Neuroscience and Health Care Facilities Workshop: Detailed Report

The National Academy of Sciences / Woods Hole MA / August 13-15 2002

Sponsored by the American Institute of Architects and the Vinyl Institute

Meeting on Neuroscience and Health Care Facilities Design

Woods Hole, Massachusetts
August 13-15 2002

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and the role of neuroscience in that future. They encourage the participants to embrace this new knowledge base and approach it with great passion.

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Meeting on Neuroscience and Health Care Facilities Design

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Preface:

While it was originally contemplated that the workshop would concentrate on finding research projects related to healthcare facilities that would be based in neuroscience, it turned out that there were two ways of approaching the bridges between these fields.

The first one was to have architects define aspects of healthcare facilities that seemed appropriate to explore, and then have neuroscientists propose appropriate research methods. The methods proposed were generic scientific techniques that were not necessarily tied to neuroscience. The second approach (and the one originally contemplated) was to have neuroscientists describe the kinds of research they were doing in understanding the creation of experiences by the human brain/ mind, and then to identify experiences that patients, doctors, and visitors have had in healthcare facilities that might be explored with such neuroscience methods. In this report we will call the first approach "methodological" and the second "neuroscientific".

During a series of interviews conducted for a video record participants were asked to reflect on the subject of the workshop. The following excerpts from these interviews show the emerging two approaches (more detailed information about participants who names are shown will be found in appendix B):

Joan Saba: I think we are on the brink of something really fantastic here. It is just mind boggling to believe that we will actually be able to prove what the effect is that space has on an individual. Architecture is an art – it's design – but it has to be based upon some facts, some proven facts so that we know that we are doing the right thing. We need evidence to help us do our work.

Roger Ulrich: Traditionally, hospitals have been designed in ways that made them very functionally efficient, but all too often they failed from the standpoint of not meeting patients' emotional or psychological needs. Rather than being designed in ways that helped patients to cope with the burden of acute stress that often accompanies illness and injury, healthcare facilities were created in ways that, unknowingly, could actually add to the stress load of patients.

Frank Pitts: There's a great deal of knowledge that I think we have implicitly and intuitively – but if we really, actually knew that it was so and if we actually knew why it is so, then we might be able to design in a way that was creative at another level in terms of really fine-tuning a response and getting something that really sang and was resonant. We have had too many accidents.

Terry Sejnowski: The real challenge that we face is to try to understand and get to the bottom of how the human brain actually behaves and reacts to different environments. We're just beginning to understand that and it's going to require, first of all, coming up with good hypotheses.

Concepts of Neuroscience

Esther Sternberg made a power point presentation on the immune system and the brain, providing an introduction to the many layers of the brain that underlie our experiences. She defined stress as the non-specific response of the body to any demand. Sometimes the stress response is needed to achieve peak performance (e.g. the top-gun pilot), but it can also become a negative force on the immune system (fig. 1). Demand and control are some of the determinants of stress, and this varies for each individual (fig. 2). Too little hormonal stress response can cause reverse actions from the immune system resulting in arthritis or asthma. Only 35% of complex traits like these diseases and possibly our stress response is determined by genetics and thus 65% is determined by environment. One potential environmental variable is previous experience. Belief systems can also impact the healing process – whether such belief systems are cultural, social, or based on expectations. The effect of belief on healing is called the placebo effect.

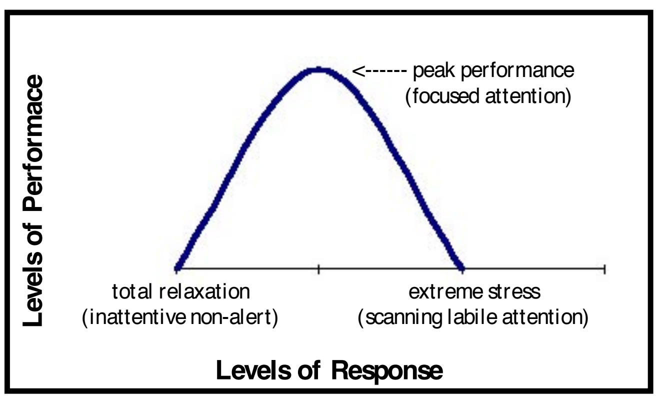


figure 1. Stress Response

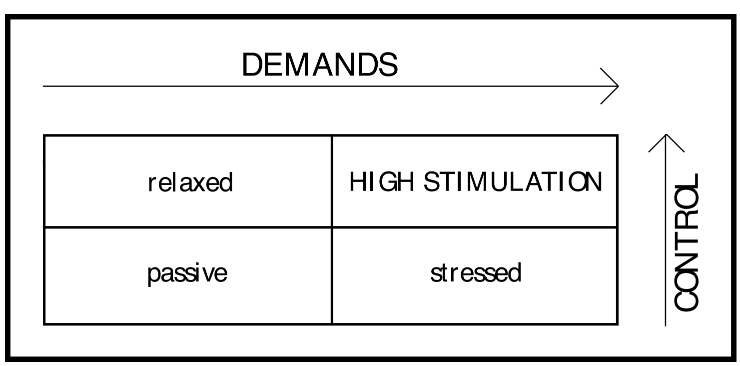


figure 2. Relationship of Demands to Control For a Given Situation

Terry Sejnowski began by posing the question: How do we know something is correct or true? In science there is a procedure for submitting an idea (a supposition or hypothesis) to experimental process. We are often surprised by the answers. It is now possible, using brain imaging techniques, to watch what is happening in the human brain when we think and behave. This will revolutionize our understanding of human brain functions such as language and social cognition. Computational Neuroscience is a way to organize knowledge of the brain at many levels of organization through the use of computers (such as simulations). He then showed a computer-based film on the synaptic processes (using animation derived from electron microscope images). This video provides ideas for scientists working on problems such as the synaptic basis of learning and memory. The model in this film provides a tool to help visualize and understand function – much like using a model of a building to understand what the real building will be like. He also provided examples of areas where advances in neuroscience can help inform the design of hospitals:

- The hippocampus is important in long-term memory. We now know that neurogenesis occurs in the hippocampus, but the survival of the cells depends on sensory stimulation and motor activity. This suggests that patients who are recovering should be active and the environment a stimulating one.

- The brain has a dozen neuromodulatory systems that are important for regulating arousal, mood, attention, memory, reward and exploration. For example, low levels of serotonin are associated with depression and risk-taking behavior, and high levels of serotonin are found in primates with high social stataus (Prozac increases the level of serotonin activity). Serotonin levels are increased by motor activity like walking. Hospitals should be organized to encourage patients to walk every day if they are able.

- The circadian rhythms in the body and brain are entrained by light. Hospital rooms should be brightly lit and kept on a 24-hour light/dark cycle.

- The treatment of patients for recovery from stroke is rapidly changing from requiring long bed rest to a recovery process based on exercise – walking and talking as soon as possible. This suggests that hospitals should make it easier for stroke patients to get physical therapy.

- Overall, these findings suggest that the hospital setting should be an environment that actively engages patients rather than the passive setting or experience that is now the norm.

Measurement with Brain Scanning Techniques

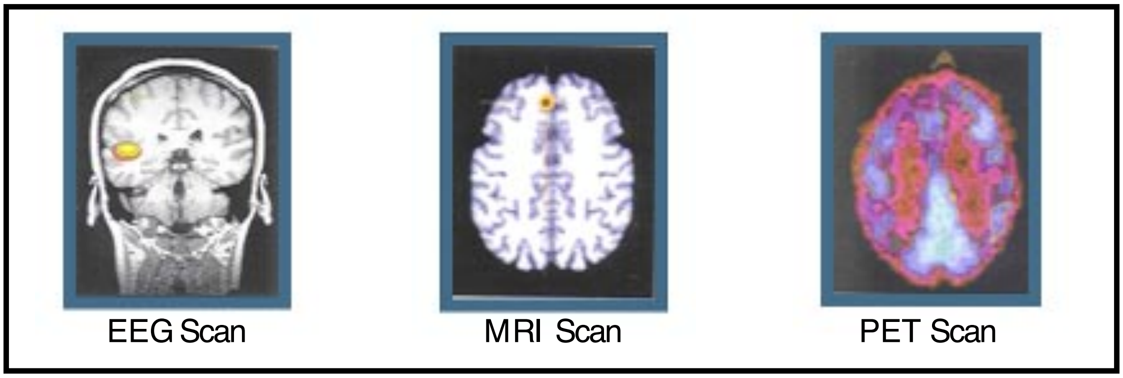


figure 3. Examples of Scanning Results

John Eberhard: One of the issues that's involved in any research like this is how do you measure the sensory input to mental state? There are number of ways of measuring, and I thought it would be useful to talk about some of those on an informal basis. And I know Patrick did a lot of research on scanning equipment. Why don't you talk about what kind of scanning equipment there is and how it can be used?

Patrick Russell: One of the relatively few experimentally quantifiable techniques that have come on line in the last ten or twenty years that have let us interact with humans the way we have with animals are the series of brain imaging techniques. In animals, you can actually look at the biochemistry. You can look at individual cells and record and get rich behavior output. At that level, we have a long way to go just in understanding interactivity. We're coming in from the top level if you will, so we can use imaging techniques that maybe give us a picture of the brain at a spatial scale of around roughly a millimeter. Some techniques you can think more along the lines of a centimeter (for example, a square patch of cortex).

We find that we can image basic sensory input modalities. We can examine what happens in the visual system as it moves through the primary visual areas to higher visual areas. The techniques are starting to be highly enough resolved that we can even look on a smaller scale and ask how is the output from the two separate eyes parsed. How are the colors and the lines in our visual environment interwoven within the visual cortex? And these are structures that are down at the scale of under a millimeter.

We can start to get some very detailed pictures of how our sensory environment is processed by the sensory input areas of the brain. Furthermore, we can start to take pictures of how we interact with that environment. Motor control is one of the most obvious areas and one of the easiest to study using these imaging techniques. We can start to look at questions like when you are given a mental rotation problem (i.e., you are given a picture of something, then you're asked in your mind to rotate it 180 degrees). And we see hints that not only does it involve your sensory areas, but it may tickle your motor control areas as if you are reaching out and mentally rotating it. When you are thinking, you are actually in a sense performing imagined motor actions. Such things could be very relevant to the types of questions we'll ask in architecture.

We have two different kinds of techniques, apropos of our discussion today. One of those will give us a spatial picture, a detailed spatial map of the brain. These are techniques like functional MRI, PET scan, etc. What we can do is measure changes in brain physiology and I want to emphasize that word 'changes.' I'll come back to that. We can measure where blood flows, for example using functional MRI.

It is changes in the brain as a result of changes in our environment or in our actions. So we're not getting a direct picture of neural activity, but studies, detailed physiological studies are suggesting that there's a very direct correlation between where in the brain large populations of neurons are becoming more active - which is really when we are talking about brain activity what we really would like to know. Where are your neurons firing and how are they interconnected?

One indirect very useful measure is using these physiological mapping techniques that can tell us where the blood flow is increasing in order to support neural activity. So functional MRI is one of the tools and so is PET.

PET is positron emission tomography, a technique whereby we can label chemicals that we inject into the blood and then they settle in the brain depending on the local physiological process (fig. 3). For example, sugar metabolism, we can look at where the sugar is going in the brain and being burned to support neurological activity. And those techniques are useful because they can be quantified. You can actually say this much more sugar is being burned in this part of the brain. And you can make baseline measures. How much activity is your brain undergoing under so-called resting state? How much activity at an active state? And you can make measurements like that. Functional MRI which has the primary advantage that it's available to us in a much greater number of locations. It's less expensive, and it's non-invasive in that you don't have to inject any substance into the blood, much less a radioactive one. You can study totally normal populations with relatively little difficulty. And the disadvantage is that it's not quantitative the way that PET is. We can only make difference maps of activity. You can never make a functional MRI picture of just simply brain state A and ask how much blood is flowing in each part of the brain. Rather, you can provide a baseline state.

Let me give you an example. We'll place a subject in an MRI scanner in total darkness if we're studying the visual cortex. And we need to take a series of images with the subject in total darkness. That gives us a set of MRI pictures (fig. 3), again, that are not quantitative but that gives us a baseline picture of what the tissues look like in that state. Then, we start flashing an image on a screen that the subject is viewing in the scanner. And we again collect a series of images with the subject viewing that visual stimulus. In a simplified way, imagine we subtract the images in the baseline dark state from the images in the state of viewing the flickering stimulus. And then we can simply get a map of where the differences in activation level, the differences in blood flow are occurring. If you're curious, the reason we can do this in functional MRI scanners without using any injected tracer is simply that when your brain is more active in a certain region, the amount of oxygen extracted from the incoming blood changes, not necessarily in the direction you expected. But the oxygenation state changes under the increased demand. And it turns out to be just forces in nature. MRI is sensitive to the oxygen level in the blood, whether your hemoglobin molecules have oxygen in them or not affects their magnetization properties. An MRI is based on strong magnetic fields, and so we can actually take indirect pictures of how oxygenated the blood is. But only in this differential mode, so we can only compare two brain states.

So, again to emphasize, whenever one wants to design a functional imaging study where we're looking for just these spatial maps, you have to conceive of comparative states. You have to have a baseline mental state that can be compared with another one. For example: imagine we say we want to know what happens in the brain when a person who's provided a virtual reality image of walking through a well-designed building is to be compared to a walk through of a poorly designed building.

Janet Baum: Could that be done on a child while he's sleeping and having these wonderful dreams?

Patrick Russell: It poses significant challenges because of the need for that baseline state and because functional MRI is exquisitely sensitive to head movement. We really want our subjects holding. I'm not necessarily totally current on the state of the art, but techniques are being developed to overcome head movement.

Lloyd Siegel: Why flickering?

Patrick Russell: Oh, why flickering the image? Because that provides a much more vibrant signal in the visual cortex. We respond much more strongly to a constantly changing stimulus at a few hertz . That's an example of something you can quantify using such studies. You can map how much signal change occurs as a function of how rapidly you're flickering the stimulus. If it's very slow, it's not as big a signal change from darkness. If you flicker it around six, seven, eight hertz, that gives you the largest possible change. And then if you get to too much faster than that, the signal goes back down. So certain things can be quantitative using these differential techniques.

Roger Ulrich: You stress that the functional MRI is a super magnet. Does that imply that to project a digital image, for example a baseline picture or building interior or window view that you wanted to compare that with another window view , that this would be projected on plastic, glasses, goggles?

Patrick Russell: Almost all of the above are among the techniques employed to get your visual picture to the eyes of the subject. How many of you have had an MRI scan? So you know that in most cases you're in this fairly narrow tube. The main reason we lose subjects in studies from doing the studies is claustrophobia. It's a bit much for some people. So we do have a limited geometry. Systems have been devised for projecting into a mirror and then into the patients eyes, goggles, LED. So that's just one example of the most basic type of way of tickling the visual cortex into activity. You don't have to flicker the image. You can now simply display a video of an environment for example. So you could just display a real time video image.

Roger Ulrich: Could you do an animation, realistic of a kind of pedestrian case walk-through? Is that possible?

Patrick Russell: Absolutely, anything you can film onto a video, you can then project it and have the subject see it. There are some newer techniques that do start to let us look at just sudden changes, single shock changes in the blood flow using fMRI. I'm not going to go into detail on those because they're a little new fangled and not as tried and true. In general for these differential state maps that I've described, it would be that you would only get an aggregate image of the general state of the brain during the display of this video.

Another major type of brain imaging technique that I think will be very relevant to this community as well (with very different constraints and a different picture of the brain) would be more time resolved techniques such as - electroencephalography and magnetoencephalography, EEG and MEG.

Both of these techniques are very similar, and they mean nothing more than measuring the electron-magnetic fields produced by neural activity. This is an area that has seen some huge advances in the last ten or twenty years. MEG is one that has the advantage which the magnetic fields produced by large aggregates of neurons firing can be recognized. We have all these neurons with their electrical impulses traveling down the axons from one neuron to another, and then you have some electrical activity as one synapse is excited and then changes the excitation state of the next neuron. All of this is electrical except chemical interaction which happens at the synapse. Both EEG and MEG are looking at the combined electrical activity of millions of these neurons. And that produces a signal strong enough that it can be measured with detectors placed outside the skull. In studies of animals, often we're implanting electrodes. With human beings, we can paste or even just place caps full of EEG electrodes on to the scalp and measure those electric fields, similarly with magnetic fields (fig. 3). Although this techniques is much rarer and much more expensive, it has the advantage that the magnetic fields that come from the brain are not changed by the skull as they pass through. And so you are getting a direct look into the brain's magnetic fields. In EEG, the fields are altered by the presence of your skull and other soft material. MEG may give us better spatial resolution, but both techniques give us temporal resolution of the changing electric patterns of the brain in the order of a millisecond.

Using these techniques, you can make moment by moment charts of the electric activity of the brain. An example of this might be, if we're in a relaxed state in a well designed hospital room, is there a certain rhythmic pattern of activity in the brain? We know the brain has certain basic rhythms that are present, and the amount of the frequency content of the brain changes depending on our state of vigilance or relaxation. So there are indices of vigilance or relaxation that we can just measure by looking at these traces of electric and magnetic fields. If we want more detailed information (for example: where in the brain specific field patterns are coming from) there are techniques that let those fields be mapped at lower spatial resolution in the brain.

Some of the most promising work is combining these modalities. You could produce maps that are detailed in space using something like fMRI of the brain map of activity patterns. Couple that with an EEG recording that gives a detailed picture of what's going on in time in the brain. And when you compare a rough spatial map of electric field patterns moving moment by moment with a static map of those areas of the brain that were activated throughout the course of the experiment, you can get a strong combined sense of where and when things are going on in the brain. I would predict that a lot of our questions about interaction with architectural spaces will have as much to do with the time domain as the spatial domain. We find that many of the deeper questions of consciousness are states of attention. For the kinds of questions we're asking, what's affecting our mental and emotional state in the environment, I think we'll find both kinds of techniques contribute.

Time resolved maps of brain electric field activity and spatially resolved maps of brain blood flow changes will both be important.

Bob Horsburgh: Has any detailed work been done to try to tease out emotional overlay to sensory input?

Patrick Russell: All of these things are being worked on. I'm not current on the state of the art here, but there is a rule of thumb that one can apply to these kind of experience. As we move from simple visual input and simple motor control tasks further up the consciousness ladder into more subtle questions of emotional state the signals get smaller and smaller. So we're dealing with much more, much richer combinations of brain areas producing smaller signals. And again as we move to these questions of emotional state and consciousness, we're finding that the interactivity between brain areas becomes as much the domain of our finding as just which areas are activated.

Julian Thayer: Patrick, can I follow up with some more comments on a couple different points? One is the relationship to emotion. There's been quite a bit of work done on emotions and other types of structures. And what's emerging is that there may be a similarity among brain structures that are associated with emotional processing, information processing, and physiological regulation. So people in different areas have identified a core group of structures that seem to be activated in all of these states. And some of us have put these together in a model of how a unified organism would work. Structures that are associated with emotion are the same ones that are associated with information processing and are the same ones that are associated with the stress systems that Esther was talking about. This is a fairly recent advance that is pushing the field forward as people working from different areas, including animal work, are starting to see that their findings are converging on a set of structures. What's important is that the techniques we've been talking about have primarily been giving us static pictures of what's going on. The ability to look at that temporal sequence of activity is fascinating. What's becoming clear is that these sort of static pictures are oversimplification, even for the simplest of tasks. What's going on for the complex tasks that we're talking about such as wayfinding is that many different areas of the brain are involved. There's a lot of work that's going on, and I think the future is really bright for this. However, I want to add that these techniques are not easy to use, and there's still a lot of the physics and engineering that has to be worked out. For example, it's not clear what it means when an area of the brain is active. When you see something light up in one of these, does it mean that that set of neurons is involved in excitatory action or inhibitory action? You don't know if that lighting up means that that part of the brain is actively involved in something or actively involved in shutting something off.

Joan Saba: So, how does that impact on the things that people talked about yesterday, such as measuring the amounts of chemicals. My question is: when the different parts of the brain light up so that you can track the electrical or magnetic images, how do we know what's good and what's bad? For example, how do you know, you know what's good stress, what's bad stress?

Esther Sternberg: We're not at a point where we can do brain imaging in an individual who shows up and then say, oh you have depression or oh, you're happy or you're sad. We're not yet at a point of answering the question you just asked. We're at a point of doing all of the psychological testing, the physiological testing and knowing the condition of that person based on standard psychological testing and clinical diagnostic tools. And then doing the imaging and saying okay, in this state we see this set of structures. In another set we see another set. So maybe at some point down the road it will come to the point that we will be able to do so. Much the same way we use an X-ray to see a hole and know that that means that a patient has pneumonia or cancer or something. But we're not at that point yet.

Concepts of Health Care Faciltities

Ron Skaggs described the Guidelines for Design and Construction of Hospital and Health Care Facilities developed by a multidisciplinary Health Revisions Guidelines Committee under the auspices of the Facilities Guidelines Institute and The Academy of Architecture for Health of the AIA. He indicated that this committee would be open to any additional input from neuroscience evidence.

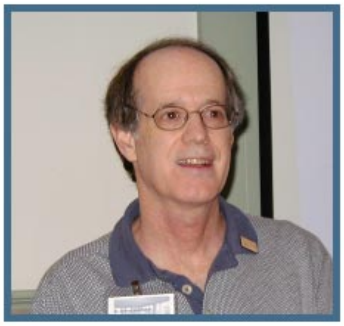
The following are examples from these Guidelines (bolded phrases are of interest to workshop participants):

Guidelines Appendix A7.2.D.7 :
" Windows should be provided so that each patient may be **cognizant of the outdoor environment**. Windowsill height should not exceed 3 feet above the floor and should be above grade. All windows in the unit should be fixed and sealed to eliminate infiltration."

Guidelines 7.6 Psychiatric Nursing Unit:
" When part of a general hospital, these units shall be designed for the care of inpatients. The environment of the unit should be characterized by **a feeling of openness** with emphasis on natural light and exterior views. Various functions should be accessible from common areas while not compromising **desirable levels of patient privacy**. Interior finishes, lighting, and furnishings should **suggest a residential rather than an institutional setting.**"

Frank Pitts described the Academy of Architecture for Health. How it came into existence, the fact that there were now 3750 members, and asked David Allison to talk about the Coalition for Health Environments Research (CHER). David indicated this interdisciplinary committee undertook applied research through contracts with others. They have recently explored subjects such as " color in healthcare environments" and " rate of change in hospital laboratories" .

Related Work in Health Care Research



Bob Horsburgh presented some alternative approaches to problem solving:

- Inductive reasoning
- Deductive reasoning
- Clinical trials with comparative hypotheses

He proposed that a designer should analyze very carefully what needs to be done and then after the design has been completed to go back and determine whether or not the original intentions were met, and if the original design hypothesis was indeed correct. If the hypothesis is found to be correct (the space is serving the intended purpose) and there were no unintended consequences, then something is known and should be recorded in order to be used again in the next design. Thus an iterative process is established for determining what is right.

Roger Ulrich talked about state-of-the-art research on healthcare facilities that he has been conducting in the U.S. and Sweden.

Psychological and social needs are largely disregarded in the design of healthcare facilities - and often marginalized in creating visitor and staff spaces. In spite of traumatizing hospital experiences and major stress from illness, little priority has been given to creating surroundings that calm patients, or help to strengthen coping resources and healthful processes. Rather, the functional emphasis often produced environments now considered starkly institutional, stressful, and detrimental to care quality.

There is a growing awareness internationally among healthcare administrators and medical professionals of the need to create functional environments that also have patient-centered or supportive characteristics to help patients cope with the stress that accompanies illness. The key factor motivating awareness of facility design has been mounting scientific evidence that environmental characteristics influence patient health outcomes. Many studies have shown that well-designed environments can, for instance, reduce anxiety, lower blood pressure, and lessen pain. Conversely, research has linked poor design - or psychosocially unsupportive surroundings - to negative effects such as higher occurrence of delirium, elevated depression, greater need for pain drugs, and in certain situations longer hospital stays.

Further, staff as well as patients benefit from good design. Supportive design of staff spaces can help employees cope better with workplace stress, reduce absenteeism, may lower turnover, and in several ways support employees in providing quality care. Well-designed staff environments are a positive factor in attracting and retaining qualified employees.

Research suggests that healthcare environments will support coping with stress and thereby promote improved outcomes if the design is oriented to fostering:

- Sense of control and access to privacy
- Social support
- Access to nature and other positive distractions

CALMING ENVIRONMENTS within healthcare facilities

(reported by group leader Joan Saba)

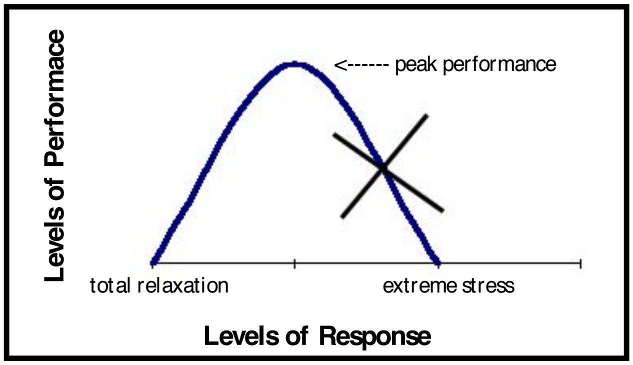


figure 4. Stress Response for Calm

This group decided that calm environments should be defined as being the opposite of stressful environments as per Esther Sternberg's presentation (fig. 4). Stress is a mismatch between what the environment offers versus what is required for the situation. Building design is only one aspect of how to provide a calm environment. People and function of the facility (ie. the operations that take place) are just as important to consider. Being in control of one's environment is an important aspect of being "calm". A calming environment may be different for medical staff versus patients.

Aspects of Stressful for the Patient

- Worrying
- Lack of order
- **Lack of information!**

Aspects of Calming for the Patient

- Engagement of some stimuli
- Ability to shift your thinking
- Feeling of being in control (having options)
- Perception is important
- Satisfaction of the 5 senses
- Givens means to control

Calming Environment for the Patient

- Easy to find your way
- Access to information
- Sense of time (Llyod's ICU Example)
- **Be an active participant in receiving care**
- Familiarity
- Provide the ability to adapt
- Face to face interaction

Calming Environment for the Staff

- Visibility of what's going on (have control)
- Opportunity for privacy
- Need for predictability

- Employee satisfaction

The points they proposed for research were:

a. What is the physiological definition of calm and its variation among people?
b. Consider individual difference factors/parametric studies – focus on where the differences occur and get a "range" of acceptable sensory perception.
c. There is not a universally accepted calming environment.
d. Different people will respond differently – and for some it is not clear that a calm environment is desirable, i.e. an environment that provides some stimulation may be desirable for a recovering neurological patient.
e. Shannon Kraus provided a diagram of the interaction between patients and staff within separate spheres of influence (fig. 5).
f. Patrick Russell proposed exploring the influence of different variables. To quote him "The advantage of applying neuroimaging techniques to understanding calm is that it gives us an environment in which to explore a more physiologically rigorous definition of 'calmness.' It would let us use new clinical populations. If we had to study only clinically populations confined to a hospital and submit them to other stressful testing, we would have a limited population to study. Neuroimaging and other techniques would give us access to a much larger control population of healthy individuals in which to explore the impact of environment on mental state. Here the techniques of neuroscience let us go 'off-line,' if you will, from the clinical environment and do tests on normal populations. Finally, as it pertains to the architectural community, we could study most of the variables that will probably be identified as relevant to stress in an architectural setting. This includes questions of which variables are most robust across populations so that you could actually build them into an architectural space. (If certain environmental variables have a profound impact but one that varies too greatly across individuals, it could well prove futile to seek a optimal value for such variables to be incorporated into a stable environment.) It may also be possible to rank these variables in order of efficacy and hence of cost effectiveness."
g. Julian Thayer indicated that recordings of Heart Rate Variability monitors could be used to measure "calmness" once a theory of data needed was determined. He explained that we have the statistical means to work with a number of scenarios and subject types at the same time.
h. Investigate use of virtual reality to "enable" calmness in the environment.
i. Should all health care environments be calming?

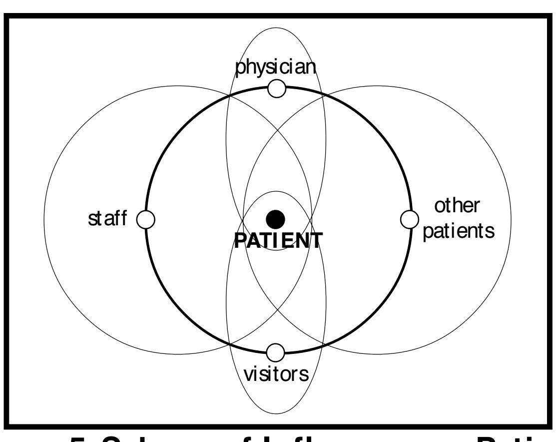


figure 5. Spheres of Influence on a Patient

INTERIOR ENVIRONMENTS

Ron Skaggs: Our assignment was actually interior architectural experiences. We somewhat redefined that into interior environments. What we tried to do was stay on the assignment, trying to define a research question that would be at the basic level. And since I kept wanting to return to applications, it would probably be better if someone talks more from the research side. Jack Snell will go through our groups discussion and conclusions:

Jack Snell: This morning, we were exposed to the very, very complex system of systems that we are exploring here, the human in the built environment. What our group tried to do is understand how all of this works. We have assumed that there is a system of systems and that they're interconnected. So if our task here is to try to understand the influence of the architectural experience on human health or the outcome in a hospital, then we need a system model of the environment, the occupants in it, and the stuff in it.

We needed to try to define the system that we're talking about. And that led to this diagram (fig. 6). It's a first-order system representation. On the left is the "physical environment" which includes the care provider, other patients or visitors or what have you, the physical interior environment of the hospital, the external environment, etc. These are all the kinds of interactions of things that need to be accounted for in trying to understand the influence of the architectural experience on wellness. Next is the patient's equipment for collecting "Sensory Inputs." The third block, the one on the right represents what goes on within the patient, the things Esther and Terry discussed which influence thinking and wellness or health. Outside of these blocks we have indicated the general domains of various disciplines we bring to the problem.

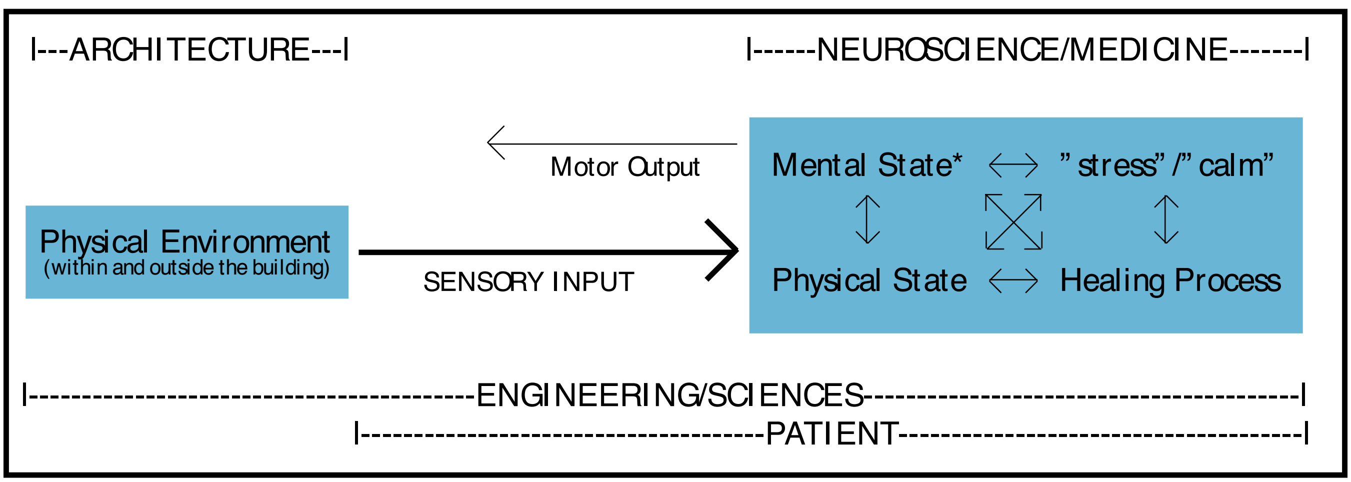


figure 6. Model of system of systems

In terms of research, then, of how this experience - that is that set of influences captured as an experience - affects a patient's physiological or mental outcome we came back to the notions of control for comfort or well-being. The top level research question is whether or how to operationalize a model like the one represented by our diagram. As to other research questions, there's a need for some very significant epidemiological work to just sort out what are the major influences. The ASHRAE guide approach to measuring comfort is at best first-order as it relates to issues we're trying to address here. There are some very significant measurement issues with respect to all of these sensory inputs. We need a scientific knowledge base to explain, measure, and predict outcomes. To do this as a better underpinning for architectural practice, we need to be able to develop and test models - elements of these systems and put them together.

Some Research Questions identified by the group:

1. How does the environment contribute to causing disease? Define an environment that does not make things worse.
2. What can the physical built environment do?
    - · To minimize discomfort
    - · Do no harm but rather be a positive modifier
3. Should the environment be static or dynamic?
    - · Changes in care
    - · Different syndromes
4. Which way do you go?
    - · Universal
    - · Multiplicity of spaces
    - · The dilemma is how do you adapt
5. Can we prove that comfort and control (choice) are important?
    - · If so – what are the determinants of control and comfort?
6. Is the specific disease/ailment a major determinant of what the interior space should be?
7. How do you identify and quantify those influences on the diagram and what do they depend upon?
8. What is the impact of corridors as opposed to individual rooms or groups of rooms?
9. What interior environments are the most important to study? > Those with the greatest impact.
10. How can an environment support multiple patient desires?
    - · Quiet v. Active
    - · Warm v. Cool
    - · Light v. Dim

The Group felt that consideration was needed for the most cost-effective research approach (i.e. epidemiology, molecular biology, physiology).

Giovanni Cizza: If I may, there is a reason why this research is difficult to determine. We have a lot of disciplines that are represented, and there were a lot of presentations that ranged from electro-physiology to endocrinology. I think that at the stage in which the field is at the moment we should ask ourselves the question which approach you do first, not to convince ourselves but to convince people outside of the community that this is the real effect. We need to show with some convincing biological studies that there is an effect that is clearly significant. It can be done with so-called prospective-retrospective studies where you can identify two or three facilities in the country with good records. Maybe one of the facilities has windows and the other without windows. And then you show that there is a difference. Something as straight forward as this. I think that there should be an effort to prioritize and to convince people outside of this room that this is a very important thing. And then you can go in any direction.

Terry Sejnowski: One of the things that we're trying to identify is what are the things that we ought to be varying. Which are the things most likely to give us a big outcome, right?

Bob Horsburgh: I'm not going to argue against an epidemiological approach, obviously. The real issue is what are the testable hypotheses. I know, in our group, we couldn't come up with a testable hypothesis. We couldn't get a definition of what privacy was. So you couldn't do an epidemiological study. But you have to first of all have a hypothesis. And, you know, privacy is not a yes/no thing. It's not like these people have it, and these people don't, and you can see if there's a difference. It's a continuum, and maybe too much privacy is bad and too little is bad and somewhere in the middle is best.

Giovanni: That's a good point.

PRIVACY for patients and for physicians

This group found the definition of privacy to be perceptual and hence one that will vary from person to person. [Dictionary says: " freedom from the intrusion of others in one's private life"].

Bob Horsburgh: We felt like privacy was not a very easily defined concept. We spent a fair bit of time talking about it. First of all, we determined that privacy is not just a concept that relates to a physical space. You can have privacy violated by smells and sounds so that it's not just limited to physical space. In addition, it's a perceptual quality in the sense that something might seem like it threatens your privacy. If you have control over it, it might not threaten your privacy - it's more the potential than the reality. You can be worried about the privacy of your medical records. The definition we finally came up with is: Privacy is a state of mind describing a more or less acceptable state of social interaction. Thus focusing on the concept of interactions with other people. We also decided to spend most of our time talking about individual privacy as contrasted to group privacy.

Privacy ≠ aloneness

How do we define privacy?
- Psychological comfort with degree of interaction
- A state of mind
- Measurement tool
- Ability to choose social interaction comfort

There were a couple of research questions that we thought would be important to look at:

a. Are there cultural predictors or perceptions of privacy? Are there cultural differences in expected levels of privacy?
b. Does it vary with your socioeconomic status?
c. Did it vary with your racial or ethnic background if you were from a foreign country?
d. Does your sense of privacy relate to what is acceptable or not acceptable? Desirability versus availability (fig. 7). Keeping in mind that it can be both ways. You may want to be in a group of nice people. You may not want to be in a group of people who threaten you. You may want to be alone.
e. Does your perception of privacy change when you are sick versus when you're well? Compare people who are sick and then after they got better and recovered. Did they have a different sense of privacy?
f. Find some sort of a privacy meter (see below).
g. Simulate certain situations in having people undergo invasions of privacy and see how they respond to them.

h. Once a good definition of privacy is found in relation to its meaning to people, it would be very important to then move on to the neuro-imaging study phase. One in which you would look to see when people have had their privacy violated or restored, what part of the brain is activated in response to that kind of challenge.
i. What part of the brain is activated when privacy is violated?
j. Would ability to control privacy be measurable on brain scans?
k. Is there a culturally dependent bubble of personal space?
l. Can privacy be a hindrance to healing as in physical therapy or intensive care units where privacy cannot be provided?
m. Generate definition of privacy. What are its qualities?
n. What do we want to know about privacy?
    - Length of stay
    - Rate of medical errors/correct decisions
    - Occurrence of "interruptions"
    - Staff privacy, visitor privacy and patient privacy
        - Measure health outcomes of patient
    - % cured vs. morality
    - state of being
    - stress outcome as a predictor of health outcome
        - variable = PRIVACY
        - Does privacy correlate to stress?

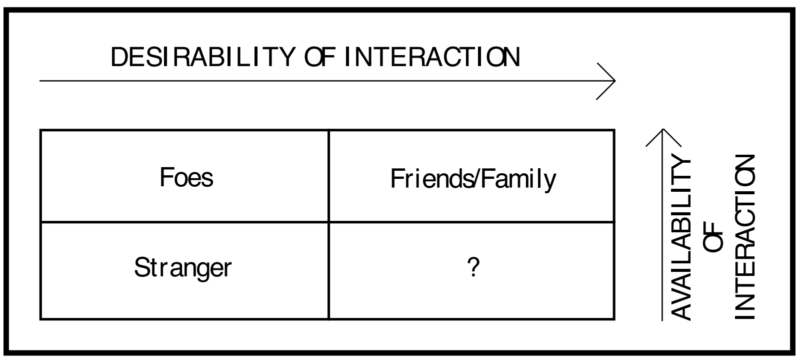


figure 7. Social Context of Availability of Interaction

The group's notes regarding a privacy meter or "**privameter**" reflected a number of ideas:

1. User survey
2. Measure stress factors
    - Serotonin
    - Testosterone
    - Corticoids
3. What is the range to calibrate privacy perception?
4. Measure what is happening
    - Vary scenario
    - Vary subject
    - Interview prior to experience then record outcome with subject
    - Threshold conditions: transitions between interactions – comfortable or not
    - Isolation of jogging or swimming
    - Passive disruption of sense of privacy
    - TV viewing is learned behavior = crutch for social interaction not present in hospital environment
    - Food preparation and meals stimulates interaction

WAYFINDING in architectural settings

(reported by Mardelle Shepley group leader)

This group felt comfortable with the concept of wayfinding as it does not need to be redefined. They showed floor plans that indicated examples of difficult paths (fig. 8). Indicated that difficult paths are a special problem for patients with Alzheimer's. Spatial orientation is a fundamental skill. It plays a more significant role in memory than color or symbols. For example, if you are looking for your car in a lot, color clues are not as helpful as spatial configuration or landmarks. Many cognitive psychologists believe that general information is stored in memory in parallel to the way spatial information is processed.

- What is seen? What is not seen? How is perception impacted by stress?
    a. Relationship between concentration and perception
    b. Virtual reality could be used to test
- Consider physical competence
    a. Compromised hearing, dementia, language
    b. All studies should address the uniqueness of the population
- Wayfinding disabilities of people
    a. Being lost is a fundamental fear
    b. Analysis of the physiology of being lost is difficult
    c. Odor and color can help orientation
    d. Spatial configuration is the most significant factor
    e. Problem is how to break the environment into its individual variables
    f. Could you study wayfinding in neonates?
- How do you measure stress when lost?
    a. Blood pressure
    b. Pulse rate
    c. Galvanic skin response
    d. Blood chemistry
- How do you measure frustration level? Questionnaires?
- What are biomarkers of stress as they relate to the physical environments?
- What are the biomarkers of spatial maps?

They suggested the following research topics:

a. What is seen and not seen when someone is in a stressed state?
    i. A study might focus on the ability to concentrate when lost.
    ii. Could use virtual reality to simplify this process
b. What are the biomarkers of stress as they relate to the physical environment? The first phase would focus on which variables in the environment should be isolated and focused

on.

c. What are the biomarkers of spatial maps or physical location? This would look beyond the role of memory.
d. What is the physiological measure of lost?
e. Because we are aware that a little stress is good, is there a physiological measure that indicates when the appropriate amount of stress has been exceeded?
f. Kinesthetic intelligence is not commonly acknowledged. How does this relate to wayfinding?
g. Understanding what is seen and what is not seen when one is stressed and trying to find one's way.
h. What are the biomarkers measuring stress associated with attempting to find one's way.
i. Studies on people who are good at wayfinding; what are their neurobiological characteristics.
j. How does being lost manifest itself physiologically.
k. A summary of research that has been done on navigation.
l. Perhaps an analysis of the movement patterns of dancers (choreography) would be useful in identifying a non-visual method for wayfinding.

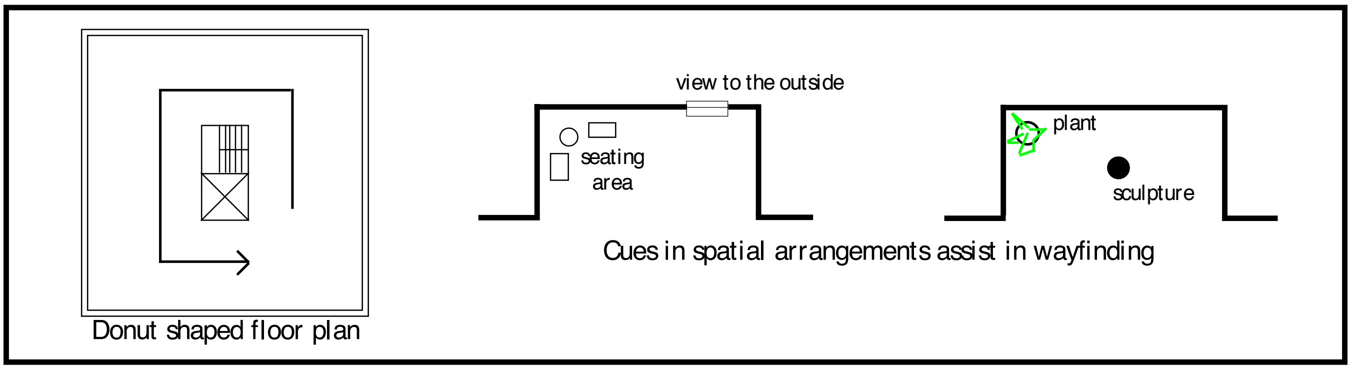


figure 8. Difficulty of Wayfinding in a Donut Shaped Floor Plan

Terry Sejnowski suggested: " There's a lot known about navigation in both animal literature and in human literature. The way it falls out is that it looks as if there are two different ways of solving the problem. Different people have different strengths. One is your ability to know your location in space and to head off in the right direction. And the other is to simply use landmarks and directions. Let's say you go one hundred yards in that direction and when you get to the barn, you turn right and go off a number of blocks. Different people are more comfortable with location ability and others with using landmarks. Usually gifted people like the second method because they can remember lots of different landmarks.

Although infrequently recognized as such, there is neuropsychological evidence for the existence of yet another specialized area within the extra striate cortex. This evidence is in the form of a subset of patients who suffer from 'topographical disorientation'. These patients, most typically following dextral lesions of the medial occipital lobe, seem to have particular difficulty using salient environmental features for way-finding. The limited neuropsychological testing that has been performed upon these patients suggest that they are primarily impaired in the perception and recognition of street scenes, landscapes, monuments, and most notably, buildings. … Commonly, these patients report relying upon less salient environmental features (i.e., distinctive door knobs, mailboxes, park benches) to learn and follow a path."

WINDOWS and their impact on patients

(Introduction excerpted from Roger Ulrich's talk)

Research on intensive or critical care units strongly suggests that a lack of windows can detrimentally affect patients. Lack of windows in ICUs is associated with higher rates of anxiety, depression, and delirium compared to rates for units with windows. Questionnaire evidence indicates that patients in acute care consider windows to be very important, and assign especially high value to nature views.

Regarding staff, many studies across a variety of workplaces (healthcare, office buildings) have found that employees, like patients, attach high importance to having windows, and nature views are most preferred. Further, employees with nature window views are less stressed, report better health and higher levels of job satisfaction than comparable groups who lack nature views or have no windows.

The finding that viewing sunshine apparently alleviates depression may explain the results of the second study - that mortality of myocardial infarction patients was lower for patients assigned to sunny, south-facing critical care rooms rather than to north-facing generally sunless rooms. Regarding staff, questionnaire studies indicate that employees also prefer window views of spaces illuminated by sunlight rather than cloudy conditions.

Windows and their role in healthcare (results of group discussion were presented by Esther Sternberg via a power point set of slides she had made based on their discussion). The group began by stating that the quality of the view was less important than the information available from looking out the window. This raised a set of research questions:

a. Is there a relationship between visual stimulation and healing?
b. If yes, then what are the elements of visual stimulation that promote healing – i.e. light, movement, etc.
c. Are the effects of the environmental elements additive or synergistic? (that is, is there something about lots of these stimuli seen at the same time that is better to promote healing.)
d. Do these elements promote healing by blocking bad sensations?
e. Does stimulation (the relief of boredom) come from visual environment?
f. Is passive visual stimulation enough?
g. Does the effect of the visual stimulus that windows provide depend upon the stages on a patients illness?
h. Is there a requirement for active engagement? (i.e. visualization or closing your eyes, seeing a place and pretending you are out there.)
i. What are the neural pathways activated by positive views? (and do these include the emotional centers that are involved in positive or negative emotions?)
j. What are the hormonal responses to this activation, and how do they impact the immune mediated diseases, and/or outcome measures of health?
k. Is memory involved in the beneficial effects of windows? (memory is certainly an important element of stress, so it would seem that it would be an important element in healing)
l. Views of nature have a larger positive population response than views of abstract art. Why is this so?

Ideas for Research Projects

On Friday morning a number of ideas for research project emerged that were seen as issues of importance to the architects who design healthcare facilities. They are recorded here in the order they were discussed and much of the original dialogue is retained to give the reader a sense of the interactions at this session.

(1.0) Julian Thayer: The way that these techniques work is that each individual image is standardized to sort of a standard brain. But, we know from studies of individuals that there are individual differences in the location of some of these brain structures. That also tends to blur the resolution that we get when we do these standardizing procedures

(1.1) Jack Snell: Some experiences are more significant than others as they relate to survival or what's really fundamentally important. Are certain kinds of experiences parked in the same place in all of our brains?

(1.2) Esther Sternberg: The hypothalmus is in exactly the same place in all of us, in every single rat, in every single mouse

(1.3) Janet Baum: It's the wiring. You can have the same anatomical structure, the wiring can be very different. The wiring is very plastic, and you can re-activate or regenerate certain pathways. It has nothing to do with the anatomy. But that gets to the point I have to ask. Since we can't really have a rat substitute for a patient going through a hospital in terms of wayfinding and other things, what other kinds of models such as brain damaged people can be used to test what works and where it doesn't work and where whose failure points are?

(1.4) Julian Thayer: The group at the University of Iowa, Damasio's group, does a lot of work with lesion studies and looking at brain imaging. And, they've done some work with epilepsy and that sort of thing.

Let me tell you about a new technique - transcranial magnetic stimulation - that's being used. This techniques uses magnetic fields to activate different parts of the brain and then you can see how they are involved in different types of experiences.

(1.5) Patrick Russell: Just a teaser from that, and when you mentioned Alan Gibbons's work. The kind of thing he'll do is put Air Force pilots through some detailed manual eye-hand control problem. What he can do by watching the detailed sequence of events from visual cortex to motion control and so forth, he can watch what's happening and categorize those. Transcranial magnetic stimulation is not what you would want to use everyday for imaging. It's literally jolting somebody. But what you can do, if you have a hypothesis that one area has to talk to another area, you can set up a task and stimulate an area of the brain at just the right instant to see if you can interrupt that flow and verify your hypothesis.

(1.6) Roger Ulrich: Patrick or Julian, if we showed a building interior space and perhaps a window view with some depth, what would be your speculation of what might light up or what the active areas might be? Would you be able to detect things that might be useful? Would visual images of buildings more generally tend to fall in the same area and human faces be quite different?

(1.7) John Eberhard: There is some interesting work along this line being done by Dr. James V. Haxby at NIMH. Historically he has explored face recognition, and he's identified an area of the brain that clearly lights up when faces are the subject of observation. What he has now found is that there is a similar area of the brain that lights up for buildings. Another one of his colleagues at the University of Pennsylvania asked why would evolution have produced an ability to identify buildings in the human brain? And remember that every part of our brain that's pre-wired, so to speak, had to be pre-wired about forty thousand years ago. His theory is that primitive man found their way by locating and where they were in space by large objects on the horizon which were monumental. Thus large clumps of trees or large clumps of rocks, or some geographical marker like that were used for markers. The argument is that evolution prepared a part of the brain to respond to these monuments for finding your way, and what we now do (as urban persons) is to use buildings to find our way. The plasticity of our brain under the Hebian principle has taken that section of the brain and programmed it for building recognition

(1.8) Esther Sternberg: There is also the study done of London taxi drivers. They have to learn all the streets of London in order to get a license to drive. MRI scans were done on the size of their hippocampus (the part of the brain that remembers spatial information) before and after these cabbies went through their intensive training. There was a significant increase in size of the hippocampus after they finished their training.

(1.9) Julian Thayer: Well let me add a twist to this. Research has indicated that there's an area called the amygdala in the brain that deals with emotions. There are some recent studies showing that activity in this area, in response to threatening stimuli, is a function of your genetic make-up.

(2.0) Roger Ulrich: Julian, does that imply a kind of research approach. For example is it possible to take somebody who's really anxious and present them with different environmental images, and see if there's more or less activity in the amygdala?

(2.1) Julian Thayer: Yeah, we do those kinds of things.

(2.2) Roger Ulrich: Okay, so you can use differential activity. You don't have to be looking at somebody who is necessarily reacting with calm or pleasantness or some you know fairly robust positive response.

(2.3) Esther Sternberg: Right, but what you need to do, and this comes back to some of the points that I think Giovanni had made yesterday, is that it's not good enough to just image these people. When you do these studies, you would put somebody in your positive group or negative group, and you would do a full anxiety scan and see whether their anxiety reduced. If their anxiety didn't reduce on a full psychological scale, doing the imaging is not going to tell you whether they're less or more anxious. It will correlate with the state that you define based on your standard tools.

(2.4) Lloyd Siegel: To cut to the chase then, the $64 million dollar question is: if you want to measure whether people enjoy a space do you really need a brain scan for that?

(2.5) Esther Sternberg: No. The answer is a absolutely not. The only reason to do the brain scan is to understand the biology of what's going on.

(2.6) Lloyd Siegel: And from our point of view as architects, do we really need to know how or why?

(2.7) Esther Sternberg: You need to know how or why, because if you have a biological readout you can tell your clients that people who have a high cortisol level feel stressed under certain environmental conditions. And, that you want to avoid designing spaces that produce these conditions. From our point of view we're interested because we want to know how conditions like stress happen. Everything you can know about the physical environment and its impact on patients is providing you with more ammunition.

(2.8) Jack Snell: I've been kind of anxious. I think this is a fascinating discussion, but it sounds like a lot of kids looking at a toy store. The question we came to address is what are the research issues. It seems to me our diagram raises some very, very important questions-questions of measurement, but also questions of discipline. I don't see the activity of engineering in the diagram. And it seems to me there is a lot of activity that is needed to enable us to get to where we want to go with this.

For example, let's look at impact of the physical environment on the mental state. What do we need to know? What do we need to measure? What kinds of avenues do we need to pursue before we are able to make meaningful connections?

(2.9) Julian Thayer: Well in our group yesterday we discussed sort of the design and methodology that would be necessary to look at these issues. And there were a couple of different approaches. We talked about the typical neuroscience approach which is kind of the reductionist approach. We try to reduce things to its bare minimum and then manipulate some independent variable and look at it. We also talked about some of the new statistical techniques that allow us to take a complex environment and look at the effect on physiology, and then from there try to glean some of the important dimensions.

(3.0) Jack Snell: From the perspective of the architect or the engineer, our measurements of the physical environment are really very crude. And it seems to me there's a whole raft of measurement systems that we need to put in place to be able to make this thing make sense.

(3.1) Julian Thayer: How to characterize the environment.

(3.2) Roger Ulrich: Let's keep it simple. Let's just talk about the visual input, then we can target the kinds of methods, like imaging, that could be used.

(3.3) Jack Snell: But the measurement systems that you're comfortable with deal mostly with the visual.

(3.4) Roger Ulrich: We can add auditory aspects too.

(3.5) Lloyd Siegel: You can also use temperature and air movement techniques.

(3.6) Roger Ulrich: Well we want to control for those. We can examine those independently and see if they have a role. Let's keep it simple. Let's say we're just being visual for the moment. There's a whole bunch of research over the last twenty years that give us a good sense of being able to anticipate what visual properties are going to be most important in terms of impacting the individual.

(3.7) Giovanni Cizza: I'll give an example of where the field stands at the moment. It is important which question you ask and when. A study that attempts to measure sixty or seventy things could kill the field. You need to say up front which one would be your primary point, which one would be your hypothesis. Otherwise the question could induce an administrator or people in the field to say it is too complicated, it is not a clear pattern.

I think the field needs a proof of concept study, where you prove in a none controversial way whether a hypothesis is true (not just discuss something for philosophical reasons). For that purpose, you need a disease model. You need a specific disease. This disease has to have certain characteristics. It has to be a common disease because of the clinical and economic rigors. It has to be a disease in which the mind plays either a major role or a modulator role. I'm thinking either of psychological conditions which are primarily in the mind or conditions such as the condition that Esther studies which are conditions of the body's immune system, where the mind play a modulatory role. And then you choose on or two end points, not fifty. Because if you choose fifty, and they all go into different directions, forget it. You choose something that is easily measurable, which is of clinical relevance, and you design a study which has a sufficient end. And then you just do that. If the answer is positive you go farther. If not, you just forget it and you change hypotheses.

(3.8) Roger Ulrich: I completely agree with you. It should be a very well-defined study with a high likelihood of proof of concept, insofar as that can be conceptualized ahead of time.

(3.9) Frank Pitts: I'm thinking about what Esther said a second ago, and I've been thinking, and I've been wondering if we can measure things like anxiety in schizophrenics using these good science tools ?

(4.0) Esther Sternberg: Yes, sure people are studying anxiety disorder, absolutely.

(4.1) David Allison: So there's are a number of places where we could intersect - where you have knowledge about a state of mind and a biochemical mechanism.

(4.2) Julian Thayer: Let me suggest that we get out of the hypothetical. And let me give you a concrete example. Let me give you some of the background of how we got to this idea because this touches upon Giovanni's notion. This is kind of cumulative knowledge.

We were interested in looking at the effects of room temperature on physiology. There's a literature that exists that talks about the effects of temperature on mental state, aggression-the higher the temperature the more aggression. We were interested in looking at physiology because one of the variables that I study is heart rate variability. There are, in looking at the rhythm of the heart, three identifiable frequencies that have been isolated: 1) that's due to respiratory modulation which is sort of related to stress and calmness. This index, in fact, has been proposed as a measure of disease and health; 2) There is another frequency that's a bit slower that's associated with receptor mediated blood pressure changes. We know a bit about that. 3) there's a lower frequency that has been hypothesized to be associated with temperature regulation. We know that temperature is associated with these mental states. We know that certain rhythms of the heart are associated with certain physiological processes. What we didn't know was whether we could measure, in an ambient temperature controlled room, the effect on physiology and mental state as well.

We assembled a group of people, males and females, so we have one variable related to the two genders. We are also looking at heart rate and we also have blood pressure. We designed the study to look at three different room temperatures- 55 degrees, 72 degrees, and 95 degrees (the hot room). 72 degrees is sort of the baseline. There are engineering principles that are in play to make sure that we measure things accurately. Because of the way that you measure the rhythm of the heart, you have to have a number of periodicities to decompose it. So the person had to be exposed to these conditions for a sufficient amount of time that we could get a valid measure of this rhythm that we thought was associated with temperature regulation. They're in each room for thirty minutes. There were ten men, ten women, thirty minutes in each of these rooms. We recorded heart rate variability continuously, blood pressure every minute and a half, and we got their subjective report of comfort and aggression. This is what's called, subjective design, that is how each person experienced each room. Each person served as their own control. In this context we were able to see what the effects of temperature were on our physiological and mental state parameters.

The results were noticeable effects on mental state as a function of temperature. The hot room produced more responses of aggression in both genders, but more so for the males. Ratings of comfort also differed. But there was an interesting interaction with gender. The females rated the warm room more comfortable than the cold room, and vice versa with the males. These are the mental states. Now, can we connect that to the physical state, to the physiology? Yes, in the hot room this good heart rate variability, the high frequency respiratory modulated heart rate variability goes down. In the cold room because the cold may be stimulating a very primitive reflex called the dive reflex it produces a decrease in heart rate, decrease in heart rate variability, and oxygen conservation. So, there's evidence that periodicity associated with blood pressure tended to go up in the hot room and go down in the cold room. What's interesting is, is that this lower frequency that is thought to be associated with thermal regulation also changed. It went up in the cold room, more so for the women than for the men. We're able to tie physical environment to mental state and physical state. We're able to tie physical state and mental state together. We're able to do this using architectural, engineering, neuroscience principles.

What we could do to answer some of John's questions might be to have them do a mental task, an information processing task in that room or an emotion identification task. So you see from our knowledge base we add something new each time. Or we could add some aspect of the physical environment-change the lighting or the windows. And we could even get to the healing process because we could measure immune responses. So you can see how, based on a firm scientific foundation, we can approach issues that are interesting to you as architects in a quantitative, systematic, programmatic way that will avoid a lot of the problems that Giovanni was talking about.

(4.3) Esther Sternberg: So actually I was going ask you guys, since you asked us a lot of questions, what question is most important to you?

(4.4) David Allison: Well let me ask a question related to Julian's study. We wouldn't normally ask as architects whether the room should be 55, or 72, or 90 because we would provide a thermostat in each room in the hospital and the client would set the ambient temperature, whatever it might be in that area. We would give them the adjustability. Now, the question that we might be interested in asking is to take Julian's study and modify it with a baseline temperature room with an adjustable thermostat. And then measure the impact of that decision. That's a question we'd be interested in asking.

(4.5) Julian Thayer: Absolutely. And that's the kind of thing that you can easily build on to the experiment I described because you now know what some of the effects of temperature are going to be.

(4.6) Esther Sternberg: So what are the other questions? I mean, are the topics assigned to the groups that we ran representative of the questions that you're interested in?

(4.7) Male: No, I don't think so.

(4.8) Frank Pitts: I have one. I'm instructed that reducing anxiety is a critical thing in treating schizophrenia in order that they will move themselves into treatment programs. So long as there is fear, the schizophrenics are holding back, staying in their rooms. And my hypothesis is that by providing choice that there is a corollary in reduction of anxiety. If I can choose to be in a particular place or to do a something different, if I have some control in that way, that there would be a reduction in anxiety. And I'd be interested in knowing whether there is any validity in that intuition.

(4.9) Esther Sternberg: Okay, so one question that you have is the degree of controllability of the environment versus a fixed environment. That's an important thing for all sorts of things, not just temperature but size of space or lighting or privacy or…

(5.0) Frank Pitts: And I suspect across a number of disease mechanisms because you were talking about cardiology. And I think that's an issue…

(5.1) Joan Saba: We spend a lot of time in my firm designing for anything related to cardiology, I mean in-patient, out-patient, and everything. So I could think of a whole host of things that we would want to study as it relates to designing facilities for cardiology.

(5.2) Julian Thayer: Right. Now, let me add that this heart rate variability measure that I indicated was a general indicator of disease, heart rate is a predictor of all cause mortality-not just cardiovascular. So what I'm talking about is a measure that measures something that is related to disease processes across the board. It's applicable to a wide range of disease. We've done work with spinal cord injury. We've done work with diabetes and all kinds of things that are completely relevant. But, to answer your question directly with respect to anxiety, it's, the same measure that can be used for anxiety

(5.3) Esther Sternberg: So, I'm still asking. I've heard a lot about the output, whether it's anxiety, whether it's psychological instruments, whether it's heart rate variability, whether it's hormonal or immune function-whatever, but what are the variables in that physical environment box that you are critically interested in knowing about how those variables affect healing? Do you want to know, one of them you just said is controllability. Is the other one size, or do you already know about size? Is the other one height of ceilings or space?

(5.4) Jack Snell: To build on the knowledge base in a scientific manner, another element of the strategy or criteria ought to be the potential impact in value added. Are variables significant and relevant. To me, the biggest low hanging fruit has to do with this topic you brought up yesterday - what is it that we are exposed to from what we breathe and what we touch in building spaces. And at the simplest level is the impact of the physical state on a disease mechanism that may be fairly well understood. I thought I heard you say before that there is a lot of influence on the individual (i.e. whether or not they get an infection catch cold or have asthma or whatever) in a building that doesn't have good air quality or has a kind of virus floating around. It would seem to me that some studies in that area would have a tremendous impact.

(5.5) David Allison: So you're distinguishing between exposure to an agent versus susceptibility to an agent.

(5.6) Esther Sternberg: Well, I think you're trying to incorporate both, so…

(5.7) Jack Snell: It may be both. You could take either one. We had the Vinyl Institute here yesterday. They're here because they're interested in self-disinfecting surfaces. That's a watershed impact that a simple material substitution can have on the uptake of disease in the environments.

(5.8) Esther Sternberg: That's an excellent question.

(5.9) Jack Snell: …that is an enormous impact. Okay, so I don't care whether the it's the physical contact issue or it's the air uptake. They're both a very high, they're home run potential tasks that we could look at.

(6.0) Esther Sternberg: And if you mapped on the kinds of physiological read-outs in a controlled environment, you have certain kinds of air flow or certain kinds of surfaces or, and then you, at the same time, incorporate the host susceptibility to such exposures. That would answer that question quite well. If you have somebody who, with stress measures has a high cortisol level, then they would be more prone to getting sick if exposed to bacteria in the air. And, at the same time, we measure the bacteria in the air and on the surfaces, then you can get the host-environmental interaction which is really what we're talking about.

(6.1) Ron Skaggs: Can I get a little more basic? From a basic side, I would, as an architect, like to know when we provide delight. I don't know how to put this exactly into words, a feeling of delight, is that beneficial? And how do you define delight? You know beauty, all these things…

(6.2) Esther Sternberg: So, I guess that's one of the questions…

(6.3) Ron Skaggs: …And I think that kind of gets back to what you were talking about earlier in the psychological centers.

(6.4) Esther Sternberg: That's was one of the things that I still haven't learned from this interchange. How you intuitively as architects design a space. You seem to know how to do it to produce delight. Do you know…

(6.5) Lloyd Siegel: Not necessarily. (laughter)

(6.6) Ron Skaggs: Some do it well, and some don't it so well. That's probably the same in medical science too.

(6.7) Joan Saba: There's a huge benefit when one's successful.

(6.8) Esther Sternberg: Right, okay, so I was just going to ask you that. So do you have element of instruction when you go to school concerned with delight? Do people, for example, say you should build this ratio of ceiling height to…

(6.9) Ron Skaggs: We talk about proportion. We talk about color, scale, all those things…

(7.0) Esther Sternberg: So you know the elements that tend to produce positive feelings.

(7.1) Ron Skaggs: …We learn how to deal with them.

(7.2) Shannon Kraus: So what we're talking about in terms of getting to that kind of thing would be somewhat related to anxiety, fear and its effect on stress and all the physiological things. But in terms of physical, if we had some baseline where 100% or 99% of us would agree, it's just kind of clinical, institutional the big no-no in healthcare or whatever. Start with that baseline no-no, and then begin to quantify physiologically what is good and what is bad versus taste…

(7.3) Esther Sternberg: But, there's has to be some rules such as saying you want to build something that is symmetrical, and that will be more calming. Or are there no rules?

(7.4) David Allison: There's a thing called balance. There's things you shoot for, but then you have to realize that the practice of architecture is a field in which you operate within an incredible number of constraints. So you're shooting for an ideal, given, within a realm of constraints. It's based on the ability of the creative team that may be involved. It's based on a wide variety of factors, so we rarely ever get to rules that we would all agree on.

(7.5) Julian Thayer: Sounds like science. (laughter)

(7.6) Esther Sternberg: If I asked you to build a spiritual space that would guarantee that somebody who walked into it would immediately feel a sense of awe, is there an element that you know has to be part of it?

(7.7) Ron Skaggs: Intuitively.

(7.8) Mardelle Shepley: I think one of the most important problems related to your question is that preference is culturally based. And what's soaring to one, what is religious or mystical or delightful to one group may not be the same to another. And this gets back to why I'm interested in this idea of neuroscience. We usually separate people into groups. We talk about what makes us different. And, I'm interested in what makes us the same. And that's what our commonalities are. And that's why things that are more physiologically based have an appeal for me because I feel like I'm circumventing some of the confusion that's generated around self-satisfaction and culture. So if I can understand that there are some common responses -universal responses - to the environment- then I just want to know that that exists. And if that's the premise, can we build from there?

(7.9) Julian Thayer: Now let me give you another example. My dissertation was basically on this topic because I did research on physiological responses to listening to music. The same idea holds. Music has preference. People have preference for different kinds of music. So, what were the universal factors that determine a person's emotional response independent of their preference? I systematically went through and identified what those parameters were in music. Tempo is the most important. Mean pitch level was the second most important. What's interesting is that those map on to two dimensions from the theory of emotions. It maps on the activity or vigor dimension and the valence dimension. Similarly, those types of things have been done with art. I don't know if they've been done with architecture. That's could be a whole set of studies. To map what are the parameters, what are the factors in architectural design that map on to parameters of known emotional response? Similarly, we've mapped those dimensions of vigor and valence on to physiology. Tying all of this together, I think that the experience that I have with music may be very helpful in this enterprise with respect to architecture because we have the same problem. Preferences pervade, but what we want to know are the basic parameters that are producing emotional responses. The example that I always give is that some people like sad music. And, some people like happy music, but the same characteristics of sound make the music happy and sad. It's just some people like one or the other. I think that a similar approach can be brought to bare with architectural features.

(8.0) Esther Sternberg: So, you have three questions so far. One is controllability. Another is parameters that universally rather than culturally induce certain emotional states and physiological responses. And, the third is air quality related to environmental host interactions in terms of susceptibility to infectious disease.

(8.1) Roger Ulrich: Another way of approaching these issues, and this is often used in environmental psychology, is to characterize physical aspects of the environment-space, sound, colors, etc. And then map what the effects are for different individuals or populations in terms of the impact on the individuals. This is the valence, emotional valence that Julian was referring to. That is the quality of the emotional or affective reaction to the situation or the way it's evaluated or the state of the individual that is produced by this experience.

An example of a clinical population that I've worked with are patients at MD Anderson Cancer Center in Houston awaiting to undergo deep hip bone marrow extraction. That is usually done under local anesthesia. But, it is still acutely painful. These people have cancer or are about to find out they have cancer. It's an extremely anxiety-provoking situation. There are large numbers of these folks. And there is an anticipatory period where they are anxious, the goal can not be to get them into a state of pleasantness. You're not going to be able to do that. But clinically speaking, and from the standpoint of basic research, you would want to see if different settings could move them from highly anxious to calmer.

(8.2) Joan Saba: I'm trying to think of what I could ask you that would help me do what I need to do. Do we know what the best physiological state is for healing? And maybe it's for a particular condition like cardiac surgery.

(8.3) Esther Sternberg: We know more about health in the absence of disease than health itself. We do know that chronic stress is associated with significantly prolonged wound healing. So chronic stress is not a good thing. There are measures of the total amount of stress that we experience. You can get an idea of how chronically stressed an individual is. Since you don't want somebody to be chronically stressed, the question is what do you want somebody to be? What is it that we do want is not quite so clear. Do we want somebody who is happy and meditating and relaxed or do we want somebody who is fighting the disease?

(8.4) Giovanni Cizza: We base some things on the situation – the setting for the experience. When you talk about the effects of the environment on the physiological condition, are you thinking of an acute hospital? Are you thinking of a chronic kind of place? Are you thinking of an office?

(8.5) Joan Saba: It can be all those things. Do you have to select?

(8.6) Giovanni Cizza: You have to select. You have to be realistic, and you have to think realistically of which condition and in what environment can the larger difference be compared to other conditions. And then you really have to think of what you will ask first. You cannot do all of these things at the same time. I think that probably looking at the office space and ameliorating conditions for such patients (such as the patient with early form of dementia or with chronic psychological condition) might make a bigger impact than trying to change where there is a patient with an incurable disease.

(8.7) Joan Saba: What can we learn from research in order to design the best recovery room?

(8.8) David Allison: We have to get to the issue of significance – e.g. what has the greatest significance? Recovery room design is a big interesting architectural question, but we're interested in healthcare first of all. Right? We're probably going to have to start somewhere where most of the healthcare architects in this room focus their practices, that is in acute care settings. Patients generally in hospitals are sicker, more acute, whatever, so acute illnesses like cardiac surgery have some of the greatest potential benefit from modifications to the environment.

(8.9) Esther Sternberg: So you've just defined your outcome measure. You're interested in the impact of the architectural space on the disease outcome, and that is cardiac outcome. So your outcome measures are going to be cardiac.

(9.0) Julian Thayer: So for example, the heart rate variability measure that I talked about would very useful in the cardiac study as a general indicator.

(9.1) Esther Sternberg: So, if what you're interested in is arthritis outcome, you measure arthritis parameters. If you're interested in cardiac outcome, you measure cardiac parameters. You need to define very specifically your outcome, your disease outcome measures. You can then throw in some general physiological outcome measures. And you need to use your outcome measures to deliver satisfaction. That's an important thing-social support and satisfaction. So what are the important things in healing? Social support is very important. If the family is discouraged from coming because there's no room in the room, then you have less social support. Social satisfaction, or family satisfaction, visitor satisfaction is not only important in terms of whatever business parameters you're interested in, but really in terms of the healing. You need to put all of those things in your outcome measures, and then modify your architectural space in whatever way.

(9.2) Giovanni Cizza: Let me just give two very quick examples. There are two stories or examples, one in which the environment was extremely healthy and the other in which the environment was not. In both cases changing the environment was not a cure. It was the development of new pharmaceutical products. In the first example:

- When polio was prevalent, there was a movement where everyone wanted to build very nice swimming pools for the polio victims. But, what saved the day was not building those swimming pools, it was the vaccine.

- The second example is the treatment of patients who are psychotic. Fifty to sixty years ago there were no antidepressants. Patients in psychotic hospitals would be locked in, and they stayed forever in a terrible environment. No amount of change to the environment could have been as effective as the eventual development of antidepressants.

To find a condition that can be modified by an environmental intervention you have to put yourself in the condition, in the best possible condition. I don't know if in acute settings we have favorable conditions for change.

(9.3) Bob Horsburgh: I think Giovanni is making an important point here. And that is that we have to have a good hypotheses on the table in order to do good research. Then, the first thing we have to do is see if there is a correlation between the hypothetical difference in say a beautiful environment and a non-beautiful environment and the psychological state that results. The next step is to do an interventional study and see if you change the environment, would that change the outcome? We're not ready for that at this point in the history of architectural research. Farther down the line we can ask the scientists to give us the biological explanation.

What they can ask (with today's state-of-the-art), is if we do find that changing the view changes the way people feel and changes how quickly they get better, then how is that happening? What is the mechanism by which changing the view leads to that? That's the order of steps we need to take. Let's define some initial conditions as Giovanni suggested in his previous speech. That is, pick a particular population, look for a particular outcome, and then just observe if there's an association between your variable of interest, and your outcome variable-the psychological state. If there is, then we can go to the next step and see if changing the view changes the psychological outcome. If it does that, we can look and see how that happens. You have to go through steps 1-2-3, and Giovanni has suggested that very nicely.

(9.4) Lloyd Siegel: I once had a very interesting experience where we were called in by a hospital to change their new psychiatric unit. They had in this psychiatric unit an " emergency" room, so to speak, for the more violent patients. This room had tile walls, bars on the windows, a drain in the floor, and patients were put in there. They did what was expected of them-threw feces on the walls, etc. It was very easy to clean up, etc. When the new director came in, he had the floor carpeted. He had drapes put on the walls. He had some pictures put in. When they put the violent patients in there, they did not act up. That was a change which had very, very remarkable consequences. As a result we changed the layout of the entire unit, and it did change the involvement of the patients with their environment. And according to the director, it did have better outcomes.

Similarly, I know of a nursing home that was once in an old building with the usual things one could expect to see including vinyl tile floors. 80% of the population there, elderly women, required walkers and wheel chairs. When they moved into their new building across the way, carpeted floors provided a more residential feeling. The number of non-ambulatory patients went down to 40%.

Now these are very good examples. And I'm sure most of the architects in the room have similar examples of direct change in patient care and outcome by changing the environment. But they're all anecdotal.

(9.5) Esther Sternberg: You just came to the point that Giovanni was trying to make. That is, all you have at the moment is anecdotal stories. What you need to do is to design a study to get all of these together in a prospective way. Pick the outcome measure. Pick the situation that will affect healing and health and well-being and everything else – such as a sense of independence, controllability, speed of recover, speed of wound healing, speed of muscle mass increases, appetite, everything else. You could do a large epidemiological study that would absolutely prove or disprove what you know already by anecdotal reports. And then you have the ammunition to say architecture matters to health.

(9.6) Bob Horsburgh: Right, you can do a cohort study of a group of patients and follow them and see if they get better and see if their psychological state is related to their improvement. You have to have evidence that suggest there's an association between what you're trying to do and a better outcome. The first thing you have to do is say there is some association between the outcome of this disease and the physiological state. Otherwise, why bother to go any further?

(9.7) Ron Skaggs: In the last ten or fifteen years, there's been a shift in pediatric disciplines where we are now designing children's hospitals to look " childlike." Many people say that those children would do just as well in adult settings as in childlike settings. Which may be. In fact, adults might do better in childlike settings. We're providing two different types of environments because there's two different types of perceived patient needs, but how could we determine if this is a good idea?

(9.8) Esther Sternberg: That's where you could do the kind of study we've been talking about. You develop comparisons. There would be some architectural features that you can not test because there's not enough data. But this sounds like there would be enough of the two different types of environments that you could evaluate in terms of outcome measures…

(9.9) Ron Skaggs: They exist. And it's intuitive, you know, color, geometric shapes, that's all things we do for the kids. We don't do that for the adults.

(10.0) Frank Pitts: That suggests another experiment that might be done where there's a replacement hospital, and where you have a patient cohort that remains largely intact through the replacement.

(10.1) Esther Sternberg: Well that could be a great study.

(10.2) Bob Horsburgh: You could look at four or five examples of where an elderly patient population that uses a lot of walkers has moved into a new facility. Some will have carpet, and maybe some of them will move into another one that has the same kind of floors as the old one. And the question is, is there really a difference as a result of the flooring, or is it moving into a new facility that makes people feel better and walk more.

(10.3) Esther Sternberg: Right, exactly, and you can design experiments to test this hypothesis. And in terms of going back to Giovanni's point of establishing field studies, something that makes an elderly population more mobile and less dependent on numbers of healthcare personnel, that would be something that would really impact the field.

(10.4) Giovanni Cizza: If I hear our friend's argument clearly, it sound like we have to prove something that we all know. So when, you know, evidence based medicine, you can rate evidence. Class C is anecdotal. Class B is the epidemiological studies. Class A are the intervention studies. To me it sounds like a lot of the anecdotal evidence. Professionals working in the field believes that this is the case, but have failed to convince the administrators and the neuroscientists. My personal opinion is that the environment can matter a lot for some conditions and has no effects for other conditions. And the charge is to find the condition where an environmental intervention can make a difference. But there have been no interventional studies mentioned so far.

(10.5) Shannon Kraus: One important thing could be a different set of studies (probably with other anecdotal evidence) about waiting rooms and staff environments. Things that are not a matter of healing patients, but the person visiting the patient or delivering the care.

(10.6) Janet Baum: It would be a form of a productivity study.

(10.7) Giovanni Cizza: There is a big problem with the anecdotal evidence, because you always support the positive observations. No one will likely come and say I changed everything in the hospital, and the patients still are not doing very well, because it is negative evidence. They don't report it. So don't put too much faith in anecdotes. Go to the next level.

(10.8) Shannon Kraus: That's what we want to do.

(10.9) Esther Sternberg: So let me just make this point because this is the exact experience that I had in the field of the science of mind/body dimensions. We all knew for 2000 years, 5000 years, since we've been around on this Earth that stress makes you sick and believing makes you well. We had not convinced, the popular culture, the scientific community or the medical community that this was true until we went beyond the anecdotal stories and took it to the next steps, to the clear proof of association. But just association does not prove cause and effect. And once you prove the association, then you can go on to do intervention studies that prove cause and effect. And then you can go on to do the mechanistic studies to answer how these effects occur. You've got to move to more specific levels of evidence. Even though you all have this intuitive sense that space matters. And place matters. We need to move to the next step to prove it.

(11.0) Giovanni Cizza: It is a dangerous process, if I may, because if you choose the wrong condition to prove your concept, and the study comes up negative, you know you're delaying the field for thirty-three years. So it is a dangerous process, and a lot of thinking goes into it intuitively to choose the right condition, the right environmental intervention.

(11.1) Roger Ulrich: When you're looking for certain clinical situations in which to do intervention studies, or cohort studies, there are a few situations that are very important in healthcare. In the treatment of patients, you can get very quick indications of differences with environmental manipulations or with producing positive environments that enhance the patient's emotional state. Just a narrow example: I've worked with bone marrow patients at a major cancer center. They make a decision in the anticipatory state of that procedure as to whether they're going to have general anesthesia or local anesthetic. The policy of the hospital and medicine generally is to, insofar as possible, keep it under local anesthetic. It's still very painful. So they know that, and many are coming back for the third or fourth time. And they're very anxious. If it's done on an outpatient basis, that is with local anesthesia, they sit in the waiting area for an hour or two ahead of time. And then they go into the procedure which takes totally about a half hour, fifteen minutes of which is very painful. And then they wait for two to four more hours to find out how sick they are, or whether they're terminal, or whether it's in remission and are very anxious. There are a number of decision points in there that are critical from the standpoint of the administration as indicators of outcomes and also impacts in terms of healthcare costs. For example, just in the anticipatory phase sitting there in the waiting room if they suddenly say I know I can't take it, I want general anesthesia, that means the whole thing goes up an order of magnitude or two in terms of expense for the provider. They have to be admitted, and that's when you want to reduce that number as much as possible. But you don't want to, at the same time, inflict unnecessary agony on the patient population. The waiting room experience may presumably be quite sensitive to this anticipatory phase. So for instance, you could put them in a waiting area designed to be calming or one that's barren and typical that would be presumably not calming. A comparison study could thus be undertaken.

(11.2) Ron Skaggs: Or you could make 'em wait less.

(11.3) Roger Ulrich: Patrick, mentioned earlier in his excellent talk of imaging that functional MRI provokes a lot of anxiety. It's very claustrophobic. And you've got this jackhammer sound going on around you. People who come in for functional MRI or MRI are often quite anxious because they're concerned they've got something. And the early termination of functional MRI's is a very frequent and immensely costly problem in medicine. If patients are anxious and if they endure it at all, then you get movement and you get fuzzy resolution, and they have to do it again. Or, unfortunately, it may not be detected which can lead to medical misdiagnoses. All too often, people just panic and want to get out after twenty minutes. Could we put them in a waiting room that's calming as opposed to the usual room and see if the early termination rates and the number of the amount of movements is directly related. That is, is there a clinically meaningful outcome?

(11.4) John Eberhard: One last comment, and then we want to start wrapping up.

(11.5) Mardelle Shepley: This is a sort of a fuzzy kind of comment. Your struggle in trying to find out what research to do is absolutely what we might expect. We don't have a research agenda that is scientific. We borrow from anthropology, psychology, sociology. We are now going to neuroscience and trying to borrow a methodology to provide support for what we're trying to accomplish. What we really need is a better of understanding of what are the most important questions in our field? The truth is there are just short of an infinite number of possibilities in terms of what can be done.

(11.6) Esther Sternberg: Right.

(11.7) Mardelle Shepley: And so, I'm thinking this is going to be facilitated by serendipity when an occasion presents itself to produce a fine study. We are a very, very new science. We are not sophisticated enough yet to provide you correct answers. So I think everyone agrees with that. But I do understand that being here in the situation and trying to plant the seeds is a step to get us there eventually.

(11.8) Esther Sternberg: Right. I think you're 100% right.

Footnote by John Eberhard

And, thus a very interesting discussion was concluded. While the possibilities for research that would be done by neuroscientists in their laboratories was not very often specifically identified, what was shown was the way in which the scientific participants proposed looking at architectural research questions. More needs to be done, in the future, to extract from this rich collection of ideas a few good projects to be done with neuroscientists using their tools and laboratories. The AIA research program will plan to do so.

Summary Diagram of the Relationship of Neuroscience to Architecture

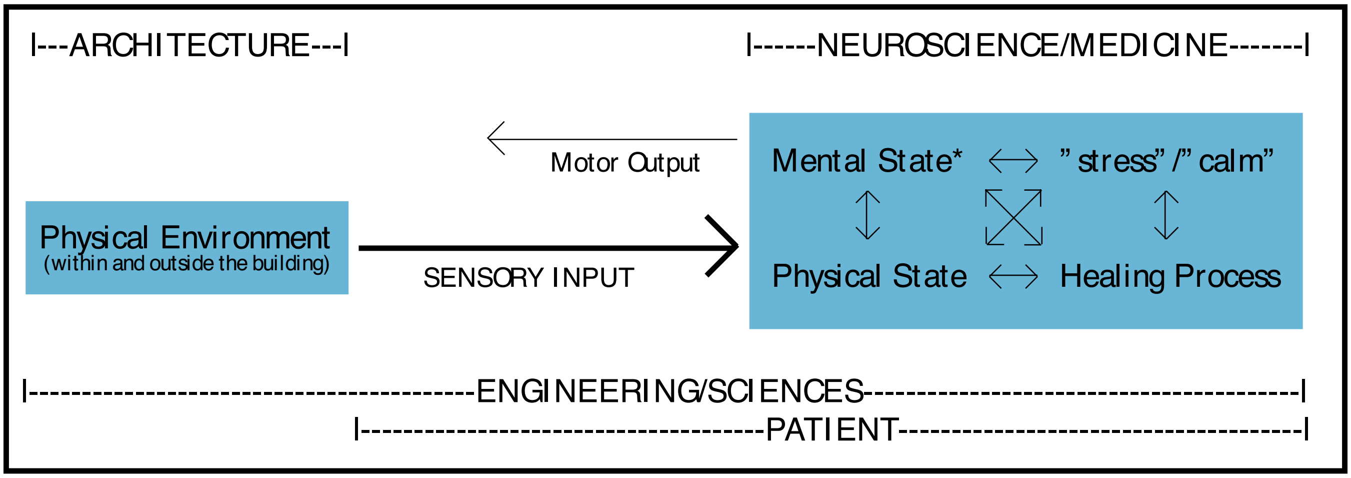


figure 9. Diagram of the Dynamic Interaction between Mental and Physical States

John Eberhard: In the process of our discussions yesterday, we eventually came up with this diagram. David, why don't you just go over it verbally again since you drew it?

David Allison: Well actually it's Jack Snell's birth child. It really summarizes some of the things we were talking about, obviously the dynamic and interactive processes of the patient, the mental state and physical state, stress and the healing process. I think what we added yesterday was a two-way relationship between stress and the healing process. We considered stress as both a positive and a negative factor. Jack had talked about engineering sciences, and I thought that it should be continuums of architecture, neurosciences and medicine, and engineering sciences. What we're trying to do is find some way of meeting in the middle in that area.

Lloyd Siegel: I would just suggest that the arrow of engineering sciences extend all the way over to medicine because all the engineering that goes into things like artificial hearts, etc., etc, CAT scan, tomography, machinery, and all that sort of…

Esther Sternberg: I would put a bi-directional arrow on the arrow from stress to mental state and from healing to physical state, because stress can change your mental state, and mental state can affect your stress. And healing can affect your physical state, and physical state can affect your healing.

John Eberhard: Esther, talk for a minute about the word 'mental state.' Is there a better term than to talk about 'mental state'? For example, what Dr. Gerald Edelman defines as the mind. He says that we know that this podium and this microphone don't have a mind, because inorganic objects don't have brains. Animals have brains, and sometimes animals, like dogs and cats, seem to have a mind. But what we do know is that we are the only species whose mind is able to think about the past, to contemplate the future, and to be aware of the fact that we are aware. And no other animal, as far as we know, has that ability. Since that's what makes us unique, just saying 'mental state' seems a limited term.

Esther Sternberg: Well, I think it's an easier to use in doing these kinds of studies. When you get into issues like what you're talking about, about the mind, you're getting into philosophy and theology. If you want to do research, you need to be able to quantify and manipulate the various components that you are examining. And, so 'mental state' in this way, exactly in those words, is used not to talk about something as ephemeral and interesting and fascinating as the mind, but something that you can actually get your arms around and measure and change. 'Mental state' refers to whether you are alert or sleeping. The other form of mental state is of emotional states. Affective states such as sadness, happiness, and then the extremes which become pathological - depression versus mania. Those are the kinds of things that we mean when we refer to mental states. I interpret 'physical state' here to mean whether you're healthy or sick. Whether you're sick with some kind of infectious disease, inflammatory disease, cancer, whether it's a localize organ or systemic - whatever. Once these are defined, then you can do the kinds of the studies that you asked us to set up and design.

If you are going to do research on design, if you're going to say where do architects come in, and where do neuroscientists come in, and where do engineers come in, you can't talk about something as ephemeral as the 'mind'.

Closing Remarks

John Eberhard: Architectural practice today is somewhat like the medical field in the middle 1800's. If you were a conscientious physician in 1850, and somebody came to you who was ill, you did the best job you could of diagnosing the kind of problem they had, what their illness was and prescribing some kind of a solution to this illness. But you were doing that in 1850 before there was a "Germ Theory" of disease, before there were microscopes in which you could see the germs, before there was a pharmaceutical company to develop drugs that could cure these diseases, before there were teaching clinics in hospitals in which you could learn to couple the research that was coming out of the clinics with the knowledge that was being gained in practice. Nobody in the practice of medicine today could survive if they didn't know about the Germ Theory of disease, how to relate the pharmaceutical companies products to the cures, or how to do diagnoses with sophisticated equipment. Architects are in the same position today that physicians were in 1850. And what's going to potentially change what it means to be a professional architect, I believe, is that neuroscience will become the basis of design knowledge.

Architects learn about design in school. There is an overwhelming amount of time dedicated to this subject even though only a small number of the students who graduate from architecture schools are really able to be designers (in the sense that you can create an original and satisfactory design solution aesthetically). Finding a job as a designer is limited, because there are only a few people who need to do aesthetic design in a firm. What is needed is a lot of other things in order to get a building built. Working drawings and specifications including engineering - construction, heating, ventilating, air conditioning, lighting systems, acoustics, etc. Estimating, financial planning, code review processing, construction supervision, etc.

What the profession has done, as a result of more information than any one person can absorb, is to acquire incremental knowledge - usually about a limited field of application. Healthcare would be one of those. So, a firm that specializes in the design of healthcare facilities begins to acquire, through the professionals in that firm, more information than they ever had in school about what it means to develop a satisfactory architectural solution. However, "satisfactory" is still a question of judgment, a question of intuition, and a question of peer group review. Periodically the AIA at the national, state or local levels, conduct what are called design competitions. Those of you who are professionals in the scientific field would be surprised to learn what the basis for deciding on design awards is. Photographs of empty buildings - never any people in the photographs. And if you want to win a design competition, you better have a good photographer because that's the real secret. Even if the building is not well designed a good photographer can help you win a design competition. If that is the criteria that establishes the paradigm for what it means to be a good professional, it's pretty hard to inject a new knowledge base into the academic setting or for research to be of importance to the field.

I think we now have a chance with neuroscience to substantially change the knowledge base of professionals who design spaces and places for human activities. That's why I'm excited about working on developing connections between these two fields. I think we've made a good deal of progress on this potential linkage in the last two days. My hunch is that we will all be surprised by how much we did accomplish once it gets written down and restructured and once David edits some of the material that he has been filming. Eventually, the media material that David is putting together will result in material that will be available at the AIA convention in San Diego in May of next year. And after the convention is over, the intention is that this material will be available for local chapters to use to put on programs of neuroscience and architecture. I appreciate all of your time and your willingness to come, and look forward to seeing all of you and working with most of you on future activities. Dr. Horsburgh, as co-chairman, why don't you say a few words of wrap-up.

Robert Horsburgh: I personally think that the move towards evidence-based design is the only way for the profession of architecture to go, and I hope that it moves there quickly. I think it will have incredible benefits in terms of improving the ability of the profession to influence our life. And I think we need that. We need the influence of architecture on our daily life. I would say that I don't think it's necessary to wait for the field of neuroscience to develop in order for the world of evidence-based design to flourish, we just need to begin down the path of developing those anecdotes into a case series, developing those case histories into cohort studies, developing those cohort studies into interventional studies. I think the material is there, and I think the tools are there. The neurosciences will provide better tools, and they will provide explanations, and they will provide sort of the infectious disease theory to go behind what you can now observe.

So, in fact, this is what the task is. It is to go out there and demonstrate with the appropriate tools so that other people can be convinced. But I would also be prepared for surprises because you won't be right all the time. And sometimes you will find things that are not at all what you expected. Although it's a bit shocking, the most fun of doing scientific inquiry is to find, in fact, that reality was totally different and that other things are at work that you never even thought of. We make scientific advances by trying to demonstrate what we think we know, and in fact often we find something else.

It took fifty years for medicine to get to the point where a commitment was made to evidence-based medicine. I don't think it should take architecture fifty years. You're in a position where you could start now and do some incredibly important work which will increases geometrically the options. Just doing one study leads to three more. And it's incredibly exciting. I think once support is there, you will find that it's very easy to involve students in this. Students are not attached to the ways of the past. They're craving to try and do these kinds of research projects. And they are the place to start. Resources do need to be available for student projects and for research projects that are more sophisticated - where you really can prove your points. So that's a challenge. The other challenge is not to wait, to start now.

John Eberhard: And Ron Skaggs, as the other co-chair will you provide some closing thoughts?

Ron Skaggs: I'll begin by quoting Le Corbusier, an architect from France, who said, " Good design comes from patient search." And certainly when we hear about research, we hear how much patience you need to search for the right solution. That's what we do as architects, whether we're generalist architects or healthcare architects. I know that we as a profession have a desire to find the right solution for the problem we're dealing with. So it doesn't make us that much different from scientists. We want to put creativity into it – in to that good design we're talking about. The frustration here is how can we have evidence that supports what we believe is good design? And that's what we keep looking for? Another quote I guess I might use is the Nike quote: " Just do it" .

So we thirst as architects for knowledge that we can apply to the development of better environments. I think everyone in this room cares very much about providing better healthcare facilities. So I would just end by saying let's select something, whatever it is, that we can do together. Let's realize it's going to require some patient search, but let's just get about doing it.

John Eberhard: Thom, as next year's President of the AIA, would you like to make some closing remarks?

Thom Penney: Yesterday I asked the question about why, why don't we learn how to do good design in school and what really constitutes good design rules. Thousands of years ago architects knew some of the rules. And about one hundred years ago we were taught as architects to throw out all the rules. We started doing things that were very creative, which is wonderful, but at the same time we lost track of some of our roots of historical architecture - why certain things were done. The public, I think, followed our lead and began to throw out all the rules. We started getting pretty bad buildings, because the public didn't understand the common language of good design that once was understood by everyone. If you look at historic cities most of the architecture is wonderful. What I see is that evidence-based design can help bring back a sense of good design not only to architects understanding, but to the public.

I feel like this has been a historic event, just thinking about what's been happening. The last time I was at the Salk Institute preparing for the 2003 San Diego convention, there were some para-gliders sailing down the cliffs beyond the Salk Institute. And I started thinking about the Wright brothers and all of the attempts that they made to get off the ground. And they finally did. It probably wasn't rigorous as some, but they began to make those steps. I will echo what Ron said. We just need to do it, and begin to provide our members and the public with information they need that shows what we all know in our hearts. And that is, that design matters. I think if we can begin to prove it, it will be a wonderful world to live in. Thank you.

John Eberhard: And, last but not least, Gordon why don't you close the workshop.

Gordon Chong: John, thank you for this opportunity. Certainly in my household I never have the opportunity to get the last word, so this is a rare opportunity. I began the session by thanking all of you for taking the time to be with us. And let's all end the session by thanking you for sharing your knowledge with us and for giving me a new vocabulary to think about. It probably underscores for me what I think is happening in our profession today. That is, it is a more expansive definition of design - making sure that people understand that when we speak of design, it's not just about the object (the building) that we're working on. It's the process that we go through in coming to our final design. So my definition of design is much more complex and includes the aspect of research that we have been talking about. I believe one of our strong suits as architects is our ability to think broadly and to be integrators of a lot of disparate kinds of information. That's really our strong suit and our skill, and I think that we should cherish that and not apologize for it. The other aspect of what we see as our strength is this idea of innovation. And innovation, I believe, requires risk taking. While we must build on knowledge that we have from the past and while we should not choose improperly what we might pursue, we shouldn't be inhibited from taking risks and exploring new ideas. I think that's the only way that innovation ever occurs, is by risk taking. And, innovation is something that I believe is one of the strong suits of architecture.

So, I hope we can build the processes, the scientific process and the architectural process, and build bridges between neuroscience and architecture. I think what we're doing here is changing the culture of practice for architecture. It's a long term process. There are some short term opportunities, but the long term change to the culture of how we practice is probably the greatest benefit of what we are starting to establish here today. I thank you all for that contribution. And I look forward to working with everybody on not just the idea of neuroscience and architecture, but the idea of research and the importance of research and knowledge to our profession. Thank you all. Travel safely.

And a P.S. from Lloyd Siegel: I would like to remind us that we are getting back to our beginnings. The first physician that we know of, was Asclepiades. He was the Greek god of Medicine, and son of Apollo. His name is often associated with the Egyptian name of Imhotep (the first physician in ancient Egypt who was later also made into a god). But remember, Imhotep was also the first architect (he designed the Step Pyramid at Saggarah). So, we have ancient roots between medicine and architecture.

Esther Sternberg: Wonderful.

Appendix A - Workshop Agenda

Tuesday 13 August 2002

06:30 PM Reception and Dinner (Main House)

08:30 PM Welcome on behalf of AIA: Gordon Chong
Self-introductions (Carriage House): All

Wednesday 14 August 2002

07:30 AM Breakfast (Main House)

08:30 AM Opening Session (Carriage House)
Welcome by Co-chairs: Ron Skaggs and Robert Horsburgh
Plan for the Day's Proceedings: John Eberhard

09:00 AM Concepts of Neuroscience
Stress: Esther Sternberg
How Computational Neuroscience began at Woods Hole: Terry Sejnowski
Discussion

10:00 AM Architectural Design Efforts on Design of Healthcare Facilities
AIA Guidelines for Design of Health Care Facilities: Ron Skaggs
The AIA Academy of Architecture for Health: Frank Pitts
Discussion

10:45 AM Coffee break

11:00 AM Related work in Healthcare Research
Research in Medical Schools: Robert Horsburgh
Research in Architecture Schools: Roger Ulrich
Discussion

12:00 PM Lunch (Main House)

01:30 PM First session for discussion groups (Carriage House)
A. Windows Group: chaired by Roger Ulrich
B. Interior Environments Group: chaired by Ron Skaggs
C. Wayfinding Group: chaired by Mardelle Shepley
D. Privacy Group: chaired by Janet Baum
E. Calming Environments Group: chaired by Joan Saba

03:30 PM Afternoon coffee break

04:00 PM Open forum and reports by each chair (Carriage House)
- A. Windows Group: chaired by Roger Ulrich
- B. Interior Environments Group: chaired by Ron Skaggs
- C. Wayfinding Group: chaired by Mardelle Shepley
- D. Privacy Group: chaired by Janet Baum
- E. Calming Environments Group: chaired by Joan Saba

05:30 PM Adjourn for the day

06:00 PM Reception (Main House)

Thursday 15 August 2002

07:30 AM Breakfast (Main House)

08:30 AM Recap Session: Ron Skaggs, Robert Horsburgh, and John Eberhard

09:30 AM Discussion of Bridging Concepts: All
- How could this research involve schools of architecture?
- How could it involve medical schools?
- Would neuroscience groups be ready to collaborate?

10:30 AM Morning coffee break

11:00 AM Summary session
- What we have done, what we have learned, where we might go: John Eberhard
- Additional suggestions from the floor

12:00 PM Lunch (Main House)

Adjourn after lunch for transportation to various points

Appendix B - Participants

FROM THE ARCHITECTURE COMMUNITY:
> Janet Baum, Ph.D., Principal, Health, Education + Research Associates, St. Louis
> Gordon Chong, AIA, President of the AIA
> Norman Koonce, FAIA, Executive Vice-President and CEO of AIA
> Shannon B. Kraus, MBA, RTKL, Dallas
> Frederick M. Marks, AIA, Earl Walls Associates, San Diego, CA
> Thompson Penney, FAIA, First Vice President of the AIA
> Frank Pitts, AIA, Past President of the Academy of Architecture for Health
> Joan L. Saba, AIA, President of the Academy of Architecture for Health
> Ronald Skaggs, FAIA, Chairman and CEO of HKS, Dallas

FROM THE UNIVERSITY COMMUNITY:
> David Allison, AIA, Director Graduate Studies in Architecture + Health, Clemson University
> Robert Horsburgh, M.D., Chairman of the Department of Epidemiology & Biostatistics, Boston University, School of Public Health
> Tom Regan, Dean of the Department of Architecture, Texas A&M University
> Mardelle Shepley, D.Arch., Associate Director of the Center for Health Systems & Design, Texas A&M University
> Roger Ulrich, Ph.D., Director of the Center for Health Systems & Design, Texas A&M University

FROM THE NEUROSCIENCE RESEARCH COMMUNITY:
> Giovanni Cizza, M.D., Ph.D., Senior Clinical Researcher, National Institute of Mental Health
> Farideh Eskandari, M.D., Senior Clinical Researcher, National Institute of Mental Health
> Terence Phillips, Ph.D., D.Sc., Chief of the Ultramicro Analytical Immunochemistry Resource, Bioengineering and Physical Sciences Program, Office of Research Services, Office of the Director, National Institutes of Health
> Patrick Russell, Ph.D., former staff member of the Neurosciences Institute
> Terry Sejnowski, Ph.D., Professor, Computational Neurobiology, Salk Institute
> Esther Sternberg, M.D., Director of the Integrative Neural-ImmuneProgram, National Institute of Mental Health
> Julian Thayer, Ph.D., Investigator, National Institute of Aging

FROM FEDERAL AGENCIES:
> Lloyd H. Siegel, FAIA, Director of Facilities Strategic Management, Department of Veterans Affairs
> Jack Snell, Ph.D., Director of the Building and Fire Research Laboratory, National Institute for Standards and Technology

FROM THE AIA RESEARCH PROGRAM:
> John Eberhard, FAIA, Director of Research Planning, The American Institute of Architects
> Ed Jackson, D.Arch., AIA, Research Consultant, The American Institute of Architects
> Margaret Tarampi, Assoc. AIA, Research Assistant, The American Institute of Architects

> Michael Sheridan, Producer of Media Materials
> David Weiner, Producer of Media Materials

> Allen Blakey, Director of Public Affairs, The Vinyl Institute

Appendix C - Working Groups

CALMING ENVIRONMENTS within healthcare facilities
> Norman Koonce, FAIA, Executive Vice-President and CEO of AIA
> Shannon B. Kraus, MBA, RTKL, Dallas
> Patrick Russell, Ph.D., former staff member of the Neurosciences Institute
> Joan L. Saba, AIA, President of the Academy of Architecture for Health
> Lloyd H. Siegel, FAIA, Director of Facilities Strategic Management, US Departmet of Veterans Affairs
> Julian Thayer, Ph.D., Investigator, National Institute of Aging

WAYFINDING in architectural settings
> Farideh Eskandari, M.D., Senior Clinical Researcher, National Institute of Mental Health
> Terence Phillips, Ph.D., D.Sc., Chief of the Ultramicro Analytical Immunochemistry Resource, Bioengineering and Physical Sciences Program, Office of Research Services, Office of the Director, National Institutes of Health
> Tom Regan, Dean of the Department of Architecture, Texas A&M University
> Mardelle Shepley, D.Arch., Associate Director of the Center for Health Systems & Design, Texas A&M University

WINDOWS and their impact on patients
> Gordon Chong, AIA, President of the AIA
> Ed Jackson, D.Arch., AIA, Research Consultant, The American Institute of Architects
> Frederick M. Marks, AIA, Earl Walls Associates, San Diego, CA
> Esther Sternberg, M.D., Director of the Integrative Neural-ImmuneProgram, National Institute of Mental Health
> Roger Ulrich, Ph.D., Director of the Center for Health Systems & Design, Texas A&M University

PRIVACY for patients and for physicians.
> Janet Baum, Ph.D., Principal, Health, Education + Research Associates, St. Louis
> Robert Horsburgh, M.D., Chairman of the Department of Epidemiology & Biostatistics, Boston University, School of Public Health
> Thompson Penney, FAIA, First Vice President of the AIA
> Frank Pitts, AIA, Past President of the Academy of Architecture for Health
> Terry Sejnowski, Ph.D., Professor, Computational Neurobiology, Salk Institute

INTERIOR ENVIRONMENTS.
> David Allison, AIA, Director Graduate Studies in Architecture + Health, Clemson University
> Allen Blakey, Director of Public Affairs, The Vinyl Institute
> Giovanni Cizza, M.D., Ph.D., Senior Clinical Researcher, National Institute of Mental Health
> Ronald Skaggs, FAIA, Chairman and CEO of HKS, Dallas
> Jack Snell, Ph.D., Director of the Building and Fire Research Laboratory, National Institute for Standards and Technology

FREE AGENTS to roam between groups.
> John Eberhard, FAIA, Director of Research Planning, The American Institute of Architects
> Michael Sheridan, Producer of Media Materials
> Margaret Tarampi, Assoc. AIA, Research Assistant, The American Institute of Architects
> David Weiner, Producer of Media Materials

Appendix D - Resources

> The Academy of Architecture for Health (an AIA Professional Interest Area):

http://www.aia.org/pia/gateway/PIA_Home-pages/aah.asp

The mission of the AIA Academy of Architecture for Health (AAH) is to improve the quality of the healthcare environment by promoting, through its members, excellence in healthcare architecture.

> The American Institute of Architects (AIA):

http://www.aia.org

The American Institute of Architects (AIA) is the professional organization that helps architects serve the public's needs and builds awareness of the role of architects and architecture in American society.

> Architecture and the Mind:

http://www.architecture-mind.com

John Eberhard's website on the conection between neuroscience and architecture.

> The Balance Within: The Science Connecting Health and Emotions:

http://www.esthersternberg.com

Dr. Esther Sternberg's website with information on her book, The Balance Within. Dr. Sternberg and other researchers are now making advances that show the actual pathways connecting the areas of our brain that control immunity with those that generate feelings and thoughts. In her book, Dr. Sternberg explains the mechanisms and their significance: how nerves, molecules, and hormones connect the brain and immune system, how the immune system signals the brain and affects our emotions, and documents how our brain can signal the immune system, making us more vulnerable to illnesses.

> Clemson University - Architecture and Health Studio:

http://www.clemson.edu/caah/ath

Master of architecture students examine issues of programming, planning and design associated with a comprehensive approach to physical and mental health care delivery systems. Studio work emphasizes the integration of physical design systems with patient care techniques. Theoretical design projects, as well as those that lead to built projects, employ both investigative research and architectural synthesis. The design studies are complemented by lectures and seminars that deal with various aspects of health care, hospital administration and the environment.

> Coalition for Health Environments Research (CHER):

http://www.cheresearch.org

CHER is an organization whose mission is: To promote, fund and disseminate research into humane, effective and efficient environments through multidisciplinary collaboration dedicated to quality healthcare for all. Our focus is practical research that can directly be put to use by architects and engineers, healthcare decision makers, contractors and construction managers, and product suppliers.

> National Academy of Sciences at Woods Hole:

http://www7.nationalacademies.org/woodshole/index.html

The setting for the meeting.

> The National Institutes of Health (NIH):

http://www.nih.gov

The goal of NIH research is to acquire new knowledge to help prevent, detect, diagnose, and treat disease and disability, from the rarest genetic disorder to the common cold. The NIH mission is to uncover new knowledge that will lead to better health for everyone.

> Texas A&M University - The Center for Health Systems and Design:

http://archone.tamu.edu/chsd

The Center for Health Systems and Design is a creation of the Colleges of Architecture and Medicine at Texas A&M that is intended to promote research, innovation and communication in an interdisciplinary program that focuses on health facility planning and design.

> The Vinyl Institute:

http://www.vinylinfo.org

The Vinyl Institute is a U.S. trade association representing the leading manufacturers of vinyl, vinyl chloride monomer, vinyl additives and modifiers, and vinyl packaging materials. Founded in 1982, the Institute has a dual charter to promote and protect the industry and the markets it serves.

Appendix E - Glossary

Adrenal Cortex: This is the outer portion of the fattyacids and inhibit inflammation in allergic responses.

Alzheimer's Disease: A progressive, neurodegenerative disease characterised by loss of function and death of nerve cells in several areas of the brain leading to loss of cognitive function such as memory and language. The cause of nerve cell death is unknown but the cells are recognized by the appearance of unusual helical protein filaments in the nerve cells (neurofibrillary tangles) and by degeneration in cortical regions of brain, especially frontal and temporal lobes. Alzheimer's disease is the most common cause of dementia.

Amygdala: A structure in the forebrain that is an important component of the limbic system.

Anecdotal Study: Report of clinical experiences based in individual cases, rather than an organized investigation with appropriate controls, etc.

Anxiety: The unpleasant emotional state consisting of psychophysiological responses to anticipation of unreal or imagined danger, ostensibly resulting from unrecognized intrapsychic conflict. Physiological concomitants include increased heart rate, altered respiration rate, sweating, trembling, weakness and fatigue, psychological concomitants include feelings of impending danger, powerlessness, apprehension and tension.

Arthritis: An inflammatory condition that affects joints. Can be infective, autoimmune, traumatic in origin.

Circadian Rhythms: A cycle of behavior or physiological change lasting approximately 24 hours.

Corticoid: Having an action similar to that of a hormone of the adrenal cortex.

Cortisol: A hormone manufactured by the adrenal cortex. In humans, it is secreted in the greatest quantities before dawn, readying the body for the activities of the coming day.

EEG (Electroencephalogram): A diagnostic test which measures the electrical activity of the brain (brain waves) using high sensitive recording equipment attached to the scalp by fine electrodes. Commonly employed in the evaluation of neurological disease (for example seizures, epilepsy, etc.).

Epidemiologic Study: Study designed to examine associations, commonly, hypothesized causal relations. They are usually concerned with identifying or measuring the effects of risk factors or exposures. The common types of analytic study are case-control studies, cohort studies, and cross-sectional studies.

Heart Rate Variability (HRV): The beat-to-beat fluctuations in the rhythm of the heart that provide an indirect measure of heart health, as defined by the degree of balance in sympathetic and vagus nerve activity.

Hippocampus: A seahorse-shaped structure located within the brain and considered an important part of the limbic system. It function in learning, memory and emotion.

Intervention Study: Epidemiologic investigation designed to test a hypothesized cause-effect relation by modifying the supposed causal factor(s) in the study population.

Limbic System: Collective term denoting a heterogeneous array of brain structures at or near the edge (limbus) of the medial wall of the cerebral hemisphere, in particular the hippocampus, amygdala, and fornicate gyrus; the term is often used so as to include also the interconnections of these structures, as well as their connections with the septal area, the hypothalamus, and a medial zone of mesencephalic tegmentum. By way of the latter connections, the limbic system exerts an important influence upon the endocrine and autonomic motor system's; its functions also appear to affect motivational and mood states.

MEG (Magnetoencephalography): The measurement of magnetic fields over the head generated by electric currents in the brain. As in any electrical conductor, electric fields in the brain are accompanied by orthogonal magnetic fields. The measurement of these fields provides information about the localization of brain activity which is complementary to that provided by electroencephalography. Magnetoencephalography may be used alone or together with electroencephalography, for measurement of spontaneous or evoked activity, and for research or clinical purposes.

MRI Scan (Magnetic Resonance Imaging): A special imaging technique used to image internal structures of the body, particularly the soft tissues. An MRI image is often superior to a normal X-ray image. It uses the influence of a large magnet to polarize hydrogen atoms in the tissues and then monitors the summation of the spinning energies within living cells. Images are very clear and are particularly good for soft tissue, brain and spinal cord, joints and abdomen. These scans may be used for detecting some cancers or for following their progress.

Neuron: An excitable cell specialised for the transmission of electrical signals over long distances. Neurons receive input from sensory cells or other neurons and send output to muscles or other neurons. Neurons with sensory input are called sensory neurons, neurons with muscle outputs are called motoneurons, neurons that connect only with other neurons are called interneurons. Neurons connect with each other via synapses. Neurons can be the longest cells known, a single axon can be several metres in length. Although signals are usually sent via action potentials, some neurons are nonspiking.

Neuroscience: The study of the nervous system, which advances the understanding of human thought, emotion, and behavior.

Neurotransmitter: Any of a group of substances that are released on excitation from the axon terminal of a presynaptic neuron of the central or peripheral nervous system and travel across the synaptic cleft to either excite or inhibit the target cell. Among the many substances that have the properties of a neurotransmitter are acetylcholine, noradrenaline, adrenaline, dopamine, glycine, y aminobutyrate, glutamic acid, substance P, enkephalins, endorphins and serotonin.

PET Scan (Positron Emission Tomography): A scanning device which uses low-dose radioactive sugar to measure brain activity. This is a limited-use diagnostic tool.

Physiology: The study of how living organisms function.

Schizophrenia: A mental disorder or heterogeneous group of disorders (the schizophrenias or schizophrenic disorders) comprising most major psychotic disorders and characterized by disturbances in form and content of thought (loosening of associations, delusions and hallucinations) mood (blunted, flattened or inappropriate affect), sense of self and relationship to the external world (loss of ego boundaries, dereistic thinking and autistic withdrawal) and behavior (bizarre, apparently purposeless and stereotyped activity or inactivity).

Serotonin: A monoamine neurotransmitter believed to play many roles including, but not limited to, temperature regulation, sensory perception and the onset of sleep. Neurons using serotonin as a transmitter are found in the brain and in the gut. A number of antidepressant drugs are targeted to brain serotonin systems.

Stress: The sum of the biological reactions to any adverse stimulus, physical, mental or emotional, internal or external, that tends to disturb the organisms homeostasis, should these compensating reactions be inadequate or inappropriate, they may lead to disorders. The term is also used to refer to the stimuli that elicit the reactions.

Transcranial Magnetic Stimulation (TMS): A new technique that permits direct brain stimulation without surgery. A brief but powerful electric current is passed through a coil of wire placed near the head, creating a strong magnetic field, which in turn induces electrical currents in brain cells. Unlike electrical fields, magnetic fields pass through the scalp and skull without becoming diffused and absorbed. Thus current is delivered to the brain with great efficiency. TMS is a powerful tool for the study of brain functions. It can stimulate motor activity or, at high frequencies and with precise focusing, alter neuronal transmission temporarily in a small region of the brain. Researchers have used the technique to study visual pathways, language, reaction times, attention, volition, and memory.

Definitions are from:
The On-line Medical Dictionary (http://cancerweb.ncl.ac.uk/omd/)
Published at the Dept. of Medical Oncology, University of Newcastle upon Tyne

Society for Neuroscience (http://apu.sfn.org/content/Publications/BrainBackgrounders/glossary.htm)

Allianz Life Insurance Company of North America (http://azlweb01.allianzlife.com/imgate.nsf/contents/)

The Behavioural Medicine Institute of Australia (http://www.behavioural-medicine.com/articles/hrv/001.html)