., 2012; Pearson et al., 2019). The Natural Color System can aid in selecting harmonious and contrasting colors, assuming the user has sight or the capacity to detect color differences (López et al., 2019; Wang et al., 2022).

3. Building Performance and Space Quality

The choices made in construction or renovation of the built environment have the potential to support mental and physical well-being. Key factors such as light, acoustics, environmental comfort, and the choice of building materials play a crucial role in shaping the impact of the living space on its occupants.

3.1. Light

Light is essential to life on Earth and has a number of effects on the human brain and behavior. Light plays a critical role in our mental and physical health by influencing our internal biological clocks, or circadian rhythms. The primary brain structure involved in this process is a small region in the brain known as the suprachiasmatic nucleus (SCN). The SCN signals the pineal gland to produce melatonin when it is dark, and to stop production when it is light, thereby helping to regulate our sleep-wake cycle (Gaggioni

et al., 2014). Light exposure also has an influence on mood and human performance (Evans, 2003; Facer-Childs, et al., 2019; Bertani, et al., 2021).

3.2. Acoustic Environment

Acoustic design considerations include managing both interior and exterior noise. Enhancing privacy includes effective soundproofing to prevent external noise, protecting confidentiality in therapeutic spaces, and providing a sense of peace and security. In addition to soundproofing materials and techniques in construction, music or white noise machines can also help the experience of privacy (Hosford, 2016). It has been suggested that some sounds, such binaural frequencies, may have a direct physiological effect on brainstem activity (Laumen et al., 2016).

Sound and acoustics in various environments impact human perception, communication, and well-being. While we have the ability to close our eyes or avert our gaze to control visual stimuli, it is more challenging to filter out auditory stimuli. The auditory sense plays a crucial role in detecting danger, even when we are asleep or unable to see, and is considered important for individuals who seem disconnected from the world, such as those with hearing loss who are asleep (Clarke et al., 2019) or patients in a coma (Aellen, 2023).

Singing and music have an effect on well-being, bonding, stress reduction, and memory recall (de Witte, 2022). The ideal environment involves considering both calm and stimulating acoustics. Calm environments should minimize noise sources, achieve a balance between sound attenuation and reflection, and ensure clear interpretation of sound and speech. On the other hand, stimulating environments are essential to prevent an absence of sound, as complete silence can be challenging for functioning (Pasupathi & McLean,

2010). The role of acoustics also has an influence in landscape design, which may include utilizing water features, rustling leaves, or bird sounds (Yang & Kang, 2005; Axelsson et al., 2010).

3.3. Environmental Comfort and Safety

Numerous standards exist for environmental health and safety and these also have an impact on mental health. Environmental standards, such as Leadership in Energy and Environmental Design (LEED), may improve mental health outcomes (Breysse et al., 2015; Hoisington, 2024).

3.3.1. Thermal Comfort

Thermal comfort is another important factor in mental well being; temperatures that are too high or too low for comfort can have a negative impact on an individual's mood, making them feel more agitated or depressed (Nicol, Humphreys, & Roaf, 2012). Improving thermal comfort and ventilation has the potential to improve mental health outcomes (Poortinga et al., 2017; Bernal, 2020; Engineer et al., 2021).

3.3.2. Non-Toxic Building Materials

The use of non-toxic building products has garnered attention for its potential impact on mental health, largely due to the role of indoor air quality and exposure to harmful substances.

Traditional building materials often contain volatile organic compounds (VOCs) and other toxic substances that can off-gas into indoor air (Jones, 2011). Prolonged exposure to these substances has been linked to a range of health issues, from respiratory problems to neurological effects, including cognitive impairment, headaches, and fatigue (Wargocki & Wyon, 2007).

Research indicates that improving indoor air quality by using non-toxic or low-VOC building materials can have a positive effect on mental well-being. For instance, a study by Allen et al. (2016) found that occupants in "green" buildings, built with non-toxic materials, scored 26.4% higher on cognitive function tests compared to those in conventional buildings. The use of natural materials like wood has been shown to reduce stress and improve mental health (Tsunetsugu, Miyazaki, & Sato, 2007). Wood emits natural compounds known as phytoncides, which have been demonstrated to reduce stress hormones, lower anxiety, and improve mood and concentration (Li, 2010). The psychological impact of knowing one's environment is built from sustainable, non-toxic materials can also contribute to a sense of well-being and reduce anxiety related to health concerns (Wilson & Boehland, 2005).

3.3.3. Energy Efficiency and Mental Health

The intersection between energy standards in building and mental health is an emerging area of interest that underscores the interplay between sustainable design and human well-being. Energy-efficient buildings often employ technologies and designs that not only reduce energy consumption but also create a more healthful indoor environment (Afkhamiaghda et al., 2017). For instance, better insulation and window designs not only conserve energy but also mitigate noise pollution, which has been linked to stress and poor mental health (Stansfeld & Matheson, 2003).

Moreover, energy-efficient buildings often incorporate natural lighting to reduce electricity costs. Natural light exposure is crucial for regulating circadian rhythms, which in turn affects mental health (Facer-Childs et al., 2019; Killgore et al., 2020;). Poorly regulated circadian rhythms can lead

to sleep disturbances, exacerbation of mood disorders, and cognitive impairments (Figueiro et al., 2016, 2017). These problems can also be reversed with proper lighting (Figueiro et al., 2017; Facer-Childs et al., 2019)

Ventilation is another key element in energy-efficient buildings with positive mental health impact. Improved ventilation systems not only reduce energy consumption but also improve indoor air quality (Wargocki, Wyon, Baik, Clausen, & Fanger, 1999). Poor air quality has been linked to various mental health issues, including cognitive decline and increased rates of depression (Allen et al., 2016).

The use of sustainable, non-toxic materials in energy-efficient buildings further contributes to mental health, as discussed in the previous section. Green building standards like LEED and Living Building Challenge, thereby not only improve energy efficiency but also create healthier living environments (Wilson & Boehland, 2005).

4. Smart Systems and Mental Health

The advent of smart systems has opened up unprecedented opportunities for enhancing mental health care, offering a fusion of technology and psychology that promises to revolutionize both diagnosis and treatment. The integration of smart home technologies can be used to create more efficient and stress-free living environments, although such features must be universally accessible to avoid inadvertently marginalizing certain groups (Balta-Ozkan et al., 2013). At the heart of this transformative power is the ability to continuously monitor individuals in unobtrusive ways, enabling timely interventions and personalized care. Several key components of smart systems offer

opportunities to monitor and improve mental health, ranging from passive sensors and ambient soundscapes to sophisticated feedback loops powered by artificial intelligence.

4.1. Passive Sensor Design

Passive sensors, using wearable devices or embedded in the built environment, offer the ability to gather data on various physiological and environmental parameters. From tracking heart rate variability (an index of stress) to monitoring sleep quality and movement, these non-intrusive sensors provide real-time insights into an individual's mental state without requiring active engagement (Kumar et al., 2013).

4.2. Ambient Sound Design

Ambient sound design is another significant area of interest; by reducing unwanted noise and by incorporating pleasant sounds (or even white noise), environments can be created that are more conducive to mental well-being. Sounds have been shown to influence mood, stress levels, and even cognitive performance, making them a vital element in a holistic approach to mental health (Boyce, Hunter, & Howlett, 2003; Yang & Kang, 2005; Axelsson et al., 2010).

4.3. Electronic Assessment and Intervention

Ecological Momentary Assessment (EMA) is a real-world data collection technique that captures individuals' mental states and behaviors in real time. This method permits a nuanced understanding of mental health in the context of daily life, thereby overcoming the limitations of traditional, episodic

assessments (Faurholt-Jepsen et al., 2015). EMA has been delivered through connected smart devices, but may also be placed as a fixture within the built environment.

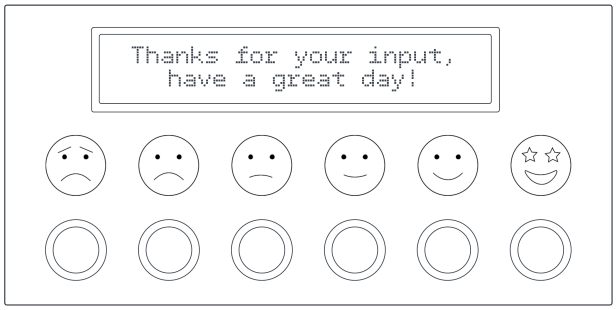

Figure 3: Example of a Push-Button EMA Interface, La'i Communities, Patent Pend.

Lastly, artificial intelligence (AI)-based feedback loops promise to tie these elements together by analyzing the multifaceted data to provide actionable insights. Whether it's identifying patterns that may signify the onset of a depressive episode or offering adaptive coping strategies, AI algorithms are becoming increasingly proficient at providing real-time, personalized guidance (Martínez-Pérez et al., 2015; Ebert et al., 2019; Zhou et al., 2022; Sharma et al., 2023).

By integrating these components, smart systems hold the potential to reshape the landscape of mental health care, offering more adaptive and responsive systems within the built environment.

5. Special Considerations for Cognitive and Mental Disorders

Special considerations in the design of residential space include factors that may influence the resident negatively or positively, as a result of trau-

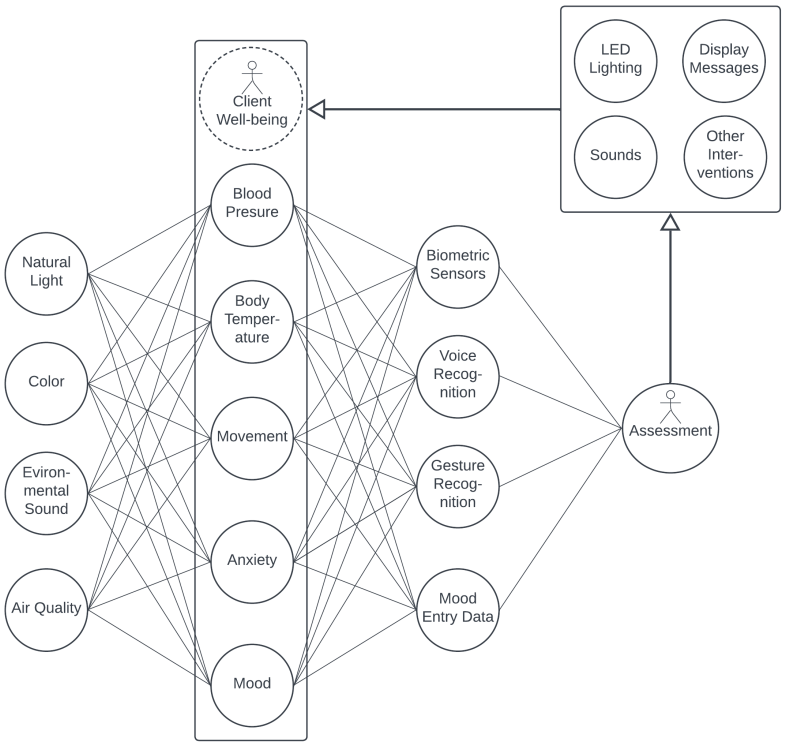

Figure 4: AI Implementation Design, La'i Communities, Patent Pend.

matic experiences, cognitive impairment, mood, or other psychiatric disorders. For those with a history of psychological trauma, a primary goal is to promote a sense of safety and reduce hyperarousal. For those with cognitive impairment, key considerations involve supporting one's orientation in space and time. Mood disorders are especially susceptible to changes in light intensity, while a variety of different psychiatric disorders are impacted by under-, over-, healthy, or unhealthy socialization. For specialty healthcare settings, all of these factors become important as they are often congregate living settings.

5.1. Trauma-Informed Design

It is estimated that over 70% of adults worldwide have experienced some form of psychological trauma (Benjet et al., 2016). Highest rates of trauma are experienced among military veterans (Nash & Watson, 2012), those who have lived through civil war (Betancourt & Khan, 2008; Steel et al., 2009), survivors of natural disasters (Norris et al., 2002), victims of domestic violence (Warshaw et al., 2009), refugees and asylum seekers (Porter & Haslam, 2005), and children in foster care (Pecora et al., 2006). For those who have experienced trauma, a state of hyperarousal produces highly sensitive responses to triggers, which may include overstimulation due to bright light or glare, loud noises, limited access to exits, and even clutter or busy patterns (Bayramzadeh et al., 2021). Among those who have experienced Adverse Childhood Experiences (ACEs), trauma-informed approaches can reduce symptoms (Tabone et al., 2023). Design considerations include how elements in the built environment impact arousal, perception of safety, and perceived social support and empowerment, with many of these concepts contained in SAMHSA's *Concept of Trauma and Guidance for a Trauma-Informed Approach* (SAMHSA, 2014).

Trauma-Informed Design (TID) is an emerging field that brings together insights from psychology, neurobiology, and architectural design to create spaces that promote healing and well-being for individuals who have experienced trauma (SAMHSA, 2014; Samuelson et al., 2017). Ajeen et al. (2023) found that trauma-informed design in homeless shelters produced statistically significant results when comparing pre- and post-surveys. Tabone et al. (2023) found that using a trauma-informed approach called the Attachment,

Self-Regulation, and Competency (ARC) framework, children who experienced up to six ACEs showed reduced symptoms (although these effects lessened with seven or more ACEs). In a review of case studies from trauma-informed design in permanent supportive housing, Bollo & Donofrio (2022) discovered four common features of effective TID:

1. **Common Areas** - Common areas, including multiple small areas, that maximize resident choice and safety
2. **Spatial Separation and Visual Connection** - Separate spaces with walls connected by interior windows to provide safety
3. **Central passageways** - such as a central stairway, to encourage social engagement
4. **Places for Personalization** - Design places that provide empowerment and resident voice

By making conscious design decisions, housing that is optimized for those who have experienced trauma has the potential to improve outcomes over and above the specific treatment modalities used.

5.2. Cognitive Impairment

The built environment can significantly influence the well-being of individuals with cognitive disorders, including dementia (Alzheimer's and other types), autism, ADHD, and various encephalopathies, among others. The design of buildings and spaces can either support cognitive functioning and independence or exacerbate cognitive challenges (Schilling et al., 2003; Zeisel et al, 2003; Mostafa, 2008; Fleming & Bennett, 2017).

5.3. Mood Disorders

Approximately 20.8% of the general population experiences a mood disorder in their lifetime, with 46.4% experiencing any mental disorder (including anxiety disorders, 28.8%, impulse control disorders, 24.8%, and substance use disorders, 14.6%). These disorders can be heavily influenced by the built environment (Billings et al., 2020; Reichert et al., 2020). The design of interiors and exteriors (especially the design of natural and artificial light sources) may significantly impact stress levels, mood, sleep, and overall mental health.

5.3.1. Other Psychiatric Disorders

Individuals with psychotic disorders (including schizophrenia) may benefit from environments that are calm, predictable, and provide opportunities for social interaction. (Lovell et al., 2015). For those with eating disorders, spaces that are calm, not overly crowded, and provide privacy can create a more comfortable dining experience (Proaño et al., 2017).

This document does not cover an exhaustive list of all the potential disorders that may benefit from specialized design, but the preceding features, and those that follow, provide a core set of features that are generalizable to the most common mental health conditions.

5.4. Spaces for Personal Reprieve and Creativity

Spaces for wellbeing, focusing on reprieve, art, and creativity, employ the therapeutic benefits of artistic expression (Stuckey & Nobel, 2010; Kaimal et al., 2016). Artistic activities foster self-esteem, relaxation, mindfulness, and social connections (Kaimal et al., 2017; Malchiodi, 2019). Designing spaces for art involves equipping areas with appropriate materials and collaborating

with professionals, such as art therapists, occupational therapists, and others. These spaces are enhanced by soothing colors, comfortable seating, and natural light. Implementation includes assessing needs of the stakeholders and continuous evaluation and adaptation to maintain the effectiveness of these spaces.

5.5. The Personal Dock - A Space for Organization

Optimizing mental health through the built environment involves creating spaces that enhance personal organization, habit formation, and promote independence. Incorporating features like compact desks, dry erase calendars, and medication dispensing systems in a personal docking station assists in managing daily routines, supporting memory, and reducing stress (Cutrona et al., 2019; Wolf et al., 2019). Integrating technology like simplified display screens supports memory and communication, especially for those with cognitive impairments (Petersen et al., 2016; Schmitter-Edgecombe et al., 2017). Personalization options in these stations enhance the sense of control and autonomy. Such interventions are adaptable across various mental health settings, from healthcare facilities to senior living communities, and are particularly beneficial for individuals with cognitive or memory impairments (Nasreddine et al., 2017; Baker et al., 2019).

6. A Pattern Language for Mental Health

In his 1977 book, "A Pattern Language: Towns, Buildings, Construction," architect Christopher Alexander popularized the concept of the *pattern language*, a structured and integrated method of describing good design practices. By organizing patterns into a hierarchical structure, the pattern

language enables designers to solve complex problems by combining individual patterns in a language-like syntax, facilitating a stepwise and comprehensive approach that meets the unique demands of individual projects. In order to effect the principles described herein, La'i Communities has created a new pattern language to optimize residential settings for behavioral health outcomes. These are contained in the *La'i Community Standards* (Martinez et al., 2024). Here we briefly summarize the components of this pattern language as an expository presentation of the basic components.

6.1. Organization of the Pattern Language

The standards that make up the following pages are divided into sections A-E. The criteria in Section A relate to the user experience and well-being. The patterns in Section B relate to building performance, such as lighting, ventilation, and other factors in the built environment related to health and safety. Section C relates to Smart Systems to impact mental health. Together, Sections A-C comprise the general pattern language for optimizing mental health that is suitable for a variety of residential settings. Section D has specialized patterns for mental health settings. Lastly, Section E contains assessment protocols to evaluate the success of implementation.

6.2. Section A. User Experience and Well-being

The patterns in Section A include considerations of the individual user experience, including perceptions of safety and privacy balanced with community and social interaction. Elements from the natural world and the surrounding environments are considered, as are textures and color-choices.

Section	Topic Area
A.	User Experience and Well-being
B.	Building Performance
C.	Smart Systems
D.	Special Considerations
E.	Assessment

Table 3: Pattern Language Sections - A, B, and C are the core sections, while D and E relate to specialized mental health facilities

The user's experience with personal organization and ease of use also impact well-being. Finally, the last pattern in Section A describes spaces for personal reprieve and creativity.

A1. Safety - Implements measures to enhance building safety (fire, windows, etc.) and personal safety (lockable spaces, etc.)

A2. Privacy - Includes visual privacy, sound control, and other confidentiality measures

A3. Communal Space - Promotes community and healthy interactions, while balancing the need for privacy

A4. Natural Connection - Uses the concept of Biophilia to bring natural design elements indoors and out

A5. Texture and Color - Using color hue and nuance to reduce behavioral activation

A6. Personal Dock - Important for orientation and accessibility

A7. Ease of Use - Wayfinding, flexibility, and accessibility are key features

A8. Spaces for Art, Rest, and Wellness - Allow for personal creativity and community engagement

6.3. Section B. Building Performance for User Wellness

Patterns in Section B include elements of building performance that have an influence on mental health, including lighting, acoustic comfort, thermal comfort, non-toxic materials, air and water quality, and energy efficiency.

B1. Lighting for Impact - Includes light frequency, temperature, intensity, and glare

B2. Acoustic Environment - Describes acceptable levels of mechanical sounds, sound masking, reverberation, and acoustic separation

B3. Thermal Comfort - Describes features for floors, insulation, skylights, etc.

B4. Materials - Includes a list of nontoxic materials and uses a Circular Economy

B5. Air Quality - Considerations for HVAC, ventilation, air exchanges, VOC monitoring, and cleaning routines

B6. Water Quality - Including drainage, building protection, irrigation, and drinking water quality and monitoring

B7. Energy Efficiency - "Zero Ready" designs, Grid Harmonization, high efficiency protocols and resident training

6.4. Section C. Smart Systems

Patterns in Section C describe the design standards for non-intrusive sensors for monitoring mental health and identifying behavioral patterns while prioritizing the individual's privacy and comfort. Section C also includes a description of *soundscapes*, including those inspired by nature and "spa" environments, which have the potential to reduce stress, promote relaxation, and enhance well-being (Annerstedt et al., 2013; Nilsson et al., 2010).

In addition to the passive sensors that detect behavioral patterns, Section C also describes the use of client-entered rating data through the use of Ecological Momentary Assessment (EMA). EMA involves the collection of repeated measures and observations of individuals' behaviors, experiences, and psychological states in their everyday lives.

These data are used to train artificial intelligence (AI) models, by correlating the passive sensor data and the client input through EMA. AI can thereby be used for 1) Assessment of the current mental state from passive sensor data, and 2) Feedback interventions to support mental health. For example, the system may be trained that loud sounds in the environment trigger anxiety for the client, especially in the evening hours. The feedback intervention may be to introduce nature sounds to mask the environmental noise, allowing for better sleep.

C1. Non-intrusive Sensor Design - For biometric monitoring, ambient light and sound, and environmental quality

C2. Soundscape Design - Model for electronics, control, speaker placement, etc.

C3. EMA and User Interface Design - Thoughtful designs for the best possible user experience and funtionality while measuring mental health in real-time

C4. Artificial Intelligence Feedback Loop - Evaluation and intervention, infrastructure,424-240-8511 and algorithms

6.5. Section D. Special Considerations

The patterns in Section D include designs for mental health and other congregate settings and list design considerations for those with cognitive or mood disorders.

D1. Residential Mental Health Facilities - Including special needs for safety, privacy, therapeutic spaces, and sensory features

D2. Designing for Cognitive Dysfunction - Simplifying designs and wayfinding, enhancing safety, and promoting orientation and memory support

D3. Designing for Mood Disorders - Including lighting and safety measures, evaluation methods

6.6. Section E. Assessment

The patterns in Section E explain the process to measure the impact these designs are having in the resident population. Pattern E1 (Existing Condition Assessment) and E2 (Post-Occupancy Assessment) may be used

in either mental health or non-specialized facilities. The final two patterns E3 and E4 are aimed at assessing specific mental health needs and mental health impact, respectively.

E1. Existing Condition Assessment - Evaluation of building performance measures, accessibility, planning, and safety

E2. Post-Occupancy Assessment - Accessibility, functionality, environmental monitoring, system maintenance, with user feedback and improvement planning

E3. Mental Health Needs Assessment - Stakeholder review of demographics, needs, costs, and ongoing expenses

E4. Assessing Mental Health Impact - Using physical and behavioral measurements, with standarized tools

7. Conclusion

With the potential for the built environment to improve mental health outcomes, an opportunity exists for thoughtfully designed communities that empower their inhabitants. Having a pattern language that overlaps significantly with other building standards, the architect may easily employ its syntax to achive these aims. We are also in the midst of rapid development of smart technologies and AI, with the potential to enhance mental health even more. For more information about the *La'i Community Standards*, please contact Jeremy D Martinez, MD at jdmartinez@laicommunities.com.

LA'I COMMUNITY STANDARDS

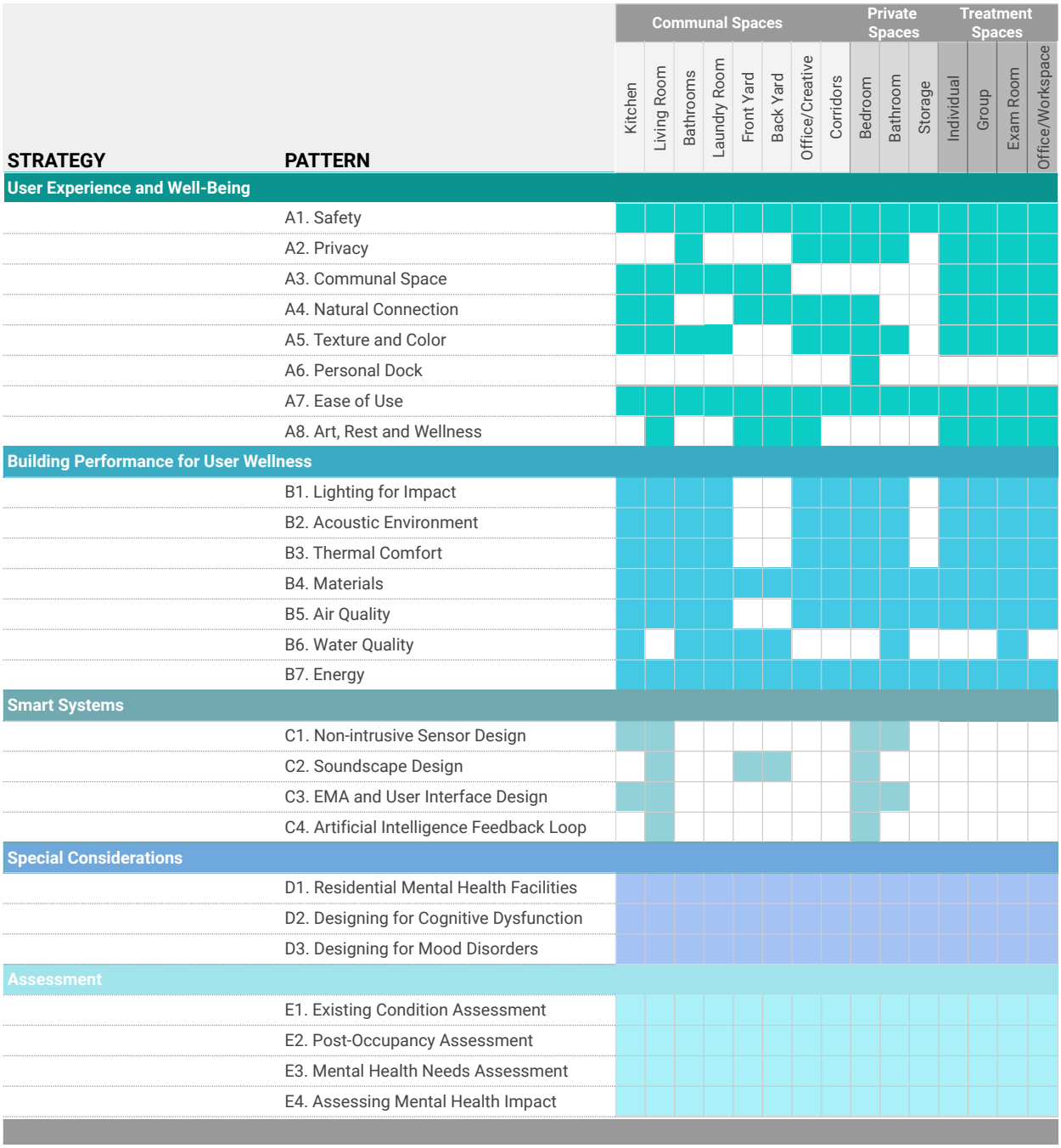

Figure 5: La'i Community Standards Checklist

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