Exploring a Sustainable Building's Impact on Occupant Mental Health and Cognitive Function in a Virtual Environment

MING HU
University of Maryland

MADLEN SIMON
University of Maryland

SPENCER FIX
University of Maryland

EDWARD BERNAT
University of Maryland

ANTHONY VIVINO
University of Maryland

Keywords: EEG, sustainable building, conventional building, virtual reality, cognitive load

The objective of this experimental project is to develop, test, and validate a data-driven neuroscience approach, using virtual environments with electroencephalogram (EEG) and event-related potential (ERP) approaches. The goal is to provide objective neurophysiological information about how people respond to built environments and how sustainable buildings (SBs) impact people differently compared to conventional buildings (CBs). The hypotheses are centered on assessing for increased visual engagement with the SBs (views of external natural environment and internal spatial arrangement). The core framework is based on the idea that greater engagement with the built environment will enhance mindfulness (greater focus on the present environment), which will reduce stress and increase engagement with present-focused tasks. We employed both conventional time-domain and more advanced time-frequency analyses to assess brain activity while participants engaged in the environments.

1.0 INTRODUCTION

Given that Americans spend about 87% of their time inside buildings, the quality and design of buildings are important contributors to human well-being [1]. The trend in sustainable building (SB) models, catalyzed by the founding of the Green Building Council in 1993, offers a unique opportunity to leverage not just beneficial environmental effects but also occupancy well-being effects in the design and construction of new buildings. Case studies have consistently demonstrated the potential for sustainable buildings to increase "soft" benefits of improved well-being and productivity via surveys (self-reported assessments). Current building impact evaluation tools that measure occupants' well-being and cognitive functions are user response surveys, such as a health and work performance questionnaire and various building wellness surveys. Surveys have two main weaknesses. First, as there are many variables affecting an occupant's response to the built environment, such as familiarity with the space, time of day when the survey is conducted, and the ambient condition of the environment (e.g., temperature, smell, noise), confounding non-design factors can be hard to disentangle, to control for, and to interpret. Second, the survey response is an indirect measure of the environment, reliant on the user's opinions (perceived likes and dislikes) and cannot provide objective data about particular environments and features. What is needed are consistent, reliable, and physiologically based measures of mental health effects that capture human response to discrete architectural elements – especially in the pre-build design phase. In order to have such a reliable measurement, an innovative approach is needed.

Substantial evidence now indicates that exposure to natural environments provides health benefits, including stress reduction as well as an increased positive attitude towards resource conservation [2,3]. Sustainable building design has focused on incorporating external views of nature, appropriate internal spatial dimensions and visual connections, and key aspects of resource conservation. However, there has been little empirical work to assess the impact of these design features on occupant stress, behaviors, and attitudes. The perspective taken in this work, consistent with emerging literature, is that SBs may convey benefits similar to nature exposure, and that these benefits can be understood relative to a mindfulness framework. We employ a narrow definition of mindfulness in this work, meaning a greater focus on the present moment through greater engagement with the built environment and activities occurring in it. This is consistent with the core aspects of mindfulness as defined across current theories [1-3].

The objective of this experimental project is to develop, test, and validate a data-driven neuroscience approach. The present study utilized virtual environments and electroencephalogram (EEG) and event-related potential (ERP) approaches, to provide objective neurophysiological information about how sustainable built environments impact affective and cognitive functioning in building occupants. The goal is to assess the

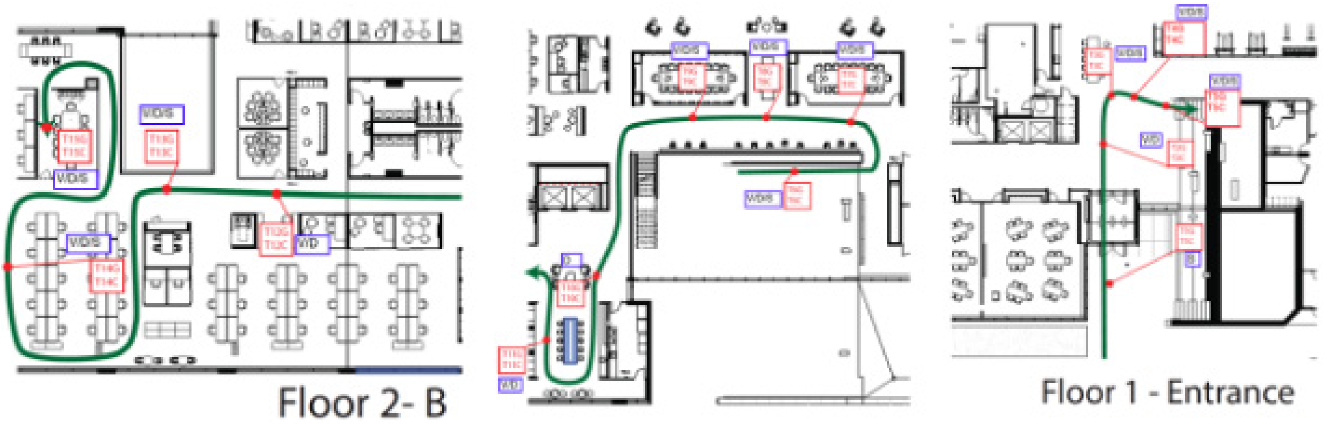

Figure 1.Walk-through routine in virtual environment.

validity of sustainable building design protocols in promoting and increasing mental health and well-being and the mechanism used to accomplish these increases. To this extent, there were two hypotheses tested using the combined virtual environment and EEG/ERP approach:

Hypothesis 1: Compared to CBs, occupants will respond to SBs with higher engagement, particularly to the sustainable visual stimuli; hence, SBs are associated with increased visual system engagement compared to CBs.

Hypothesis 2: Compared to CBs, SBs will exhibit modulated attentional focus and control processing.

2.0 THEORETIC FRAMEWORK AND SIGNIFICANCE

2.1 THEORY AND BACKGROUND

Our methodological framework is based on the combination of an EEG/ERP neuroscience approach and cognitive load theory (CLT). ERPs are very small voltages generated in the brain structures in response to specific events (stimuli) [4]; ERPs occur or are absent during an event. An event is a time period of interest, and in a visual environment, an event could be exposure to different visual stimuli, such as an image, a word, a sign, a tree, or light from outside. An EEG device is used to measure ERPs that demonstrate brain activity directly related to a specific stimulus. The continuous EEG/ERPs are particularly appropriate for recording buildings' impact on humans, since an occupant's experience, perception, and response to a building is the accumulation of that person's entire experience inside of the building. A building is composed of multiple spaces, so the continuous measurement of brain activities could provide us with more accurate insight of a building's impact. CLT was initially developed by John Sweller while he was studying problem-solving in 1988 [5]; other researchers built upon his theory and further developed the CLT model. CLT is a theoretical framework based on previous knowledge of human cognitive architecture in the brain [6], which includes long-term memory and working memory. CLT comprises two types of cognitive loads: intrinsic load and extrinsic load [7], with intrinsic load defined by the nature of the task itself, and extrinsic load determined by the way in which the task is presented [1,4], including in which type of environment the task is presented. Plass and Van Merriënboer proposed a CLT model in 1994 [8] and revised it in 2014 to include a "physical learning environment," which is disentangled from "learning tasks" and "learning environment" in order to describe the physical characteristics of the built environment in which cognitive tasks (such as learning) happen [9,10]. They recognized the importance of studying the causal effect of the physical built environment on cognitive load based on the findings of the physical environment on behavior, performance, and attitude in a learning environment [11,12,13,14]. According to Plass and Van Merriënboer, the physical environment characteristics include volume, density, lighting, spatial arrangement, and the presence of other people, and it is not easy in research to distinguish those physical learning environments from the learning task itself [15]. Recently developed novel technology, such as VE, is useful to help in disentangling those variables.

In this study, we used three sustainable built environment parameters as the design basis for testing our hypotheses: lighting, view, and spatial arrangement. All three characteristics are required design elements in the most commonly accepted and utilized "green building" design guidelines and rating systems; namely LEED, WELL, and the Living Building Challenge. Appendix A lists the requirements extracted from those design guidelines for the three parameters.

3.0 METHOD AND MATERIALS

3.1 EXPERIMENTAL STIMULI: SIMULATED VIRTUAL ENVIRONMENT

In 2018 and 2019, the research team conducted experiments using the three SB parameters (lighting, view, spatial arrangement) with 36 participants. Two different models of the same three-dimensional virtual building were built by using Autodesk Revit software to construct SB and CB designs.

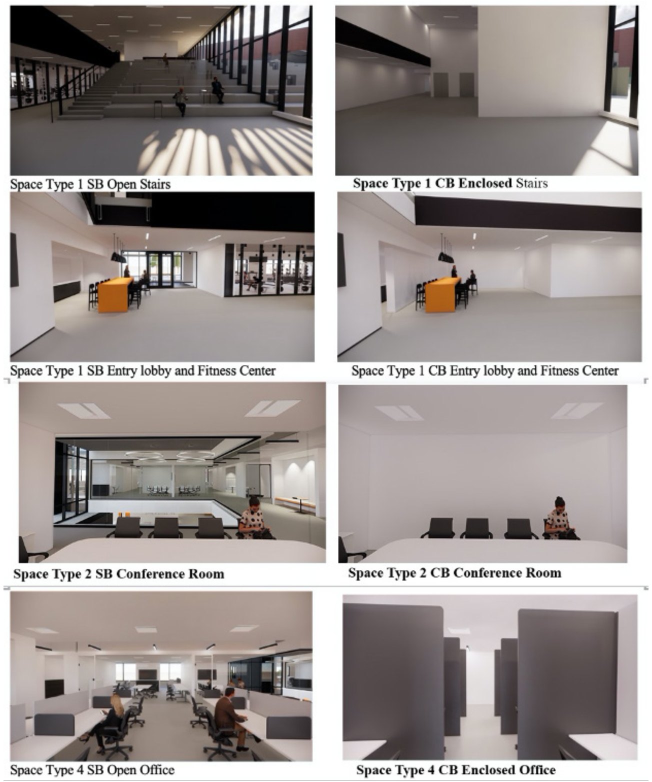

Figure 2.Virtual environments of the SB and CB designs.

These were then rendered using the plug-in virtual reality tool, Enscape, into two "real time" virtual buildings/designs for use in the experiment. The simulated environment consisted of a two-story building composed of four different spaces: (1) public: an entry lobby and open staircase, (2) semi-public: a collaboration space, a conference room, and an open kitchen; (3) semi-private: a fitness center and a conference room in an open office; (4) private: an individual working space. When the participants were in the virtual environment, a "preset walk-through" allowed them to get comfortable with the equipment and the experience. Figure 1 illustrates the floor plan with a walk-through route, and the locations where the participants stopped and looked around in the virtual environment. These stop locations were preset. They first entered through the building lobby, then walked up to the second floor's open office area through a large open staircase. During the two-floor tour, they encountered the fitness center, the open kitchen, the collaboration space, and conference rooms.

Three major changes were made in the CB design to differentiate it from the SB environment: (i) public space: the large open staircase in the lobby was replaced by two conventional elevators and a small enclosed staircase; (ii) semi-public: all open breakout spaces, the kitchen, and the collaboration area were enclosed by solid walls to block the views into the semi-public spaces; (iii) semi-private: the glass walls of the conference and fitness center were replaced with solid dry wall to block natural daylight and the view to the outside; (iv) private: the open floor working area was replaced by individual cubicles with high partition walls, removing the visual and verbal connections between different working stations. The differences in the four space types between the SB environment and control CB environment are illustrated in Figure 2.

3.2 PARTICIPANTS

Thirty-six undergraduate students were recruited through the psychology subject pool or the community, with each receiving either course credit or fifty dollars for their participation. They were recruited between August 2019 and February 2020. Nine of the participants were women. The age range was 17–23 years, with a mean of 18.41 (S.D.=1.28), and all reported no history of neurological or mental abnormalities. The study protocol was reviewed and approved by the Institutional Review Board of the University of Maryland.

3.3 EXPERIMENT PROCEDURE AND ENGAGEMENT TASKS

This study the two-step experiment procedure that was developed for measuring experiences of both buildings, employing a video and still images. In total, 45 still images and a five-minute video were created for the SB and CB designs, respectively; test subjects spend 25 minutes in each building. With sensor placements, task practice, and acclimation to the virtual viewing, one subject testing took less than 1.5 hours. To allow utilization of both continuous and event-related EEG/ERP analytic methods, for which there is a large research base to draw inferences from, the present study employed both still images (event-related) and movies (continuous). The movie was presented first, to familiarize the participant with the built environment. Participants were asked to simply view the building as they were moved through the building's environment. Analytic approaches were aggregated across the entire movie. Next, we presented still images from the movie of key points along the path (see figure 2). Analytic approaches focused on event-related (i.e., ERP) approaches to infer activity.

Figure 3a shows how the EEG/ERP data was recorded while testing subjects were viewing the video and still images. Figure 3b illustrates the testing conditions: test subjects wore an EEG cap (104-channel (96-ch EEG) BrainProducts Actichamp active electrode systems).

3.4 DATA COLLECTION AND PREPROCESSING

Data collection was conducted in a dimly lit, sound-attenuated room. Experimental stimuli were presented on a 24-inch Dell high-definition LED color monitor, centrally placed at a viewing distance of 100 cm, using E-Prime version 2.0. Data was recorded using a BrainVision 96-channel actiCAP (sintered Ag-Ag/Cl; 10-20 layout) as well as a 96-channel actiCHamp amplifier (EASYCAP GmbH). Horizontal electrooculogram activity was recorded from electrodes on the outer canthus of both eyes, while vertical electrooculogram activity was recorded from electrodes placed above and below the left eye.

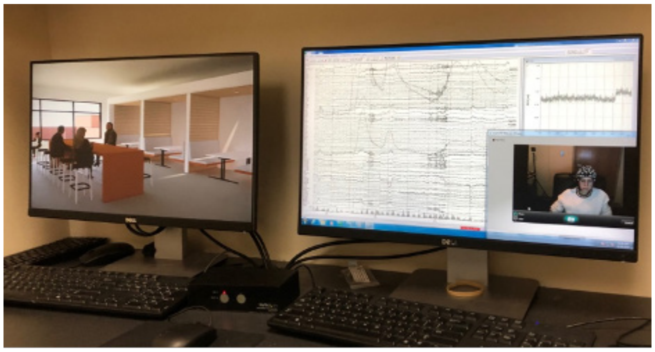

Figure 3. (top) EEG recording during viewing of still images (bottom) EEG cap fitting.

Impedances were kept below 15 kΩ. EEG signals were vertex referenced during the recording and digitized at 500 Hz using the BrainVision Pycorder (Brain Products GmbH).

4.0 RESULTS AND FINDINGS: CB VERSUS SB

Results were presented from the still images and video; based on the TF amplitude and ICPS approaches explained in section 4.5, we chose to investigate TF amplitude and functional connectivity (FC) in relation to hypotheses 1 and 2. The TF amplitude analysis provided additional information about neural synchrony that was not apparent in the ongoing EEG. It reveals which brain wave frequencies have the most power at specific points in time and space and how their phase angles synchronize across time and space [13]. FC is defined by measuring similarities between brain signals arising from two regions. Studies show that a person's creativity capacity can be reliably predicated from the strength of FC [14,15].

4.1 STILL IMAGES

Results from the still image presentation are shown in figure 4 and demonstrate robust differences between the SB and CB designs. The left panel presents the amplitude effects and the right theta band frontal and occipital functional connectivity (described further below). For amplitude, the top row contains traditional time-domain activity, and the three rows below that depict the time-frequency activity for alpha (8-12 Hz), theta (3-7 Hz), and delta (0-3 Hz). The topomaps to the right of the amplitude plots depict the amplitude differences (color topoplots, where red indicates relatively greater amplitude for the SB, and blue indicates relatively greater amplitude for the CB) and the associated significance (black and white topoplots, where white indicates $p < 0.01$, and black indicates $p > 0.10$, uncorrected Wilcoxon nonparametric comparisons). The first column presents average activity across the earlier 0-500 ms time range, and the second column the later 500-1000 ms range.

The time-domain amplitude results in the 0-500 ms range depict significantly greater activity in bilateral occipital regions (associated with processing visual information) and broad decreases in frontal regions (associated with control processing, problem-solving, movement, and social interaction[16]). Time-domain activity in the 500-1000 ms range does not show clear differences. TF results decompose this activity, as well as indexing activity not observable in the time-domain, and indicate significant differences between the SB and CB designs for each of the measured frequency bands. Occipital processing increases for the SB, relative to the CB, are readily apparent for each band in the 0-500 ms range (delta, theta, and alpha), suggesting increased engagement in occipital areas for multiple processing systems. It is important to note that alpha activity plays an inhibitory role, and thus decreases in alpha for SB (blue color, for SB-CB, i.e., greater alpha amplitude for the CB) areas were associated with increased occipital processing for the SB. This increase in occipital processing is sustained in the 500-1000 ms range only for alpha. Next, broad and bilateral increases in frontal alpha were observed in the 0-500 ms range, continuing through 500-1000 ms, with bias towards the left side during this later period. Again, increases in alpha are generally associated with greater inhibition of activity. Localized increases in lateral-frontal areas can be observed in the theta band, where hypotheses predicted modulated engagement.

Functional connectivity results for the theta band are presented in the right side of figure 4. The hypotheses centered on modulated engagement within medial and lateral frontal regions, linked to control processing, as well as within occipital regions associated with visual processing, as well as long-range communication between these regions. Seed (reference) sites are depicted in a separate topoplot below the results (i.e., significant activity between these sites and all other sites is depicted). Lines represent significant interchannel phase-synchrony between sites ($p < 0.05$, uncorrected), with effect sizes (R-values from the Wilcoxon comparisons) represented by the color (red indicating increases for the SB, and blue increases for the CB). Effects here are consistent with time and TF effects, indicating decreased connectivity within frontal regions, increased activity within occipital regions, and increases between bilateral occipital and bilateral frontal see sites – for the SB relative to the CB. Significant effects were also

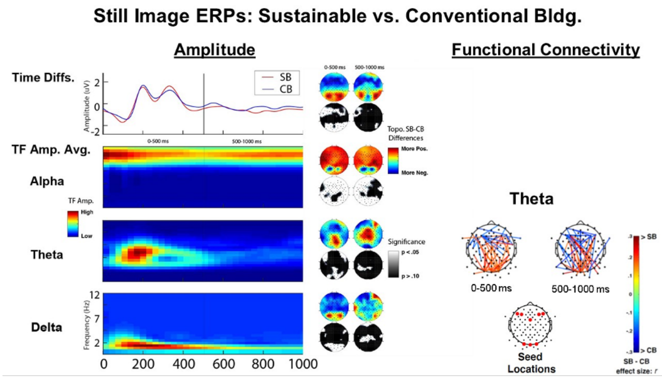

Figure 4. Still image ERPs: sustainable versus conventional building.

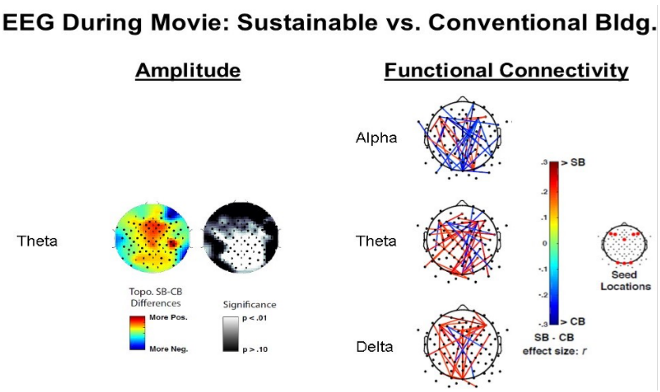

Figure 5. EEG during the movie: sustainable versus conventional building.

observed for delta and alpha bands but were not easily interpreted relative to hypotheses during this pilot work. Further treatment of these effects will be undertaken when additional data is collected and assessed. Potential inferences from these findings will be discussed in last section.

4.2 VIDEO

Results for the continuous EEG recorded during the movie are presented in figure 5. Amplitude results, in the left part of the figure, indicate significant increases in theta band activity in the SB, including medial-frontal, centroparietal, and occipital areas. Differences were not observed in alpha or delta frequency bands. For the functional connectivity (TF-ICPS measures), significant modulations were observed in the SB. Delta and theta evidenced substantially more significant increases (red lines) for the SB relative to the CB, while alpha evidenced substantially more significant decreases (blue lines) for the the SB relative to the CB. These effects are consistent with the idea of theta and delta as excitatory (increases for the SB relative to the CB) and alpha as inhibitory (decreases for the SB relative to the CB). The indication of these findings will be discussed in the following section, 6.0.

Overall, the recorded data proves the two hypotheses proposed before the experiments are correct. For hypothesis 1, test subjects demonstrated increased visual system engagement in the SB compared to that in the CB, which is particularly clear when they were viewing the video. For hypothesis 2, test subjects exhibited increased modulated attentional focus and control processing in the SB compared to that in the CB.

5.0 DISCUSSION AND CONCLUSION

The purpose of the present study is to develop an empirically driven approach to investigating the "soft" benefits of SBs using cognitive-neuroscience methods. Based on the initial empirical data, the primary findings are detailed and explained. This is part of a larger research project that seeks to further understand the psychological and cognitive impact of SBs. The present study provides initial validation of the proposed approach of combining electroencephalography (EEG) and event-related potentials (ERPs) with images and videos from emerging virtual design technology approaches to characterize cognitive-affective processing relevant to occupant experiences in proposed built environments. This sets the stage for planned extensions to using virtual design approaches with EEG/ERP in immersive virtual reality (VR) environments. Initial findings suggest that SB built environments may encourage a shift, consistent with mindfulness, toward a more active and engaged mental stance, with a greater focus on the present environment relative to internal mental processing. The contributions of this study can be discussed at two levels: the cognitive-affective processing modulated by SBs, and the method validation.

5.1 COGNITIVE-LOAD PROCESSING MODULATED BY SBS

The present findings can be explained by the cognitive load theory, which is consistent with the interpretation of greater focus on the present environment and reduced internal mental processing (cf. mindfulness), based on the observed increased theta/delta activities and greater engagement of visual systems and corresponding decreases in frontal activity in the SB environment. Emerging empirical work suggests that exposure to natural environments increases mindfulness [17,18,19] (e.g., greater engagement with the present environment), supporting the inference that integration of views of nature, and possibly greater spatial views of the interior of the built environment, are central to the observed effects. Mindfulness has been associated with receptive attention and perceptual clarity [20]. Further, improvements in mindfulness have demonstrated reductions in workplace burnout and perceived stress, as well as improvements in personal well-being and team and organizational performance and climate [21].

One way to conceptualize this shift is in terms of reductions in task-unrelated mental processing (cf. mind wandering), which has been closely investigated in empirical research on mindfulness [22,23]. This may be particularly relevant for the observed effects in the alpha band, which represent inhibitory processes. Here, focused reductions over occipital regions, combined with broad increases in alpha across other regions, are consistent with decreases in a mode of mind wandering, described as "sensory decoupling" or "attentional decoupling." That is, reductions in a mental state that is dominated by self-referential thought and is relatively disconnected with present-moment environmental circumstances [24-26]. The present findings of reduced bilateral frontal theta-band connectivity in the SB environment, relative to CBs, further supports the notion of a more mindful mental state, as hyperconnectivity between frontal regions has been associated with low mindfulness and heightened mind wandering [27]. Work in this area documents how mind wandering is associated with reduced productivity [28,29], mental health, and mindfulness [30]. Reflected as less mind wandering, in an SB environment, the extrinsic cognitive load is lower, which gives the brain more power to process the intrinsic load. Since the intrinsic load is directly related to the ability of processing and solving the given cognitive tasks, such as creating, reading, and comprehending, the occupant could produce better solutions. In addition, in an SB environment, there are fewer cognitive distractions, which typically refers to the "amount" of cognitive resources demanded from the building occupant by a competing activity. In the case of mind wandering, it is a type of competing activity that can distract people's attention from other tasks [31].

The idea of increased occupant mindfulness as a mechanism is consistent with the reports that occupants in SB environments feel stronger environmental satisfaction and support [32]. Physical workplace satisfaction has been positively associated with job satisfaction and better performance, and environmental satisfaction has been linked to contributions to the well-being of residents [33], particularly the elderly [34].

5.2 METHOD VALIDATION

Regarding the ability to manipulate and isolate the environmental stimuli, three built environment variables were used to elicit the brain activation and response. This was achieved by using virtual design technologies to change the views, lights, and spatial arrangement of the SB, compared to the CB. As shown in figures 6 and 7, the data indicates a clear difference in how subjects responded to different environments, and the clear difference in subjects' responses to still images versus a more realistic three-dimensional environment (video). The detailed manipulation and assessment of the EEG/ERP measures has the potential to offer new insights into the specific elements most impactful to occupants' cognitive and affective processing and well-being, The present findings suggest that a cognitive-neuroscience empirical assessment based on a virtual design process can provide a cost-effective approach to basic science efforts to parameterize core beneficial features of SBs, as well the effects of manipulating identified features in specific proposed built environments, before beginning costly construction. These virtual design technologies provide methods for detailed and systematic manipulation of environmental parameters, which would be prohibitively expensive to study in real environments. Such a method provides opportunities for designers to change the design based on the neuroscience response to the preferable built environment, hence identifying the optimized design solution of the built environment.

ENDNOTES

1. Dales, Robert, Ling Liu, Amanda J. Wheeler, and Nicolas L. Gilbert. "Quality of indoor residential air and health." Cmaj 179, no. 2 (2008): 147-152.
2. Kaplan, Stephen. "The restorative benefits of nature: Toward an integrative framework." Journal of environmental psychology 15.3 (1995): 169-182.
3. Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic design patterns: emerging nature-based parameters for health and well-being in the built environment. ArchNet-IJAR: International Journal of Architectural Research, 8(2), 62.
4. Blackwood, D. H. R., and W. J. Muir. "Cognitive brain potentials and their application." The British Journal of Psychiatry 157.S9 (1990): 96-101.
5. Sweller, John. "Cognitive load theory." In Psychology of learning and motivation, vol. 55, pp. 37-76. Academic Press, 2011.
6. Choi, Hwan-Hee, Jeroen JG Van Merriënboer, and Fred Paas. "Effects of the physical environment on cognitive load and learning: towards a new model of cognitive load." Educational Psychology Review 26, no. 2 (2014): 225-244.
7. Plass, Jan L., Dorothy M. Chun, Richard E. Mayer, and Detlev Leutner. "Cognitive load in reading a foreign language text with multimedia aids and the influence of verbal and spatial abilities." Computers in Human Behavior 19, no. 2 (2003): 221-243.
8. Paas, Fred GWC, and Jeroen JG Van Merriënboer. "Variability of worked examples and transfer of geometrical problem-solving skills: A cognitive-load approach." Journal of educational psychology 86, no. 1 (1994): 122.
9. Evans, Vyvyan. Cognitive linguistics. Edinburgh University Press, 2006.
10. Jamieson, Peter, Kenn Fisher, Tony Gilding, Peter G. Taylor, and A. C. F. Trevitt. "Place and space in the design of new learning environments." Higher Education Research & Development 19, no. 2 (2000): 221-236.
11. Tanner, C. Kenneth. "The influence of school architecture on academic achievement." Journal of educational administration (2000).
12. Tanner, C. Kenneth. "Explaining relationships among student outcomes and the school's physical environment." Journal of advanced academics 19, no. 3 (2008): 444-471.
13. Roach, Brian J., and Daniel H. Mathalon. "Event-related EEG time-frequency analysis: an overview of measures and an analysis of early gamma band phase locking in schizophrenia." Schizophrenia bulletin 34, no. 5 (2008): 907-926.
14. Beaty, Roger E., Yoed N. Kenett, Alexander P. Christensen, Monica D. Rosenberg, Mathias Benedek, Qunlin Chen, Andreas Fink et al. "Robust prediction of individual creative ability from brain functional connectivity." Proceedings of the National Academy of Sciences 115, no. 5 (2018): 1087-1092.
15. Beaty, Roger E., Paul Seli, and Daniel L. Schacter. "Network neuroscience of creative cognition: mapping cognitive mechanisms and individual differences in the creative brain." Current opinion in behavioral sciences 27 (2019): 22-30.
16. UPMC. "Get to know your brain series – the frontal lobe." Accessed 03 March 2020. https://share.upmc.com/2014/12/get-know-brain-series-frontal-lobe/
17. Hamann, Gwyneth A., and Itai Ivtzan. "30 minutes in nature a day can increase mood, well-being, meaning in life and mindfulness: effects of a pilot programme." Social Inquiry into Well-Being 2, no. 2 (2016): 34-46.
18. Howell, Andrew J., Raelyne L. Dopko, Holli-Anne Passmore, and Karen Buro. "Nature connectedness: Associations with well-being and mindfulness." Personality and individual differences 51, no. 2 (2011): 166-171.
19. Schutte, Nicola S., and John M. Malouff. "Mindfulness and connectedness to nature: A meta-analytic investigation." Personality and Individual Differences 127 (2018): 10-14.
20. Brown, Kirk Warren, and Richard M. Ryan. "The benefits of being present: mindfulness and its role in psychological well-being." Journal of personality and social psychology 84, no. 4 (2003): 822.
21. Kersemaekers, Wendy, Silke Rupprecht, Marc Wittmann, Chris Tamdjidi, Pia Falke, Rogier Donders, Anne Speckens, and Niko Kohls. "A workplace mindfulness intervention may be associated with improved psychological well-being and productivity. A preliminary field study in a company setting." Frontiers in psychology 9 (2018): 195.

22. Morrison, Alexandra B., Merissa Goolsarran, Scott L. Rogers, and Amishi P. Jha. "Taming a wandering attention: short-form mindfulness training in student cohorts." Frontiers in human neuroscience 7 (2014): 897.

23. Mrazek, Michael D., Jonathan Smallwood, and Jonathan W. Schooler. "Mindfulness and mind-wandering: finding convergence through opposing constructs." Emotion 12, no. 3 (2012): 442.

24. Barron, Evelyn, Leigh M. Riby, Joanna Greer, and Jonathan Smallwood. "Absorbed in thought: The effect of mind wandering on the processing of relevant and irrelevant events." Psychological science 22, no. 5 (2011): 596-601.

25. Kam, Julia WY, and Todd C. Handy. "The neurocognitive consequences of the wandering mind: a mechanistic account of sensory-motor decoupling." Frontiers in psychology 4 (2013): 725.

26. Schooler, Jonathan W., Jonathan Smallwood, Kalina Christoff, Todd C. Handy, Erik D. Reichle, and Michael A. Sayette. "Meta-awareness, perceptual decoupling and the wandering mind." Trends in cognitive sciences 15, no. 7 (2011): 319-326.

27. Peters, Amy T., Katie Burkhouse, Claudia C. Feldhaus, Scott A. Langenecker, and Rachel H. Jacobs. "Aberrant resting-state functional connectivity in limbic and cognitive control networks relates to depressive rumination and mindfulness: A pilot study among adolescents with a history of depression." Journal of Affective Disorders 200 (2016): 178-181.

28. McVay, Jennifer C., and Michael J. Kane. "Conducting the train of thought: working memory capacity, goal neglect, and mind wandering in an executive-control task." Journal of Experimental Psychology: Learning, Memory, and Cognition 35, no. 1 (2009): 196.

29. Randall, Jason G., Frederick L. Oswald, and Margaret E. Beier. "Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation." Psychological bulletin 140, no. 6 (2014): 1411.

30. Deng, Yu-Qin, Song Li, and Yi-Yuan Tang. "The relationship between wandering mind, depression and mindfulness." Mindfulness 5, no. 2 (2014): 124-128.

31. Engström, Johan, Gustav Markkula, Trent Victor, and Natasha Merat. "Effects of cognitive load on driving performance: The cognitive control hypothesis." Human factors 59, no. 5 (2017): 734-764.

32. Lee, So Young. "Expectations of employees toward the workplace and environmental satisfaction." Facilities (2006).

33. Sirgy, M. Joseph, and Terri Cornwell. "How neighborhood features affect quality of life." Social indicators research 59.1 (2002): 79-114.

34. Barresi, Charles M., Kenneth F. Ferraro, and Linda L. Hobey. "Environmental satisfaction, sociability, and well-being among urban elderly." The International Journal of Aging and Human Development 18.4 (1984): 277-293.