Executive Summary:

The Academy of Neuroscience for Architecture (ANFA) invited neuroscientists to analyze environments most familiar to them, their own laboratories and offices. By identifying key characteristics common to this end-user typology, and proposing hypotheses about the cognitive processes affected by these characteristics, the group explored the interface between the neuronal and architectural aspects of laboratories and offices used by neuroscientists.

The workshop began with three "experts" on neuroscience laboratories: a neuroscientist, Dr. Eduardo Macagno; an architect/laboratory designer, P. Richard Rittelmann, FAIA; and an ethnographic researcher, Margaret Alrutz providing pertinent background material to inform the upcoming discussion and analysis of these environments. First, Macagno explained the goals and purpose of neuroscience research labs, the spectrum and evolution of work (from the nano-scale to the atomic scale) conducted in such facilities, as well as, the importance of technological instruments and precise controls on environmental conditions (such as light, temperature, vibration etc.) to this field.

Next, Rittlemann discussed environmental implications. He emphasized the importance of adaptability within neuroscience labs particularly as experiments change and technology is updated. Rittlemann suggests that rather than forcing equipment to adapt to the model of existing labs, and assigning people to occupy the leftover spaces, it is necessary that designers address the specific requirements of the equipment and to design the appropriate interface between the equipment spaces and the occupant spaces.

Finally, Alrutz recommended that designers seek to understand the everyday activities of the neuroscientist, at the human, versus the building, scale. To that end, each of the neuroscientists attending the workshop was asked to complete a photo survey and a log of his workplace environments to facilitate an understanding of neuroscientific activities as they relate to the laboratory environment. The neuroscientists were asked to identify and record specific spaces associated with behaviors and performance outcomes, such as "the place in your building most often used for collaboration." This data was synthesized and utilized as background information during the workshop small group sessions.

Once the three presenters were finished, interdisciplinary small groups engaged in directed discussion on one of four topics: **creativity, productivity, stress and memory**. These topics were selected as specific performance characteristics of laboratory related activity. Participants examined a) the neural processes involved in each performance characteristic, and b) the potential contributions the designed environment makes to each. The goals were to utilize empirical methods of testing in order to evaluate an intuitive understanding of the relationship between environment and performance outcomes, so that scientific knowledge can be applied to design.

Below is a brief synopsis as well as one hypothesis proposed by each of the small groups:

Creativity Group:

This group analyzed the two-fold process of creativity: 1) divergent thinking, the unrestrained state of flow in generating novel combinations of information; and 2) directed thinking, the more concentrated editing process to evaluate the ideas generated (adapted from Dietrich, 2004). They discussed *neural variables of creativity* such as: cognitive flexibility / plasticity, age and disease. They also pondered the *environmental variables of creativity* including: enhanced recall via proximity to the information (e.g. proximity to a computer or library), and interacting: experimenting with group dynamics such as density (size of group) and group demographics.

Before any of their proposed hypotheses can be tested, several other questions must be answered.

- What is the most appropriate way to measure creativity in neural terms? Is there a pattern of brain activity associated with creativity? Have studies been done correlating creativity with neural processes, and if so what technologies were used (e.g., EEG, imaging)?
- What is the baseline for creativity? What changes occur between baseline and creativity?
- The ecological validity of measuring creativity in isolation would have to be correlated with behavioral studies and results measuring the human response in the ever-changing real environment.

Sample Hypothesis:
Spaces which induce a higher frequency of interaction between lab members may impact the quantity and quality of creative ideas by enhancing stimulation levels.

<u>Environmental variables:</u> High interaction = open interior courtyards or atriums Low interaction = closed rooms
<u>Measurement techniques:</u> *Behavioral:* The frequency of interaction with others can be correlated with traffic patterns recorded by video and motion sensors. *Neural/Physiological*: Electroencephalogram (EEG), Magnetoencephalography (MEG), and or heart rate recordings to be taken after periods of interaction

<u>Productivity Group:</u>
This interdisciplinary group acknowledged the difficulty of establishing a *common metric of productivity*. It discussed several potential metrics of productivity including: frequency of published literature, frequency of citations, training of Ph.D. candidates and postdocs (quality of placements), and proof of concept for experimental studies, among others. They also recognized *behavioral variables of productivity* such as*:* working long hours can result in cognitive fatigue and stress (certain procedures require lengthy experimental cycles) and sharing data and concepts can boost self-esteem and enhance mood. Finally, they pondered *the environmental variables of productivity* including: serendipitous interaction spaces in building's public and circulation spaces to invite collaboration, and easily reconfigured lab spaces allowing people to adapt the environment to their experimental needs.

Sample Hypothesis:
Daylight and/or daylight with exterior views reduce cognitive fatigue and enhance attention/clarity thereby increasing productivity.

<u>Design variables:</u> Daylight and views as measured according to luminescence factors and room size ratios
<u>Neural variables</u>: Cognitive restoration = improved attention, focus, memory, and decision-making ability as measured by cortisol level reduction, EEG measures, galvanic skin response, musculoskeletal tension, and cortical imaging
<u>Behavior/performance variables:</u> Improved cognitive restoration will result in improved behaviors including: the ability to focus on research/experiments over long time cycles (several hours), fewer errors, more productive hours dedicated to work/ research as measured by self-report diaries, number of hours worked, and managerial performance evaluations.

<u>Stress Group:</u>
This group noted likely sources of stress among neuroscientists, as well as, that frequently, stress results from "neophobia," a fear of the new or a dislike of change. Thus, adaptation to a source of stress can be achieved. They acknowledged that although stress can be damaging, there also seems to be an optimal level of stress necessary for productivity. *Neural and physiological variables of stress* affirming that stress elicits neural, endocrine and immune responses such as: the release

of hormones, cortisol and epinephrine, increased heart rate and blood pressure, musculoskeletal tone and irritability. They note the variety of types and degrees of stress, as well as, the differences in how it is experienced across subjects; while some need sensory deprivation in order to maintain appropriate stress levels, others need stimulation. This group suggested that an individual's ability to control environmental factors (e.g. temperature, lighting, level of privacy, etc.) is correlated to higher effectiveness and is a function of his/her degree of stress, a multitude of hypotheses flow from this suggestion including the one below. The group recommends that each of the design variables be tested independently.

Sample Hypothesis:
An individual's ability to control temperature is correlated to higher effectiveness and is a function of his/her degree of stress.

Experimental metrics could be assessed in terms of both individual and group statistics and include:
Behavioral measures: Measure of productivity such as the number of publications, and effective collaborations; pre- and post-occupancy evaluations; individual interviews and surveys; observation
Design measures: Participatory design allowing occupants to engage in activities which will reveal their programmatic needs during the pre-design phase
Neural measures: Musculoskeletal tone, EEG, evoked potentials, cortisol levels

Learning and Memory Group:
This group discussed the three primary components of memory: the ability to acquire, retain, and recall information. They explored the e*nvironmental variables of memory* noting that studies on the recent discovery of neuroplasticity, the brain's ability to stimulate neural reorganization, have found that enriched environments promote neural growth in regions associated with memory formation (Kempermann et al., 1997; Eriksson et al.,1998; van Praag et al., 2000; Gage, 2002; Kempermann et al., 2004; Kozorovitskiy et al., 2005). They recognize that the optimal spaces for learning and memory processes which vary according to task and individual. Environmental variables may include open-communal versus closed-individual spaces, and multi-sensory spaces versus reduced sensory spaces.

Sample Hypothesis:
Technology can be implemented to support memory.

Experiments would investigate the influence of media and technology devices on memory cuing. The social and environmental isolation that occurs with personal device use may serve to support immersion in flow and concentration by eliminating social and environmental distractions in the laboratory. Alternatively, cognitive function associated with multiple sensory stimuli may be enhanced. Implications of this study may inform the design and implementation of future memory supporting technology, such as a potential "cave surround" sensory isolation system.

Conclusions:
Engaging neuroscientists simultaneously as investigator and the topic of investigation stimulated discussion on fundamental issues inherent to neuroscience and architecture research in general, as well as those issues specific to the neuroscience laboratory building typology. The group agreed that in order to undertake experiments examining different environmental stimuli, the first priority is to address task design including: developing appropriate controls which would correlate brain activity to the environmental variables, establishing baseline responses to the stated performance outcomes, and employing measurement techniques which would effectively gauge a change in response across settings.

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