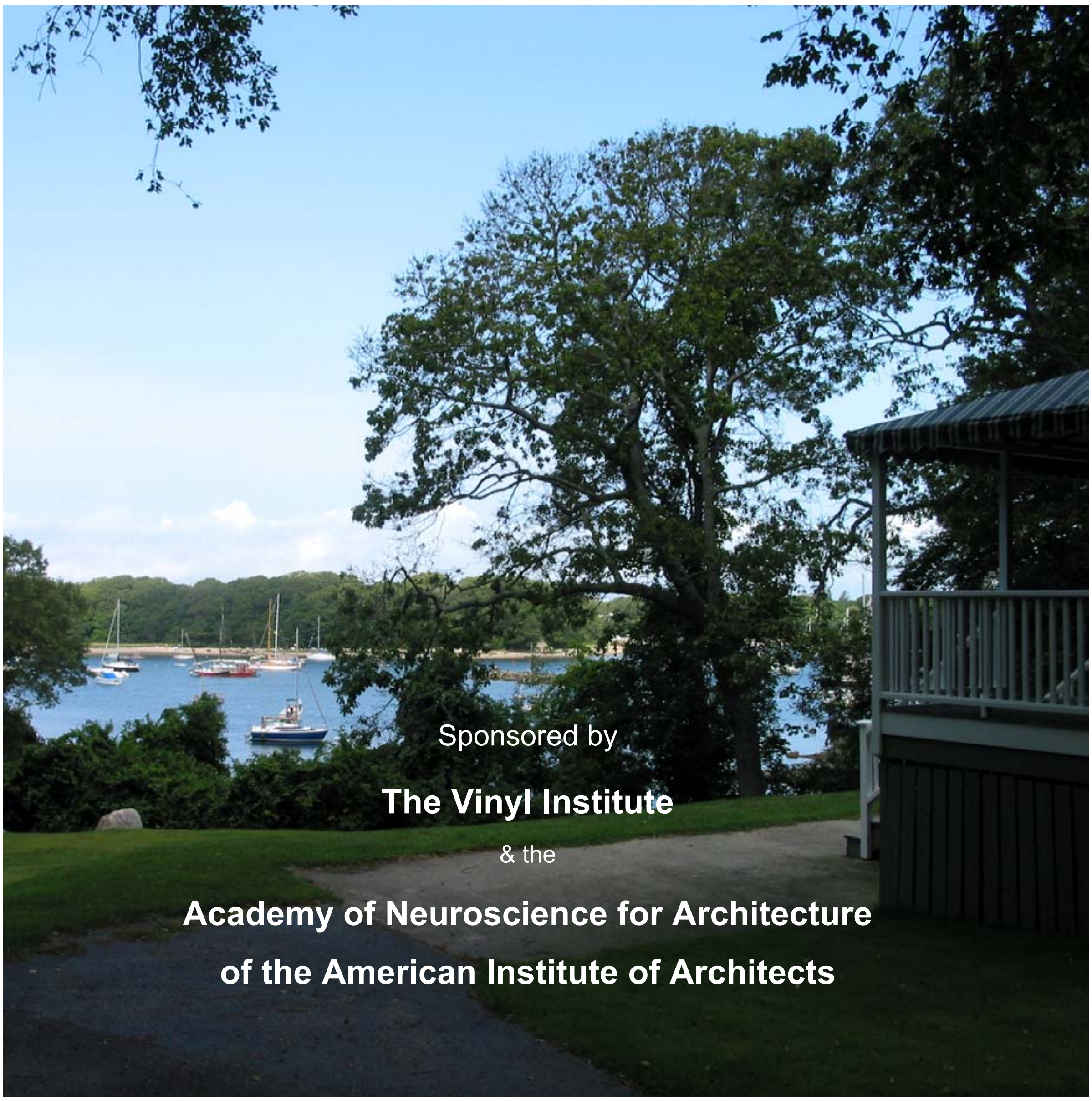
NEUROSCIENCE AND ARCHITECTURE

HEALTH CARE FACILITIES

2nd Annual Workshop: August 25 to 27, 2004



Erik Jonsson Center of the National Academy of Sciences,

National Academy of Sciences, Woods Hole

Report by Eve A. Edelstein, Ph.D., Assoc. AIA © 2005 E^2

WORKSHOP REPORT

Summary report of discussions held at the
Second Annual Woods Hole Workshop on Neuroscience and Healthcare Facilities,
August 15-17, 2004.

This paper forms part of a series of documents that describe the work of the Academy of Neuroscience for Architecture in its exploration to understand the human response to architectural spaces. This paper is written for the widest audience, to build a common language between architects, scientists, and users of built settings. The papers that follow will explore the issues of architecture and science at greater depth to encourage creative thought and experiments that will lead to neuroscientific findings of relevance that coincide with the practice of architecture. This report summarizes the workshop's presentations and discussions. Credit is attributed to individuals where possible from the available records.

PARTICIPANTS

(Affiliations at time of workshop)

Visitors experiences with WAYFINDING in architectural settings:
Eduardo Macagno, Ph.D., Dean, Division of Biological Sciences, UCSD, Co-Chair of Workshop
Roger Goldstein, FAIA, Goody Clancy Associates, Boston
Joseph Sprague, FAIA, Dallas, Texas
Peter Smeallie, Research Opportunities Management, Alexandria, VA
Barbara Sido, CAE, Staff Vice President, AIA

CALMING ENVIRONMENTS for Alzheimer's patients:
John Zeisel, Ph.D., Hearthstone Alzheimer Care
Rev. Patrick Russell, Ph.D., former staff member, Neuroscience Institute
Pam Milner, AIA, the Smith Group, Washington, DC
Charles Fay, Project Manager, New York State Research and Development Authority
Frederick Noyes, FAIA, Architect, Boston, Mass

Impact of WINDOWS on patient's recovery experiences:
Gordon Chong, FAIA, Gordon Chong + Associates, Co-Chair of workshop
Frederick M. Marks, AIA, Earl Walls Associates, San Diego, CA
Randy Peterson, AIA, HMC Group, San Diego, CA
Jane Rohde, AIA, FIIDA, JSR Associates, Ellicott City, MD
Gene Hopkins, FAIA, President of the AIA
Esther Sternberg, MD, Director Integrative Neural Immune Program, National Institute of Mental Health

Physicians and nurses: Experiences with INTERIOR ARCHITECTURE
Joyce Bromberg, Director Space Planning Research, Steelcase Corporation
Robert Horsburgh, M.D., Chairman Department of Epidemiology & Biostatistics, Boston University
David Allison, AIA, Director Graduate Studies in Architecture + Health, Clemson
Timothy F. Burns, President & CEO, the Vinyl Institute
Eve Edelstein, Ph.D., Academy of Neuroscience for Architecture

PRIVACY for patients and for physicians in architectural settings
Douglas Steidl, FAIA, First Vice President of the AIA
Thompson Penney, FAIA, Past President of AIA
Frank Pitts, AIA, Past President of the Academy of Architecture for Health
Norman Koonce, FAIA, Executive Vice-President and CEO of AIA
Carla Shatz, M.D., Chair, Neurobiology Department, Harvard University
Earl Swensson, FAIA, CEO, Earl Swensson Associates

FREE AGENTS:
John P. Eberhard, FAIA, Latrobe Fellow, Founding President Academy of Neuroscience for Architecture (ANFA)
Margaret Tarampi, Assoc. AIA, ANFA
David Weiner, Producer & CEO, Weiner Productions

INTRODUCTION

The Academy of Neuroscience for Architecture (ANFA) was created by the American Institute of Architects (AIA) as the international center for interdisciplinary activities to build intellectual bridges between neuroscientific research and those who design places for human use. In bringing together disparate disciplines and modes of thought, a novel set of issues pertinent to the practice of architecture can be addressed using rigorous scientific methods not previously applied.

Gordon Chong, FAIA challenged architects to consider how healthcare facilities can help to reduce the thousands of medication errors or malpractice deaths that occur each year. As such, the Academy's work will likely be one of the seminal points in the history of the AIA. "Future architects will look back on the research initiatives begun here and be pleased that their 'evidence-based' design decisions were to become firmly grounded in science." Without losing the art of intuition, a more scientific approach enables design to remain relevant to today's needs.

The first Neuroscience and Healthcare Facilities Workshop was held in August 2002 at the Erik Jonsson Center of the National Academy of Sciences, Woods Hole Massachusetts. Architects and scientists identified five key areas of interest to healthcare architecture: 1) windows and their impact on patient experience and healing; 2) calming environments for patients and staff; 3) wayfinding /spatial navigation in complex buildings; 4) privacy issues in the healthcare setting; 5) interior architecture effects on hospital staff.

The goals of the 2004 meeting were to develop a series of specific hypotheses based on the categories explored in the first workshop. Distinguished scientists represented expertise from leading institutes and universities, and several past presidents and executives of the American Institute of Architects joined architects accomplished in the design of health care facilities. Participants developed a series of hypotheses with a view to developing neuroscience experiments to increase our understanding of design on neural responses within the health care environment.

Discussions also explored the tension between the application of 'soft' and 'hard' sciences to architecture. Historically, knowledge of architectural design processes was experiential, with learning growing from one project to the next. Sociological and psychological methods that observe 'what people do' in architectural settings do not provide knowledge of how or why an environmental effect occurs, and require a leap between observation and interpretation. Neuroscientific methods offer the opportunity to isolate cause and effect.

The distinction between soft and hard science has been a 'wedge' issue that separated disciplines for many years. Rather than condoning historical divisions between disciplines and methods of study, a series of experiments utilizing behavioral and neuroscientific methods can provide a comprehensive 'either and' rather than an 'either or' approach. This approach meets the growing demands of health care facility clients who desire 'hard measures' that justify design decisions in terms of experimental and statistically significant and meaningful outcome measures. The additional demands of users compromised by illness, ability or anxiety can also be addressed by research into the architecture of health care settings.

Working teams were formed to focus on each of the topic areas developed by the first workshop. The discussions and hypotheses of each group are outlined below. In addition, the rigorous process of creating hypotheses and executing experiments is also described. (See Table 1)



Table 1
FORMULATION OF HYPOTHESES & EXPERIMENTS

The following steps are used in development of neuroscience experiments to explore how the environment is processed by the brain:

I. Formulation of Hypotheses

- Determine the general question of interest
- Assess the current state of knowledge (perform literature reviews)
- Break the general question into answerable parts
- Formulate a hypothesis

II. Devise Experiments

- Measure widely
- Define what is to be measured to test each hypothesis
- Are you measuring what you think you are?
- Specify and control environmental variables
- Specify experimental and control subject groups

III. Establish Controls

- Measure control as well as experimental groups (e.g. double blind study)
- Explore healthy subjects as well as patient responses
- Differentiate hard from soft findings
- Do counter experiments to validate or disprove the experiment

IV. Analyze Findings

- Conduct statistical analyses
- Determine significant results
- Consider sensitivity, specificity & efficacy

V. Interpret Results

- Derive interpretation
- Elucidate confounding variables and limitations of the study
- State conclusions and limits to conclusions
- Suggest needs for further experiments
- Peer review of experimental procedures, results and conclusions

VI. Repeat or refine experiments

- Continued exploration of variables
- Utilize findings from earlier studies in design
- Build a 'body of data' and subject to further analysis

WAYFINDING

'Wayfinding' is a term to describe the strategies used to navigate through space. The working group explored the difficulties faced in designing a navigation system for a large complex environment such as a hospital facility. Both route or 'dead reckoning' as well as landmarks and cue strategies have been described in animal and human studies.

Discussions focused on the goal of enhancing hospital function by creating navigation systems that are amenable to patients, visitors, and staff. For the purpose of developing specific experimental suggestions, the group hypothesized that landmarks are critical elements for navigation through architectural settings. A series of experiments were proposed to first define the most effective elements of navigation landmarks, and then to identify the neural and cognitive strategies involved. Investigations of individuals talented in certain navigation skills were suggested as a means to understand efficient cognitive strategies and memory mechanisms. In addition, studies of subjects with disabilities would serve as another layer of comparison to increase the accuracy and understanding of the findings. Conclusions derived from such experiments could be tested initially in virtual environments, and followed with hospital based tests to validate findings.

HYPOTHESIS #1:

It is hypothesized that landmarks are critical elements for navigation

The following provides possible experimental approaches to explore and define the attributes of landmarks that effectively support navigation through healthcare environments.

I. Identify the characteristic elements of landmarks, and determine the most effective features for navigation.

Proposed experimental procedure: neuro-imaging responses to stimuli

- Determine the most easily recognized characteristics
- Test the influence of background stimuli
- Universally understood landmark characteristics
- Investigate characteristics of effective landmarks, and the influence of multiple cues

- Determine neural areas involved
- Identify brain response changes associated with changes in landmark characteristics

II. Evaluate navigation strategies

The method of navigation that individuals use to move from landmark to landmark should be investigated to understand the effectiveness of navigation cues relative to the strategy used.

Proposed experimental procedure: neuro-imaging responses to virtual stimuli or navigation through mock up built environments.

- Methods of movement between landmarks
- Investigate what type of learning strategy that reduces threshold to landmark recognition

III. Explore navigation abilities in different groups

In order to be relevant to health care architecture, the impact of ability, disability, or disease should be assessed in terms of landmark effectiveness for patients, visitors, and staff.

<u>Proposed experimental procedure:</u>

- Data should collected from a large group of subjects to enable statistical analysis
- Sample widely from control, normal, and patient groups
- Both gifted and challenged individuals should be tested
- Evaluate computer game players to determine if they are more adept at navigation

IV. Assess the influence of stressful environments and real hospital settings

The impact of attention, stress, age, ability, illness, and learning or memory strategies should be evaluated in real settings. Incorporate findings from previous experiments in experimental design.

Proposed experimental procedure: Test physiologic responses during navigation through set course in operational setting.

- Measure wayfinding responses:
  - Time taken to navigate to a determined end point
  - Record stress levels before, during and after task

WINDOWS

The scientific method offers a means by which the brain's response to changes in the environment can be measured and correlated with specific outcome measures of importance to healthcare settings. By careful framing of hypotheses, experiments can be devised to explore how each variable of the environment affects a certain brain process, which in turn, alters a specific outcome measure. A broad range of variables and outcomes of interest can be suggested (see Table 2). Further collaboration between architects and scientists would yield a more complete list. Each architectural program would generate a specific list of environmental variables and desired outcomes to be investigated via appropriate neurophysiologic measures.

The object is to consider how each variable of the environment affects a certain brain process, that in turn, alters a specific outcome measure.

HYPOTHESIS #1

It is hypothesized that windows influence the healing process by means of variations in environmental variables affecting brain processes that in turn alter outcome measures.

HYPOTHESIS #2

It is hypothesized that windows influence staff performance by means of variations in environmental variables affecting brain processes that in turn alter outcome measures.

Table 2

EXPERIMENTAL MEASURES

ENVIRONMENTAL VARIABLES

Light	intensity / glare / spectrum / color, direction, source
View	natural, abstract, interior, familiar, animated, dynamic, static,
Air quality	flow, filter
Sound	intensity, frequency, direction / phase
Smell & taste	intensity, type
Touch	soft, hard, intense, texture, pattern, direction
Proportion	scale, volume, relationship
Orientation	horizon, vertical, azimuth
Timing	duration, cycle, pattern, controlled, spontaneous
Contrast	foreground / background, ambiguous, distinct

BRAIN PROCESSES

Sensory Systems	eyes, ears, smell, taste, touch, balance
Brainstem	core, survival systems
Midbrain	emotions, stress, hormone, memory
Autonomic	sympathetic and parasympathetic
Cortical	learning, memory, cognitive analysis
Neuromuscular	voluntary / involuntary, movement

PHYSIOLOGICAL MEASURES

Chemical	hormonal, immunological, neurotransmitters
Cellular systems	biomechanical, biochemical, biomolecular electrophysiological
Muscular systems	electro-muscular, neuro-muscular, movement force / pressure, movement
Cardiac systems	blood pressure, rate, rhythm
Neural systems	anatomy, electrophysiology, imaging

OUTCOME MEASURES

	RECOVERY RESPONSES
Length of stay	Significant change
Medication required	Treatment, pain management
Infection / severity	treatment, antibody, sample, recovery
Immune responses	DTH, antibody production to vaccines, T&B measures, cytokines
Psychological	Satisfaction, pain measurement questionnaires
Behavioral	Observation
	HEALTH PROVIDER RESPONSES
Errors & omissions	
Absenteeism	
Attrition	
Satisfaction	
Efficiency	
Advancement	

CALMING ENVIRONMENTS

The group focused on two distinct issues. Firstly, they defined the elements and characteristics of "neuroscience and architecture (n&a) hypotheses." Secondly, they generated a set of three hypotheses that include these elements.

It was proposed that a "comprehensive" neuroscience and architecture hypothesis could include investigations of physiological and behavioral outcomes of the influence of design environments.

- Certain hypotheses would contribute more to basic science, but not be immediately "applied" to solving design problems, and could be explored in future research.

  Such basic science hypotheses might explore hard-wired environmental memories. For example, how does the brain process 'hard-wired' memories, what is the nature of such hard-wiring, and what is the range of hard-wired environmental attributes?

- Hypotheses that immediately applicable to design problem solving might be considered "clinical/architectural" hypotheses.

  These may include findings related to spatial perception, color, how people "read" different architectural styles, or the impact of different materials on neural responses.

- Certain hypotheses would be both great contributors to basic knowledge and to clinical/architectural practice. These we called "robust" hypotheses.

  Hypotheses that relate brain processes to practical wayfinding issues might fall into this category, especially if the hypotheses bridge basic and applied questions. A good example might be a set of questions related to the nature of cognitive mapping processes, along with questions of what particular landmarks contribute most effectively to people wayfinding abilities.

MODEL

Each hypothesis was expressed in terms of the influence of environmental variables on brain processes, physiological responses, and outcome measures. The table below illustrates how each hypothesis can be described in these terms.

HYPOTHESIS #1:

It is hypothesized that the circadian system and rhythms contribute to reactions to environments.

Hypothesis: Circadian system and rhythms contribute to reactions to environmental variables			
Relationship between environment and outcome			
Environmental Variable Lighting	**Neural Response** Circadian responses	**Physiologic Response** Stress	**Outcome Measure** Sleep patterns
Measurement Methods			
Light spectrum, intensity Temporal pattern	Core temperature Melatonin levels	Cortisol levels	Sleep lab Observation Self report

HYPOTHESIS #2:

It is hypothesized that a certain size space contributes to a feeling of control.

The group considered that the volume and dimensions of a space influences stress levels and can alter the perception and sense of control. An experimental process was proposed that would evaluate the volume and size of a room relative to claustrophobic reactions, and track cortisol levels which indicate changing levels of stress. Neural responses would be related to psychological observation and evaluations.

HYPOTHESIS #3:

It is hypothesized that there are universal pre-set, and hard wired memories common to all humans that can be used in design to achieve certain goals.

It was proposed that hearth, fire, food, sunlight and weather are a class of environmental variables that generate brain responses in common in people of all age groups from school children to the elderly. Such responses are suggested to reduce stress response and produce a calming effect by generating a greater sense of “feeling at home”.

The proposed experimental procedures could include MRI responses to photographic images depicting specific characteristics of the environment. Neural driven responses including cortisol and cardiac rate changes could be correlated with observation and self-reports.

INTERIOR ARCHITECTURE:

INFLUENCE ON HOSPITAL STAFF

The group focused on issues related specifically to the effect of interior architecture on hospital staff, recognizing the high degree of accuracy, responsibility, and performance required of staff over long hours in the stressful environment of a hospital setting. Discussion centered on patient and nursing stations. Other workshop groups considered the effect of interior space on patients. (See: wayfinding, privacy, windows and calming environments reports)

Particular consideration was given to three topics in terms of the specific architectural variables, methods for recording neural and physiologic responses, as well as outcome measures relevant to hospital operations.

The proposed experimental procedures would select neuroscience techniques from a battery of tests available to evaluate specific changes in hormonal, immunological, cardiac, physiological and neural responses. The findings from behavioral observations and study questionnaires could be cross-correlated with physiological responses to validate the significance and validity of the results.

A variety of methods offer a broad 'test battery'

- Observation
- Audio/visual capture of activities/situations
- Survey instruments / questionnaires
- Psychological and neuro-psychological evaluations
- Cognitive performance, attention,
- Physiological measures: cardiac [BR/Pulse] , hormonal, immunological
- Neural measures: [EEG, MEG, VOR, MRI, PET, SPECT)

HYPOTHESIS #1:

It is hypothesized that access to daylight in staff work areas influences staff stress, functional efficiency, performance, satisfaction, and medical errors.

Investigation of the influence of daylighting in staff workspaces on the ease and accuracy of visual acuity and performance, and in relation to outcome measures including errors and omissions, staff fatigue, emotional affect, and stress responses.
The proposed experimental design included comparison of visual discrimination under daylight versus electrical light. The influence of lighting on emotional and cognitive performance should also be assessed under daylight versus electrical lighting.

The architectural variables to be explored include both nurse station and patient rooms. Activities of charting and direct bedside patient care must be considered in the context of lighting strategy (eg. size, type, location, orientation, intensity, spectrum, contrast / background).

HYPOTHESIS #2:

It is hypothesized that the position of nursing stations (centralized or decentralized) influences staff function, satisfaction and patient care outcomes.

The layout of the nursing unit controls access to information and ease of monitoring of patient needs which affects the quality of care. The arrangement of space for private staff interaction near the patient can influence the extent of communication and education that in turn, may affect the quality of care. Consideration of the amount of physical activity required [such as travel distances] should be related to measures of fatigue, cognitive ability and medical errors, memory performance and outcome measures. Proposed experimental processes could examine the influence of nurse station design (fortress vs. open) on neural and physiological responses that affect cognitive and emotional states as well as outcome measures.

HYPOTHESIS # 3:

It is hypothesized that the space, volume, and layout of the interior influences an individual's internal state and performance.

The influence of low ceiling space on internal emotional state, cognitive performance, and satisfaction should be investigated. Evaluation of the position of hand washing units, staff relaxation / rest spaces, and orientation to equipment and facilities influence efficiency, stress, and performance which can indicate preferred design. The ease of movement through a facility and its influence on errors and accidents should also be considered in the context of movement through doors with medical equipment, and managing patient movement.

HYPOTHESIS # 4: Visual Environment

It is hypothesized that the visual arrangement and parameters of urgent versus routine notices related to patient care can influence communication and ease of response to urgent situations.

The layout, location, color, symbols, number of signs may influence the speed and ease of interpretation of vital information.

HYPOTHESIS #5: Noise

It is hypothesized that the level and character of background noise influences staff performance, communication accuracy, errors and omissions, stress levels, and satisfaction.

Investigation of the quality and intensity of non-verbal sounds should be considered in the context of cognitive, emotional, and functional measures.

PRIVACY:

PATIENTS & HOSPITAL STAFF

A series of hypotheses developed through discussions focused on the definition of privacy, and its importance to patients and staff within the hospital environment. A set of assumptions were derived that define the importance of privacy in hospital environments.

Assumptions:

- Inappropriate stress is a deterrent to healing
- The need for privacy is inherent in human nature and in community behavior.
- A lack of privacy will increase stress in normal humans
- Privacy is a necessary element of healing and caring (probable, but not tested)
- Clinicians' ability to provide appropriate and timely care will be improved in an environment where privacy either exists or can be created
- Threshold and necessity for privacy varies across individuals and cultures
- A sense of privacy is associated with possessing an appropriate level of control given a specific circumstance
- Providing patients and clinicians with sufficiently flexible controls will improve the ability to achieve privacy and will improve health outcomes.

Additional Variables to Understand:

- Are patients different than normal healthy individuals?
- Does the set point for the need for privacy change when people become ill?
  How and why? How do we respond as designers?
- Is there a range of stimuli that will provoke normative privacy responses in spite of the variability?

HYPOTHESIS # 1:

It is hypothesized that patient rooms that address patient and staff needs for privacy affect health outcome, staff satisfaction and cost efficiencies.

It was proposed that the sense of privacy could be evaluated relative to changes in patient rooms that alter:

- Boundary control
- Acoustic control
- Variability of social setting within the room
- Privacy for consultation
- Control of visual access to the bed

The above could be assessed in a series of smaller investigations. Supportive hypothesis and investigations that could form the basis for several research initiatives is described below.

HYPOTHESIS #1:

It is hypothesized that accommodating behaviors that enable the sensation of privacy within usual surrounds might enable a sense of privacy in what might be a strange place. Accommodating ordinarily private acts and rituals within the hospital will foster a sense of wellbeing and have positive health outcomes.

Proposed procedures would evaluate the influence of provision of a residential style bathroom that accommodates a range of normal and even luxury rituals. For example, a women's hospital might provide facilities for an elaborate bathing experience (shower, tub, soaking, sink, flowers, candles, visit, view, color, privacy). Behavioral observation, self-report, emotional, cognitive and healing outcome could be assessed.

HYPOTHESIS #2

It is hypothesized that making a variety of privacy levels available in the patient room will allow patients, visitors, and clinicians a greater opportunity to find privacy, and in so doing, will reduce stress and improve health outcomes.

An experimental design could explore the impact of allowing a range or choice of places within each patient room. The influence of a room that has niches and places in different relationships on neural responses could indicate changes in stress, cognition and healing outcomes. Comparison with ‘bed-centered’ rooms would form a control condition.

HYPOTHESIS #3

It is hypothesized that the range of needs for privacy, intimacy, and community is variable across culture and situation. Allowing for choice of place will allow for accommodation of that range, and ultimately reduce stress levels.

Evaluation could explore the influence of provision of four levels of space within the widest range of situations in the hospital: public, semi-public, family and personal.

HYPOTHESIS #4

Providing patients and clinicians with the ability to control noise levels will result in achieving greater privacy, lower stress levels, and better health outcomes.

Investigation of the influence of provision mechanisms for patient, family, and clinicians to control noise levels should be evaluated (e.g. doors, earphones, white-sound generators, muffled wheels, absorbent surfaces, soundproofed walls, rules that restrict staff noise levels.)

HYPOTHESIS #5

The sense of privacy will be increased if the behaviors of others can be controlled and predicted.

The efficacy of a rule that one must knock before walking into a patient room could be evaluated in the context of healing response, stress levels and outcomes.

HYPOTHESIS #6

Un-moderated visibility of a patient increases stress, and for most patients the positive returns of greater staff observation are more than offset by increases in stress.

Test the effect of a bed positioned so that it is not visible from the public corridor.

HYPOTHESIS #7

The places of interaction where privacy can be important are continuous throughout the experience of the hospital for patients and physicians. Providing a continuum of experience where privacy can be established will make it easier to establish privacy within the places of primary transaction.

Evaluate the effect of controls for patients and clinicians that allow them to establish privacy from front door to floor and from parking place to bed.

CONCLUSION

Neuroscience and Architecture

Historically, behavioral and psychological studies observed the impact of the physical environment on human responses, and proffered suggestions on how design could be adapted to people's needs. Technological developments provided the means to measure human physiology and ergonomic analysis of the interaction between body and form. Now, a new layer of knowledge can be applied by using the instruments recently developed in neuroscience in order to understand how the brain perceives architecture, and how it responds to place. In addition, neuroscience can tell us about the body's response during motion and the resultant dynamic changes in the perception of place. Further investigations can enhance understanding how the senses receive input and how cognitive processes, memory, learning, and emotions alter the perception of stimuli received by the senses.