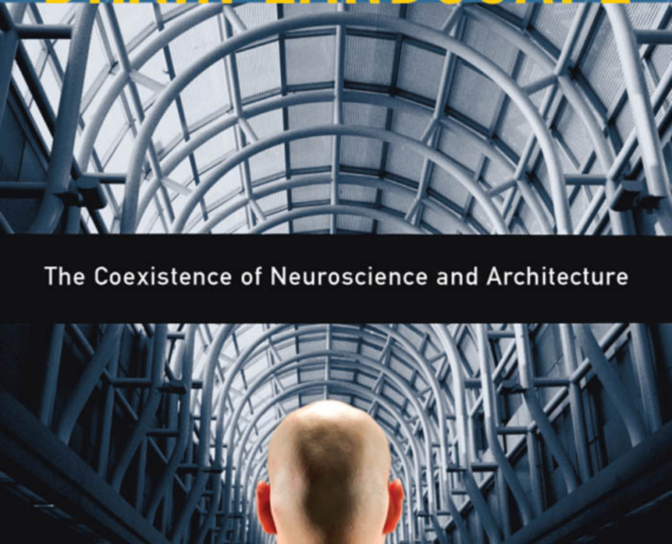
John Paul Eberhard

BRAIN LANDSCAPE



The Coexistence of Neuroscience and Architecture

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The Coexistance of Neuroscience and Architecture

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Dedicated to Jonas Salk,
whose wisdom created the
opportunity for me to explore
neuroscience

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Acknowledgments

This book is the result of a number of events in my life that led to me becoming the only architectural member of the Society for Neuroscience. As indicated in the autobiographical material in Chapter 1, I was recruited by Norman Koonce and Syl Damianos in 1995 to become the director of discovery of the American Architectural Foundation in Washington, D.C. The idea had been stimulated by Jonas Salk's proposal to the foundation that someone in the architectural world should be looking at human experiences with architecture from a scientific viewpoint. This led me to many years of study of neuroscience research.

In 2003, the San Diego chapter of the American Institute of Architects (AIA) asked me to help them form the Academy of Neuroscience for Architects (ANFA). Alison Whitelaw was especially important in spearheading this effort.

In 2006, thanks to encouragement from Jim Cramer, CEO of Greenway Communications, his Ostberg Library of Design Management published my book *Architecture and the Brain*.

In the same year, Craig Panner, senior editor, Neuroscience and Neurology, for Oxford University Press, arranged a contract for me to write this book. I am grateful to Craig for his wisdom in seeing the value of a book like this to the neuroscience community, as well as the general public.

He has provided many hours of constructive editing to my manuscript as it has progressed from concept to content. My other two editors are my wife, Lois (who actually could be considered my coauthor), and my daughter, Barbara, who is a professional editor as well as marketing manager for a large corporation.

Sections of the book have been written by Fred (Rusty) Gage from the Salk Institute; Gordon Chong, current president of ANFA and a national leader in architecture; John Zeisel, a colleague and pioneer in the behavioral sciences; Bonnie Albert, a colleague from my years at the State University of New York at Buffalo, and an authority on Chinese architecture; and Melissa Farling, a colleague and research associate in ANFA (who assisted me in writing about professional practice). Tom Albright from the Salk Institute and Terry Phillips from National Institutes of Health have provided consulting services on technical aspects of some chapters. To all of these friends and colleagues, I owe a large debt of gratitude. Anything said correctly in my text is to their credit, and anything incorrect is due to my own limitations.

FOREWORD

From the Perspective of an Architect

GORDON CHONG

We know as architects that the ability to measure human response to environmental stimuli still requires more years of work. We are pleased that neuroscience is beginning to provide us with an understanding of how the brain controls all of our bodily activities and ultimately affects how we think, move, perceive, learn and remember.

Even before architecture was first recognized as a profession over 150 years ago, architects have been referred to as master builders, implying knowledge and leadership in multiple facets of the process of designing a building. In contemporary practice, there are five basic stages of architectural services, which allocate the architect's effort: schematic design (15%), design development (20%), construction documents (40%), bidding (5%), and constructions administration (20%). This framework strongly affects the process of how modern buildings are created. The modern architect focuses on the process of design: problem solving during design development, creating computer drawings during documentation, and delivery methods during construction administration. Approximately 85% of architectural services are oriented toward defining how a building should be built. The most recent primary advances in the profession have been in computer technology. Computer-aided design and building information modeling are major advances that have changed and improved the way architects deliver projects. However, they do not address the questions of what to design nor why we should design a given project.

Now, in the first decade of the 21st century, there is a great opportunity to achieve a better balance and integration between the issues of how architects design and what and why they should design. Profoundly critical issues, such as global warming, energy conservation, and the need for buildings that reduce our carbon footprint, begin to responsibly define how, what, and why we design buildings and other built environments. This is a welcome rebalancing of the role architects play to enhance the quality of our communities and the world.

Additionally, for new construction projects charged with meeting needs of health, rapid advances in scientific discovery are significantly influencing education, housing, and workplace environments. Given that a large majority of an individual's time is spent in built environments, the need for a greater understanding of human response to environmental stimuli inextricably links design to scientific research. The promise is that architects and scientists will collaborate more to determine what we build and why it will enhance the human experience.

Following the 20th-century advances in computer technology, the 21st century is heralded by many as the era of biological discovery.

Not coincidentally, technological advances such as functional magnetic resonance imaging and computational neuroscience have made possible greater understanding of the brain. As in any pioneering effort, there is a high level of excitement. However, neuroscientists are quick to caution that adequate knowledge is not yet available to substantively inform design decisions as evidence based.

Nonetheless, one cannot resist thinking "what if?" while pondering exciting new possibilities. Can we be predictive of human response? Can we use neuroscience to establish a framework for design decision making? In turn, can our environments enhance the quality of life linked to scientific outcomes, such as reduction of stress, reduction of chronic disease linked to stress, enhanced mental acuity, increased cognition, prolonged worker productivity, enhanced spiritual and emotional response, reduced episodes of depression, and even increased longevity? Those of us in the design profession strongly believe that thoughtfully informed and designed environments can contribute to these desirable scientific outcomes. Can we prove it? How will we know what, and even how much, we contribute?

To engage in this new frontier, architects will have the opportunity to expand their creative, intuitive approaches to design with an increased ability to collaborate with the sciences. This could well lead to a redefinition of how knowledge is gained and shared through a culture of research as well as design practice. This will not be easy to accomplish. As with all explorations, there will be missteps, inconclusive evidence, contradictory results, slower than desired progress, and of course, naysayers of change. Fortunately, we will also enjoy incremental advances, new client and marketplace demands, and academic advocacy that will encourage new interdisciplinary models of practice.

Publication of *Brain Landscape* by John P. Eberhard is a major step forward into this new frontier. As in his earlier book, *Architecture of the Brain*, Eberhard never relinquishes his role as an architect, a master builder. Rather, he has become more expansive in his vision and more integrative in his thinking as he masterminds a bridge between the seemingly separate professions of architecture and neuroscience.

Gordon Chong, FAIA, is the past president of the AIA as well as current president (2007) of ANFA

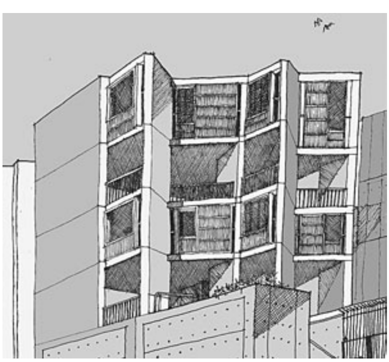
FOREWORD

From the Perspective of a Neuroscientist

FRED H. GAGE

John Eberhard has written a book to challenge neuroscientists to study how architecture affects the brain. His goal, though, is to open a dialogue between architects and neuroscientists, and this book will be at least as useful to the architects as it is to the neuroscientists. So this foreword is meant for the general audience that I expect this book to reach.

Neuroscience is the study of the brain, and neuroscientists believe that the brain is the organ that controls behavior. The brain is composed of areas that control vision, somatic sensory experiences, and motor output, as well as areas that help us navigate through novel environments.



A view of the Salk Institute.

The principal cell of the brain is a neuron, and there are something on the order of 100 billion neurons in the human brain, joined by 100 trillion connections. In addition to these neurons, the brain is made up of many different types of cells that interact with each other to allow us to perceive and think.

In the past, the dominant theory of adult brain function encouraged us to think of the brain as a fixed structure, an organ that in many ways is more like a computer than a biological structure. The brain, like other tissues, is generated based on a blueprint. Much as architects work with blueprints to build structures, our body and brain tissues are built on a blueprint, a genetic blueprint, beginning with DNA. Within every cell is the DNA complement that can make all the functional proteins that are required for that cell and the brain to function. Within every cell of the brain, this genetic material continues to make proteins and functions throughout life.

A major component of this early theory of brain function was that the changes that occur in the brain happen during development. Each of us develops from a single fertilized cell into a fully functional organism. That growth and development are predicated in our DNA blueprint. However, we also know that the development of the brain from early stages to a full-grown organ is dramatically influenced by environment. Thus, although the blueprint is active from birth, in defining the *basic elements* structure, the environment plays a very important role in the final product.

For many years, neuroscientists believed that once the mature postadolescent brain had been formed, it was fixed and immutable. One of our early neuroscience heroes, Ramon y Cajal, described it in this way: "Once development was ended, the fonts of growth and regeneration of axons and dendrites, which are the processes of our neurons, dried up irrevocably. In adult centers, the nerve paths are something fixed and immutable; everything may die, nothing may be regenerated."

This view of the fixed, immutable structure of the brain caused us to think about the brain as a computer. Recently, however, this dogma of the static nature of the brain has been challenged. It is now becoming clearer that the existing neurons are more "plastic" then previously believed. The connections between neurons can be increased or decreased based on experience, and even the total number of neurons can change in certain areas of the brain due to changes in experience and physical interaction with the environment. This change in brain structure in response to environmental changes is greatest during development, but surprisingly and remarkably, this environmentally induced structural plasticity continues throughout life in all mammals.

In summary, the brain controls our behavior, and genes control the blueprint for the design and structure of the brain, but the environment can modulate the function of genes and, ultimately, the structure of our brain. Changes in the environment change the brain and therefore can change our behavior.

What does all this information about neuroscience have to do with architecture? I contend that architectural design can change our brains and behavior. The structures in the environment—the houses we live in, the areas we play in, the buildings we work in—affect our brains and our brains affects our behavior. By designing the structures we live in, architects are affecting our brains. The different spaces in which we live and work are changing our brain structures and our behaviors, and this has been going on for a long time. John's book will open a dialogue between architects and neuroscientists to begin to determine how these different disciplines can work together to understand and improve the impact of space on the brain and our lives. This dialogue is a needed first step, and it will require participation of both neuroscientists and the architects; importantly, these two groups need a translator or they need to learn a new language to have this dialogue. This book should provide a foundation to assist both groups to speak together.

Fred H. Gage is professor and Vi and John Adler Chair for Research on Age-Related Neurodegenerative Diseases at the Laboratory of Genetics of the Salk Institute.

Preface

C. P. Snow in his well-known book *Two Cultures* says, "Constantly I felt that I was moving among two groups—comparable in intelligence, identical in race, not grossly different in social origin, earning about the same income, who had almost ceased to communicate at all. Who in this intellectual, moral, and psychological climate had practically nothing in common." He was speaking in broad terms about scientists and artists. In this book, I want to speak about a way of providing common cause between two specific and important groups: (1) the architectural community that creates designs for the buildings in which we spend more than 90% of our lives and (2) the neuroscience community that has focused on understanding how the brain and the mind have evolved to provide us with an ability to experience the world around us.

Both groups at their best provide us with beauty: one with a beauty expressed in physical terms that we perceive with our senses and use to shelter the activities of our lives; the other with the inner beauty of the mind and the beginnings of understanding how the mind comprehends and why the body experiences pain and pleasure. We need both. Each stands on the brink of understanding the other. The hope is that this book can stimulate intellectual links that will enrich us all.

As Professor Lord Porter said in his Second Athenaeum Lecture in London in 1998, "The scientist and the artist have much in common; both strive for originality through imagination; each tries to make a new statement and each hopes that the statement will be in some way acceptable to others. The fundamental difference between them is the type of statement that is made."

This difference is described by Nobel Laureate Herbert Simon in his book *The Sciences of the Artificial* (1996), "Historically and traditionally, it has been the task of the science disciplines to teach about natural things: how they are and how they work. It has been the task of engineering schools [read architecture] to teach about artificial things: how to make artifacts that have desired properties and how to design them."

In organizing possible intellectual links, I have chosen to use the term *framework* proposed by Francis Crick and Christof Koch (1997). A framework is not a detailed hypothesis or set of hypotheses; rather, it is a suggested point of view for an attack on a scientific problem, often suggesting testable hypotheses. A good framework, they suggest, is one that sounds reasonably plausible relative to available scientific data and turns out to be largely correct. (It is unlikely to be correct in all the details.) The framework often contains unstated (and unrecognized) assumptions, but this is unavoidable.

For general readers, this book provides an insight into ideas not previously contemplated. For the architectural community, I show exciting new possibilities for expanding our knowledge base by increasing the range of evidence-based design criteria. For the neuroscience community, I challenge scientists to begin exploring these new research horizons as a way of expanding future opportunities for newly minted doctorates and postdoctoral students.

Contents

BRAIN LANDSCAPE

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Introduction

The goal of this book is to invite the neuroscience community to devote a portion of their research agenda to architectural hypotheses. These hypotheses are framed by questions of why the mind—with its organ, the brain—produces specific cognitive experiences for humans in the spaces and places designed for their use. Spaces include open areas such as parks, playgrounds, ceremonial plazas, and other landscape designs. Places include urban complexes, buildings, and especially interiors designed to serve some functional purpose.

As you walk into the Abbey Church in Bath, England (see Fig. I–1), your brain goes into overdrive. Not only does the shape and size of the space and the sparkling colors of the windows of stained glass behind the altar visually stimulate you, but all of your senses are formulating a sense of awe. The sounds of your footsteps on the hard pavement, the reverberation of music as an organ plays, the hushed voices of other visitors are being processed by your auditory cortex. We sense the rough texture of the stone before we actually touch it. We smell the musty odors of an old building and perhaps the remnants of recently burned incense. We assemble these sensory experiences in our brains and then filter them through our memories.

Figure I–1. Bath Abbey.

It is obvious that our brains and minds are interactive with the architectural settings in which we live, learn, worship, and work. The dramatic response of our sensory systems when visiting the Abbey Church are present in less dramatic form in 90 percent of our waking hours—the amount of time most of us spend inside of buildings.

However, we know very little about the ways and whys of our brain/mind interaction with architectural settings. The rapid development of neuroscience shows promise to begin assembling a body of knowledge around architecture and the mind. This book is intended to present the case for doing so and to suggest methods and models for going about creating such a new knowledge base.

THE HISTORICAL BASE FOR ARCHITECTURE IN PHYSICS

Little advances in physics were made during the Middle Ages. Although great medieval universities were founded in the 13th to the 15th centuries, these universities were places for scholarship in philosophy, literature, or the arts. There was little or no science based on experiments, even in the medical schools. There was a brief flowering of science in the 17th century, primarily based on the work of Sir Isaac Newton. However, from the time of Newton until the 19th century, little happened to advance physics.

In the 19th century, discoveries in electricity and thermodynamics were firmly established by experiments, and principles of these discoveries were incorporated in mathematical formulas. This enabled the engineering community of the 20th century to develop special areas of competence in electrical engineering, mechanical engineering, and environmental engineering.

It seems likely that just as 19th-century physics underlay the development of 20th-century engineering applications, so neuroscience (combined with genetics) will become the basis for new applied science tools in the 21st century. In the next few decades, it is likely that the fundamental aspects of neuroscience will become the domain of a new generation of applied social and behavioral scientists, engineers, and architects.

NEUROSCIENCE AND ARCHITECTURE: TWO NEW PARADIGMS

The concept of paradigms, first introduced by Thomas Kuhn (1970), is described here for both the architectural and neuroscience communities. An indication of the difficulty of introducing new knowledge into such communities is discussed. An example of a successful change in the design of neonatal care units based on knowledge from neuroscience is presented. This section concludes with comments on the likely path of paradigm shifts in the design professions.

Kuhn introduced the concept of paradigms. He says:

> Close historical investigation of a given specialty at a given time discloses a set of recurrent and quasi-standard illustrations of various theories in their conceptual, observational, and instrumental applications. These are the community's paradigms, revealed in its textbooks, lectures, and laboratory exercises. By studying them and by practicing with them, the members of the corresponding community learn their trade. (Kuhn, 1970)

The architectural and neuroscience communities are quite different communities whose paradigms are relatively clear. In the architectural community, the studio exercises of students, concentrated on designing buildings, become the central focus of their paradigm. With the exception of books on the history of architecture, textbooks in architectural schools are almost exclusively related to an engineering discipline whose basic tenets grew out of 19th-century physics. To become licensed to practice, a novice architect is tested for knowledge of structural design, lighting design, HVAC (heating, ventilating, and air conditioning), acoustics, and so forth. The core paradigm, however, is premised on creating *design solutions for buildings* that meet building codes and are constructible by skilled craftspeople. The profession awards prizes to designs (usually only shown to the judges in photographs) based on the changing value systems of one's peers. To be published in this community is to have photographs of buildings printed in professional journals accompanied by descriptions prepared by writers whose material is based on personal views, is lightly edited, but is not subject to the rigors of peer review. The architectural press, as well as the accolades of architectural fan clubs, change their allegiances every few years and encourage a striving for original design solutions.

The neuroscience community has sufficiently defined its paradigm through the classic medium of textbooks, lectures, and laboratory exercises required of students. The conceptual, observational, and instrumental applications of neuroscientists are organized around the brain, its genetic origins, developmental progress, network structure, chemical and biological activities, and so on. In rare excursions, these lab exercises will touch on aspects of the human experience, but generally the puzzles they address are ones that, when solved, advance our understanding of how to deal with disease.

The community of cognitive neuroscientists includes studies of how the behavior of animals (including humans) is caused by, modified, or prohibited by brain activity. To be published in these communities is to prepare a detailed, rigorous description of an experiment, how it was conducted, and what results were achieved. One's peers who are versed in the special language of the experiments review such publications. The articles are usually accompanied by detailed illustrations of the observations made with technologically sophisticated instruments.

Shared Paradigms and Developing Crisis

Kuhn suggests that communities who share a paradigm also share the belief that the kinds of problems they are prepared to address have solutions for which their skills are needed. They reinforce this belief by accepting only those problems into their community that they can solve. Problems that lie outside of their field of knowledge are considered to belong to another discipline or need to be rejected because they are too difficult. The result can be that the community is insolated from those important problems that are not reducible to their puzzle form and hence cannot be stated in conceptual terms they understand.

Kuhn proposes that a shift away from an existing paradigm occurs when a crisis develops. The crisis might be created when a discovery becomes known (e.g., x-rays) that no one had known about earlier. Or it might be produced by an anomaly—something about a puzzle being studied does not produce the results expected (e.g., Copernicus could not explain the motion of planets by using the existing paradigm of the time, namely, that the Earth was the stationary center of the universe). The difficulty with facing a crisis is that the decision to reject or modify an existing paradigm will not be made unless there is a new one to take its place. Those who hold the existing paradigm will take their time and be very cautious about comparing the new one with the old one before making the change. Historically, new paradigms have been adopted by another generation, leaving the practitioners of the old paradigm to retain their beliefs and methods for the balance of their careers.

Kuhn goes on to say:

> When a new paradigm begins to emerge, members of the existing community will be reluctant to embrace it unless convinced that two all-important conditions can be met. First, the new candidate must seem to resolve some

> outstanding and generally recognized problem that can be met in no other way. Second, the new paradigm must preserve a relatively large part of the concrete problem-solving ability that has accrued to science through its predecessors. (Kuhn, 1970)

The crisis in the architectural community is of two kinds. The first is a general dislike the public shares of the advanced design concepts of the architectural stars (those who are published as taste makers). For example, a letter to the editor of the *New York Times* (after their issue on architecture) says, "the whole architecture profession is ego gone wild. Here in Denver [where the author of the letter lives], Daniel Libeskind has given us a new art museum that looks, God forbid, like a collapsed skyscraper, jagged and inverted."

John Silber in his book *Architecture of the Absurd* (2007) argues that form meant to please one's self (or one's theoretician cronies) is architecturally irresponsible. He is displeased with "the heights of pretension and bogus philosophic and historical exposition."

A contributor to ArchVoices (a student Web page) wrote:

> One stated example of architectural leadership in the public realm is service on an architectural review board—with the goal of making it easier for architects to get modernist designs built in their communities. When our cities and countries are facing rapid ecological degradation and increasing inability to provide well-designed buildings and neighborhoods that are equally accessible to all people, is stylistic guidance truly the kind of leadership we need from design professionals?

The crisis in the neuroscience community is created by the existence of the enormous body of research emerging from the neuroscience community that is largely unknown to the architectural community—much like the existence of x-rays was unknown to the scientific community before Röntgen's discovery in 1895. There are two very different reasons the architectural and neuroscience communities have failed to bridge their intellectual gap.

The architectural community, although intellectually curious about new ideas such as neuroscience, is not prepared to give up the existing paradigm that serves them well in solving the kinds of problems they see as relevant. They do not "recognize problems that can be met in no other way." The architectural community also has their existing paradigm reinforced by clients (the source of income), code authorities (the source of law enforcement for correctly solved puzzles), and by the academic community (the source of new employees who can move comfortably into offices practicing the existing paradigm).

The neuroscience community, though intrigued by the possibility of interdisciplinary studies with architects, sees no possibility that a new paradigm would preserve a large part of their current problem-solving ability. Their field is so new that discoveries are being made every day, making it unnecessary for them to resort to a new way of working. Even novices entering the field (through graduate programs in universities) dare not entertain visions of a new paradigm for lack of assurance that careers paths will be open to them.

The Case of Dr. Stanley Graven and His Colleagues

Here we include an example of a new paradigm approach. The sensory systems of the human fetus develop in sequence. Four of them (called the somatosensory modalities), touch, pain, position, and temperature sensitivity, are the first to appear in the fetal life. These are followed very shortly by vestibular modalities—the sensory systems of the middle ear that detect motion. The third set of systems to develop and begin to function are the chemosensory systems of smell and taste. These are all well established with connections to the midbrain and basal ganglion in the second trimester of fetal life. The sensory auditory modalities, including responses to sound and vibration, appear early in the third trimester. After the critical stage for auditory development has past, it is followed by visual development. It is interesting to observe that at this point in development, the human fetus has no need for light or visual stimuli to have perfectly normal visual development.