Neuro-Universal Design: The Nexus of Neuroscience and Universal Design

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ABSTRACT

The intersection of neuroscience and architecture offers new perspectives and approaches to an international community who use rigorous research from neuroscience to inform design innovations for the benefit of all. This paper explores a process of universal design innovation that has been applied in a pragmatic model for teaching and adoption in design practice, architecture and planning policy. Scientific principles revealing sensory processing, space perception, emotion, motion and cognition are incorporated in a practical grid that integrates neuro-scientific findings to inform 'research-based design' innovations, recommendations and priorities.

The adoption of research-based principles in professional practice include analysis of clinical and physiological studies of the environmental responses of people with multiple needs. This approach is examined in the context of a pedagogical study of design studios and neuro-universal lecture courses at four universities, and for the Berkeley Prize Universal Design Teaching Fellowship. The opportunities provided by peer-to-peer and pre-studio working groups, as well as iterative interaction among students, educators, and individuals with disabilities are explored.

Keywords

Neuroscience; architecture; universal design; evidence-based design; research

INTRODUCTION

The relationship between the mind, brain, body and built environments is now subject to the scrutiny of science. The evolution of neuroscience and technological innovations enable an inclusive approach to research-based design inquiry that considers environmental sustainability, public health and social justice. By considering together the many facets of context and function, scientific and clinical research along with more traditional studies reflecting the social sciences and humanities, may inform the design of spaces that serve all peoples and places.

Neuro-architectural Process

The fundamental synergy between architecture and the human sciences has recently been embodied in a 'neuro-architectural' approach (Edelstein, 2013). The conceptual framework is derived from the scientific method to relate the sensorial input of built environments to their bio-clinical impact and measurable behavioral output. Given the complexity of built settings, and the broad range of human needs and abilities, an interactive feedback loop between all elements of represents the complex interaction between physical attributes and human outcomes. This 'input-response-output' relationship between each physical feature and the likelihood of achieving universal outcomes is used to prioritize and rank the benefits and limitations of the many competing design interventions. The range of reactions of a diverse range of ‘users’ may thus be considered in terms from clinical to cultural differences, as well as in the context of many functional ‘uses’.

Beneath the layer of culture, biological and clinical data add to psycho-social observations to expose the fundamental interaction between people and places. Research-based design protocols translate rigorous and valid data to describe human responses to specific physical conditions. Clinical and physiological data offer a significant benefit as they describe the range of human responses in all architectural types. For example, the perception of speech is determined by the physics, materials, and geometries of a space in addition to the individual’s clinical ability to hear, regardless of the architectural type. The 7 universal design objectives serve as essential outcomes.

To date however, there are few who have entered the design profession with training in the scientific method or the translation of biological research into design applications. Therefore, a decision grid was formulated that lays out the many specific components and reactions that must be considered at once. The presentation of this complex database of information in a singular grid focuses design thinking on the diverse range or ‘users and uses’ that each design decision must embrace. The neuro-architectural decision grid includes: the physical input that each design option modulates (light, sound, texture, dimension etc.); the human reactions to those features in terms of the neural system that drive those responses (sensory, perceptual, emotional, cognitive, and behavioral); and the associated behavioral outcomes.

The evidence, cost of each design option, proposed benefits and risks, and the return on investment is set out in human, ecological and economic terms. The confluence of human-centered and sustainable design is evident in the development of guidelines for healthcare facilities through healthy cities by institutions such as BREEAM for Health, the United States Green Building Council, LEED® for Healthcare, the AIA Facilities Guidelines Institute, and the AIA Design & Health Summit, the Joint Commission, and the Global Health and Safety Initiative, among others. Historically, these guidelines focus on exposure to pollutants and toxins in air, water and via physical contact with materials. However, clinical outcomes are equally important and guidelines are being directed at improving both human and environmental outcomes (Edelstein & Macagno, 2012).

Architects, engineers and environmental experts contribute to the definition of the physical features that comprise the physical stimuli to which the program, and people respond. Using an integrated project delivery process, research-based design consultants (neuro-scientific, clinical, physiological, and psycho-social specialists) supplement the design team to search for and translate bio-medical research into terms that can be applied in design. Scientific consultants assess the reliability, repeatability, validity of such data, and draw up design principles. In order to generalize these principles into design, user/experts provide insights and guide priorities to identify outcomes and rank solutions that are best suited to he diversity of needs.

Practice

The intersection of neuroscience and universal design offers to build a community of practice who support, encourage and teach each other to use rigorous research from neuroscience, informing design innovations for the benefit of all (Edelstein & Sax, 2014). If the adoption of innovation is based on the perception of merits of the innovation itself, the increasing global interest in healthy design offers to promote this cause. The World Health Organization defines health very broadly a fundamental human right and more than the mere absence of disease. They advocate for human-centered development even when it does not “result in immediate economic gains and may require public investment" (WHO European Health 2020, 2012. pp 97).

Significant improvements in health and longevity have been correlated to a wide range of environmental interventions that are now in recommendations, guidelines, and white papers by institutions focused on health promotion including: the World Health Organization (WHO), the Japanese and WHO Alliance for Healthy Cities, the Canadian Public Health Agency, the Australian Department of Health & Healthy Urban Development, the National Institutes for Health and Center for Disease Control, and the United States of America Healthy Peoples 2020.

Pressures for universal design increase with the world's aging demographic and the increasing prevalence of preventable chronic diseases including respiratory, obesity, diabetes, and cardiac conditions that are related to lack of exercise and public space (Edelstein, 2014). Design must also serve the increasing prevalence of those with cognitive conditions such as dementia, autism, or developmental disorders. Inclusion of those with learning disabilities in mainstream and workplace facilities to the greatest extend possible also provides an opportunity to consider how brain, mind, body, and behavior are influenced by design.

However, the form and function of architectural environments too often neglect to take into account the influence of the built setting on human health or user needs (Edelstein & Macagno, 2012, pp27). Further, there is a great deal of research that has yet to be translated from studies over the past decade in which neuro-scientific studies revealed the influence of specific physical features on the brain's sensory, perceptual, motor, emotional and cognitive responses.

For example, the guidelines and legislation that limit sound exposure to prevent noise-induced hearing loss, set limits based on research in the 1990's. Even the 2003 Directive (2003/10/EC) by the European Union defines the maximum averaged continuous noise levels based on exposure levels defined by ISO 1999:1990. Further, the Directive's limits for impulse sounds, now common in recreational as well as industrial and military settings, use a single value limit of 140dB including hearing protection, but does not take into account any frequency or duration information, and lacks any scientific validation (Buck et al. 2012).

Exposure to such increases the risk of noise-induced hearing loss, as well as physiological and psychological changes. A consistent trend towards an increased cardiovascular risk has been observed with daytime noise levels exceed moderate levels, and stress reactions, such as cortisol disturbances, have been observed in children with long-term low frequency traffic noise exposure averaged at less than 55dBA. (Ising & Kruppa, 2004) Unwanted noise exposure as well as lack of speech confidentiality and privacy further diminishes performance, communication, satisfaction, and the healing quality of healthcare environments. A survey of 118 medical leaders listed acoustical conditions in healthcare settings at most common complaint. Concerns include loss of speech intelligibility and associated medical or medication error, increased stress and sleep interruption (Edelstein 2013). Even more difficult, is speech perception in noisy environments if listening in a second language where an additional 15dB is required for equivalent perception, or with hearing loss where standard acoustic design is not sufficient. Empirical acoustical tests demonstrate that typical wall system design that meets privacy standards for office spaces are insufficient to ensure confidential communication, especially in settings where voices are must raised to command attention, to express great need, or to communicate with hearing loss.

A large body of neuroscientific and clinical research reveals that exposure to light has significant impact on mental state, cognitive function, behavior, and physical health in addition to vision itself. Although rigorous circadian research has taken place over more than

60 years revealing the human need for natural light/dark patterns, the impact of changes in spectra, intensities and timing of light that entrains cardiac, brainwaves, and melatonin, and cortisol fluctuations is only recently being incorporated in best practice. Edelstein et al. (2007) demonstrated in carefully controlled office conditions, that heart rate variability (HRV), a well-established indicator of health risk and stress, was highly significantly different during memory tasks performance when subjects were exposed to less than 15 minutes of red light, versus bright white (with a blue peak) light. Whereas many studies have focused on the influence of blue and bright white light of melatonin responses, this experiment demonstrated that red light was associated with changes in cardiac responses (Edelstein, 2008).

This body of research has direct implications for enhancing universal guidelines for circadian health and visual function. Rather than guidelines that suggest average light levels across an entire building, or suggest percentages of exposure, lighting design should respond to the specific needs of the users in addition to the uses of a space. The 'one size fits all' lighting strategy is now being replaced by individual and dynamic lighting strategies that provide for safety and egress, as well as controls to modulate light exposure according to individual visual needs, functional tasks and circadian status. (Edelstein, 2008).

In keeping with this approach, the programming of spaces for night-shift workers such as clinicians, factory workers, air-crew or business travellers receive preferential access to spaces with natural light. Further, the control of light and access to darkness is driving design decisions. The unwanted distribution of light into places occupied by others is a primary consideration in lighting design for healthy places.

Practice to Pedagogy

Understanding of the relationship of people to their built surroundings is an essential condition that must inform design. Yet, despite increasing and strong evidence, the inclusion of human-centered and community-centered principles outlined in architectural accreditation criteria have recently been diminished or dismissed in the 2014 National Architectural Accrediting Board (NAAB) draft conditions. These conditions define the criteria that professional architectural degree programs are required to meet to prepare students in their careers. In response, the Environmental Design Research Association (EDRA) Board of Directors called for action, noting that "the proposed changes are not adequate to protect the health, life, safety, and welfare of the public, nor are they concurrent to the standards of engaged and responsible practice or global citizenship." EDRA called for a strong futuristic vision and thoughtfulness to "ensure students understand how to integrate research evidence into design decision-making, the critical relationships between humans and designed environments, the changing dynamics of people and environments, and are able to work collaboratively in interdisciplinary teams." (See http://bit.ly/edra_response.)

It is important to explore why attitudes toward architectural equity have stalled, and why adoption of human-centered values has not gained greater traction in all academic or professional settings. The Berkeley Prize Teaching Fellowship offered experience to yield insights into teaching approaches that may foster appreciation for human-centered values in the next generation of architects.

The inclusion of neuro-architectural or universal principles in a densely packed, accredited curriculum limits the time available for students to think about human-centered curricula. Yet, in a post-course faculty survey it was noted that "incorporation of human centered outcome criteria into the entirety of our taught coursework, enhanced the students' experiential and design thinking skills."

Whilst it could be argued that human-centered content be taught in a separate studio, all architectural projects, regardless of the type, must consider human interaction with the site and the functional program. Every project must take into account the range of human uses and the diversity of users. Therefore, a neuro-architectural analytic process and universal design outcomes are appropriate for all projects and within every studio project.

Neuro-Universal Curriculum Development

Undergraduate and graduate students introduced to the scientific method, critical analysis, and research-based inquiry were able to readily adopt the neuro-universal process. This approach has been developed and taught over several courses taught in collaboration with the Interwork Institute, College of Education at San Diego State University, and the Academy of Neuroscience for Architecture at the NewSchool of Architecture & Design and the University of California San Diego, and the College of Architecture, Planning + Landscape Architecture at the University of Arizona. The curricula introduced the neuro-architectural process and universal design principles to students enrolled in environmental psychology, research-based design courses and design studios. Assignments were devised that challenged students to think about a range of needs including 1) an educational institution to serve students and faculty with a broad variety of cognitive, emotional and physical needs, 2) accessible residential design for a real-world client with multiple sclerosis, 3) transportation centers and 4) a high-rise community center (Edelstein & Sax, 2013).

Expert users and staff specializing in the provision of resources for people with diverse abilities joined the design studio faculty and students in discussions and field trips, representing a broad range of perspectives and abilities, faculty from 1) design and architecture, 2) bio-psycho-social research-based design, 3) assistive technologies and 4) environmental equity. A series of lectures by the Disability Resource Center (DRC) and invited expert users discussed the philosophy and impact of equitable design. The concept that architecture can and should ‘flex’ to meet the continuum of human needs was introduced, in contrast to design philosophies that demand people ‘bend’ to built settings. The politics of design equity was highlighted, challenging students and faculty to consider if the ‘poetics of stairs’ should supersede the ‘politics of space’.

The disability resource faculty and expert users attended studios, mid-term and final juries, providing iterative feedback and insights to inspire equitable design, prompting students to consider the balance required in design for social equity. Discussions had students consider their own dynamically changing needs across their own life-span in their daily interaction in urban, built, and natural settings. Regular and repeated conversations built relationships and broke down conversational barriers. Philosophical and pedagogical concepts were supplemented by lectures and field trips. Designers, clients and users provided valuable real-world perspectives and built examples of creative, high-quality design that employed spaces and a variety of assistive technologies for mobility, navigation, environmental, and equitable use.

Special assignments required that that a design hypothesis was developed using the ‘neuro-architectural’ decision-grid to explore the impact that design elements might have on human outcomes. In addition to linking 1) the physical parameters of the built environment as ‘input’, 2) the brain, mind, body and behavior as ‘responses’, and 3) universal design objectives as measures of ‘outcome’, the physical, mental, clinical, and cultural status of users were related to universal principles in the context of the program to be designed. The relationship between these data prompted comparison of the interactions of each design option were translated into principles to inform design choices that serve individual, group, public, and social contexts (Edelstein, 2013b.)

Results

Faculty and students alike noted the value of regular contact and open discussions with expert users. Rather than singular events or 'disability simulations', repeated meetings were considered to be important in overcoming communication barriers and encouraging participants to begin to understand the continuum of diverse needs that users experience in urban, built, and natural settings. In discussions, students were encouraged to consider where their own sensory, cognitive, emotional, and physical abilities were positioned along a continuum of needs and abilities, and how this might change over the course of their own lives. Once students were able to articulate their own abilities and limitations, they were more prepared to consider how design might impact the experience of others. Review of the students' designs demonstrated the incorporation universal design thinking. The students openly attested to their appreciation of authentic learning experiences during field trips. The students began to incorporate neuro-universal design principles in their projects as second-nature, assuming that all projects and places should offer equitable universal design.

Surveys and discussion groups revealed how student attitudes changed as a result of these pedagogical strategies. A post-course survey was completed by the Berkeley Prize 'neuro-universal' studio after the academic year. A total of 17% (11 of 63) of the students answered eight questions using a 5-point scale (Strongly agree = 1; Agree = 2; Neither Agree or Disagree = 3; Disagree = 4; Strongly Disagree = 5). Four questions probed how students thought about design, and another four asked how the experience of the class influenced their thinking. Ninety % (n=10) of the students strongly agreed or agreed that "These experiences made me think about designing for people with a broad range of abilities." Seventy-two % (n=8) strongly agreed or agreed that "These experiences made me think about how my senses, movement, emotion, and thinking change with design." Eighty % (n=8) strongly agreed or agreed that "These experiences influenced the design of my studio projects." Ninety % (n=9) strongly agreed or agreed that "These experiences will influence how I design in the future.

In open questions, students revealed the benefit of both the neuro-architectural conceptual framework, and universal design objectives:

> "I had a much broader range of considerations after these experiences, I began thinking about all the senses and not just physical mobility or blindness."

> "UD is no longer an afterthought… the goal is now imbedded into initial sketches…before any hard lines are drawn."

CONCLUSION

Post-course discussions and surveys indicated that learning in the context of a neuro-architectural conceptual framework and universal design principles offered opportunities for students to incorporate knowledge about sensory processing, space perception, and cognition, and to create designs to achieve more comprehensive objectives. The importance of peer-to-peer conversations, networking, and iterative interaction among architecture students, educators, and individuals with disabilities were also demonstrated.

A greater commitment to human-centered design is essential in education and in practice. Pre-course workshops with expert users will enable all faculty to become 'equally fluent' in research-based universal design. Expert users should also spend time in these discussion and workshops to learn about the process and real-world constraints on design.

One faculty member noted that:

> "Even though it should be an inherent part of the design process, there needs to be a commitment beyond the superficial, … it is not a simple issue … of additional check box item."

In addition to articulation of current knowledge from a broad range of rigorous studies, it is important that research data be readily translated into practice guidelines using quantifiable metrics that demonstrate the value of design to human, environmental, and economic outcomes. Continued systematic efforts to continually collect robust evidence will inform a wide range of policies to improve health and wellbeing.

The exposure to neuro-universal concepts resulted in a significant shift in student attitudes. One student, outspoken in her passion and attention to universal design wrote:

> "I may not be able to change the entire world, but now I can begin."

Most rewarding was a comment from one of the students, a wheel-chair user, who observed a dramatic change in his peers compared to his previous 2 years with the same cohort.

> "I can assure you that you have had a great impact on the way students think."

The adoption of universal design principles may thus be served by such efforts to change the 'design product or process' rather than 'persuading individuals' to change.

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