February 26 - March 1, 2006
San Diego Convention Center
and
San Diego Marriott Hotel & Marina
San Diego, CA

Sponsored by the American Society for Healthcare Engineering (ASHE) of the American Hospital Association (AHA) in conjunction with the American Institute of Architects Academy of Architecture for Health (AIA/AAH)

Translating Neuroscience into Design

Eve A. Edelstein, *PhD, Assoc AIA, Principal Investigator & Visiting Scholar, Academy of Neuroscience for Architecture, San Diego, CA*

Translational Design:
The Relevance of Neuroscience to Architecture

Eve A. Edelstein, Ph.D., Assoc. AIA,
Academy of Neuroscience for Architecture & Visiting Scholar, University of California, San Diego

White Paper to ASHE December 20, 2005

Abstract
The term 'Neuro-architecture' can be used to describe a new discipline that unites the emerging field of Neuroscience with the experience of architecture. By exploring scientific findings that reveal how the human mind processes the built and natural environment, a steadily increasing level of thoughtfulness in design can be achieved [i]. In bringing together seemingly disparate disciplines and modes of thought, a novel set of questions pertinent to the practice of architecture can utilize methods not fully applied to the interaction with health care environments. The goal becomes one of establishing the knowledge base, protocols and skills needed for defining, collecting and sharing neurophysiological and architectural data to be used for further collaborative studies and applications within architectural projects [ii]. A model of 'translational design' [iii] is suggested that utilizes information from the basic and clinical sciences as well as the rigorous methods from science to enhance and inform the design of built settings.

The Burgeoning Discipline of Neuroscience
Today, understanding the brain serves as one of science's most daunting frontiers. Much of the groundwork for modern neurobiology was inspired by the pioneering work of Santiago Ramón y Cajal (1852 – 1934). In proposing the 'neuron doctrine', he described the nerve and its connections as the basic functional unit of the brain. Such discoveries set in motion an important paradigm shift for those who studied and interpreted the human mind, and the relationship between the brain's 'form and function' persists as an area of study. By investigating normal and disordered brain activity, the biological and medical sciences continue to relate the brain's structure to behavior. Although the relationship between the brain's form and function remains clear, it is also important to note that the response to even a simple task is widely distributed throughout many neural structures. The inherent complexity of the brain and mind continues to challenge researchers. However, the advent of novel techniques, including neuroimaging and genetic analyses, provide new means to extend this exploration toward further understanding of human thought, emotion and behavior.

The burgeoning discoveries from neuroscience also offer the potential to explore new perspectives on the human reaction and interaction with the environment. One of the most relevant bodies of work that led to another paradigm shift in neuroscience, resulted from research suggesting that the brain should be regarded as a 'plastic' organ, able to change and grow throughout adulthood. Until recently, it was held that the number of nerves and connections were rigidly set in infancy and limited by critical periods in childhood. However, both animal and human studies demonstrated that exposure to enriched environments were associated with increased brain growth [iv] [v]. Such studies in 'neuroplasticity' now form one of the most avidly pursued fields in neuroscience. If one considers the role of the architect as that of a designer of environments that can stimulate brain responses (activity, novelty and memory), the relevance of neuroscience to architecture becomes additionally evident.

Translational Science
Neuroscience offers not only a wealth of knowledge, but also a rigorous methodology to validate findings and provide a framework for translating basic science from 'bench to bedside'. Followed carefully, this model facilitates the creation of credible evidence-based solutions that serves medicine well. As such, it also provides the foundation for innovation and intellectual leaps toward novel solutions.

"Achieving those objectives requires assembling building blocks of bits and bytes of information accumulated through the work of neuroscientists from across all disciplines within the field, and using knowledge and approaches from related fields. [vi]"

Translational Design
An analogous 'translational design' approach has been proposed in which the interpretation of scientific findings into terms relevant to architecture can offer validation for design hypotheses. Rigorous study design and analysis provides a paradigm for developing repeatable results leading to greater predictability about responses to environmental features. These building blocks, in combination with findings from the related disciplines of Sociology, Psychology and Anthropology [vii] [viii] [ix] [x] provide a broad basis informing design applications.

Evidence-Based Practice
A translational approach should be based upon a validated evidence base that relies on a structured approach to accessing, interpreting and assigning value to data. To deal with the burgeoning knowledge available to medicine, the American Medical Association and others convened a series of meetings over the past 15 years to develop standards for evaluating evidence and its application[xi]. Expert panels devised a hierarchy that enabled readers scouring the literature to 1) articulate the issues to be addressed, 2) conduct systematic literature reviews, 3) summarize evidence, and 4) assess the rigor and validity of findings. This leads to a unified framework for supporting decision criteria and guidelines.

Several issues arise from the application of this paradigm. The time and expertise required to analyze and implement this approach are clearly recognized, and it has been suggested that specialists must be allocated to ensure effective research, interpretation, analysis and judicious generalization of findings.

Neuroscience & Architecture

The premise is to consider how each
variable of the environment affects certain brain processes,
that in turn, alter a specific outcome measures.

A similar paradigm could serve architecture. Inspired by conversations between Norman Koonce and Jonas Salk, leaders in architecture and neuroscience convened to explore these opportunities [xii]. With support of the American Institute of Architects (AIA) College of Fellows, John Eberhard, the 2003 Latrobe Fellow, founded the Academy of Neuroscience for Architecture (ANFA) to frame a new discipline to explore how the mind and brain process and experience architecture. Relevant to this endeavor, ANFA, with the assistance of a grant from the Academy of Architecture for Health Foundation, is working to develop a system linking design databases with the body of data from science. By summarizing and annotating findings in accessible terms, the evidence available from the biological and social sciences can more readily be used to inform design. Such efforts will ultimately combine the information from many different fields and existing studies to provide a breadth of knowledge to inform design.

As part of ANFA's program, several conferences on Neuroscience and Health Care Architecture have been hosted, inviting leaders in architecture and a broad range of experts from the sciences. A series of three workshops, held at the National Academy of Sciences in Woods Hole, Massachusetts focused on interdisciplinary dialog that considered principles of neuroscience as related to health care architecture. Discussions lead to the development of a working premise and a series of hypotheses addressing the relationship between hospital design and patient or staff outcomes.

Several areas of interest were explored that reflect current issues of importance, such as those outlined in AIA Guidelines for Design and Construction of Hospital and Health Care Facilities [xiii]. The premise considered how each variable of the environment affects a certain brain process, which in turn, alters a specific outcome measure [xiv]. Each issue can be broken down into testable parts by analyzing architects' questions in terms of 1) environmental features, 2) physiological and psychological responses, and 3) patient, medical or business outcomes.

Topics of discussion included the influence of:

- Windows and daylight on healing, stress and cognitive functions
- Interior layout on patient outcome and staff performance
- Privacy and control on patient stress, emotions and outcomes
- Calming environments related to Alzheimer and dementia care
- Navigation on patient and staff outcomes and performance

The 2005 Woods Hole conference focused specifically on memory and the navigation, using a directed charrette process in which images of health care environments were analyzed by both designers and neuroscientists. Plans of complex health care facilities served as a starting point for further analyses of neural responses to specific architectural features. Neuroscientists reflected upon processes that might provide further insight. Design hypotheses were derived, and potential experimental studies were developed. Finally, the workshop considered how existing knowledge from neuroscience could inform architectural decisions in the following contexts:

- Navigation & Communication Spaces in Neuroscience Laboratories
- Stress, Gender in Neurological Intensive Care Units
- Navigation in Complex Hospital Environments

Research efforts continue with the support of the AIA College of Fellows who awarded the 2005 Latrobe Fellowship to a trans-disciplinary collaboration. The study combines the expertise of clients, architects and researchers to address questions that are of direct relevance to patient and staff responses. The goal is to produce evidence and a practice model that will be of use to health care architects, and be readily generalized to architectural practice [xv].

Translating Science into Architecture

An example of direct relevance to health care architecture comes from research revealing the brain mechanisms that regulate stress, mood, and healing responses. Sternberg and Gold (2002) note that the "intricate network that exits between the immune system and the brain" serves to substantiate the widely held observation that one's state of mind can influence resistance to, or recovery from infectious or inflammatory disease. "The popular belief that stress exacerbates inflammatory illness and that relaxation or removal of stress ameliorates it may indeed have a basis in fact." [xvi]

Disruption of the communication between the brain and immune system can lead to greater susceptibility to inflammatory disease, and frequently to increased immune complications. For example, studies show that vaccinations are less effective if administered during an exam, and chronic stress is associated with prolonged would healing [xvii]. Reduced immune response levels have been demonstrated in spouses providing long term care for Alzheimer's patients [xviii]. The regulation of the immune system by estrogens is of particular importance during pregnancy, as it plays a role in suppression of maternal immune responses to prevent rejection of the fetus, with several clinical studies show an association between maternal stress and pre-term labor [xix]. These findings suggest that the design of less stressful health care environments may yield improved outcomes.

Light appears to be an environmental factor that is closely related to outcomes. Seasonal affective disorder (SAD) presents with a constellation of symptoms consistent with neural immune disorders, and in animal models, stress and fear have been shown to modify melatonin, a circadian hormone that responds to light. The amount and type of light exposure within a building falls directly within the scope of the architect. Results from field and laboratory investigations of night-shift nurses demonstrated the efficacy of a practical interventions to promote circadian adaptation to night-shift work [xx]. Further definition of the quantity, quality and timing of light exposure holds potential to inform the environment for both staff and in-patients who spend days and nights within artificial light conditions.

The degree to which stress precipitates or exacerbates disease depends not only on the nature of the stressful stimulus but also on each individual's experience of the stressful event. Thus, the opportunity to design an environment to decrease stressors should take into account not only physiological reactions but also the social and cultural history as well as the roles of the users of that space.

Conclusion

The translation of a broad range of knowledge, crossing multiple disciplines and including recent developments from the social, psychological and neurosciences, offers the potential to enhance our understanding of the complex interactions between human behavior and the built environment.

REFERENCES

[i] Eberhard, JP. (2004) Neuroscience & Architecture. Presentation at the Academy of Neuroscience for Architecture: 2nd Workshop. Woods Hole.

[ii] Smith, P. (2005) Health Care Design: Neuro-Architectural Charrette. Presentation at the Academy of Neuroscience for Architecture: 3rd Workshop. Woods Hole.

[iii] Edelstein, E. (2005) Translational Design. Presentation at the Academy of Neuroscience for Architecture: 3rd Workshop. Woods Hole.

[iv] Eriksson, PS. Perfilieva, E, Bjork-Eriksson, T, Alborn, AM, Nordborg, C, Peterson, DA & Gage, F.(1998) Neurogenesis in the Adult Human Hippocampus. Nature Medicine 4, 1313-1317

[v] York, AD, Breedlove, SM, Diamond, MC. (1989) Housing Adult Male Rats in Enriched Conditions Increases Neurogenesis in the Dentate Gyrus. Soc. for Neurosci. Abstracts #383.11 p. 962

[vi] Barnes, C. (2005) Moving Toward a Redefinition of Translational Research. Neuroscience Quarterly. Spring, p.1-2

[vii] Zeisel, J. (2005) in *Inquiry by Design: Environment/Behavior/ Neuroscience in Architecture, Interiors, Landscape, and Planning* New York. W.W. Norton (in Press)

[viii] Ulrich, R, Quan, X, Zimring, C, Joseph, A, Choudhary, R. (2004) The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity The Center for Health Design.

[ix] Ballisto, D. and Allison, D. (2001) The Nature and Rate of Change in Hospital Laboratories. Coalition for Health Environments Research.

[x] Shepley, MM. (1996) A User's Guide to Design Research. Journal of Healthcare Design, p. 8

[xi] Guyatt & Rennie Eds (2002) *Users; Guides to the Medical Literature: Essentials of Evidence-Based Clinical Practice.* AMA Press. Third Printing 2004.

[xii] Academy of Neuroscience for Architecture; available at http://www.anfarch.org [accessed November 30, 2005]

[xiii] *Guidelines for Design and Construction of Hospital and Health Care Facilities*. (2001) Facility Guidelines Institute and the American Institute of Architects Academy of Architecture for Health and the U.S. Dept. of Health and Human Services

[xiv] Sternberg, EM (2004) Neuroscience & Architecture of Health Care Facilities. Presentation at the Academy of Neuroscience for Architecture: 2nd Workshop. Woods Hole.

[xv] The AIA College of Fellows Awards 2005 Latrobe Fellowship to Chong Partners, Kaiser Permanente, and University of California, Berkeley (2005) available at http://www.aia.org/release_080205_latrobe. [accessed August 22, 2005].

[xvi] Sternberg EM, and Gold PW (2002) The Mind-Body Interaction in Disease. Scientific American. In Special Issues. The Mysteries of the Mind. P 82-89.

[xvii] Rozlog LA, Kiecolt-Glazer JK, Marucha PT, Sheridan JF, Glaser R. (1999) Stress and immunity: implications for viral disease and wound healing. J. Periodontol. 70: 786-792.

[xviii] Vedhara K, Cox NKM, Wilcock GK, Perks P, Hunt M, Anderson S (1999) Chronic stress in elderly carers of dementia patients and antibody responses to influenza vaccination. Lancet. 353: 627 – 631.

[xix] Jansson L, Holmdahl R (1998). Estrogen-mediated immunosuppression in autoimmune diseases. Inflamm. Res. 47: 290 – 301.

[xx] Boivin DB, James FO. Circadian adaptation to night-shift work by judicious light and darkness exposure. J Biol Rhythms. 2002 Dec;17(6):556-67.