NeuroDesign: From Neuroscience Research to Design Thinking Practice. Hasso Plattner Design Thinking Research

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NeuroDesign: From Neuroscience Research to Design Thinking Practice

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Abstract
There is an increasing use of neuroscience research methods to understand the neural basis of design activity. The use of Neuroscience research tools such as fMRI, EEG and fNIRS presents a new and insightful approach to potentially understand the mechanisms underlying design thinking at the level of individual designers as well as teams. However, the results from neuroscience research while insightful are rarely directly applied to design practice. In this chapter, we explore this gap between neuroscience research and design practice and explore how the emerging field of NeuroDesign might bridge this gap. Delving into the epistemology of design practice and the promise of neuroscience, we present the understanding and practice of learning as a key bridge between the two fields. We explore the broader implication of learning in the framing of NeuroDesign and present a research agenda for further studies in the field.

1. Introduction

NeuroDesign is an emerging field of study that lies at the intersection of neuroscience research and design thinking practice. Consequently, a fundamental challenge in NeuroDesign is to effectively and efficiently apply the information gained by studying brain functioning to the development and teaching of improved design thinking practices. Neuroscience based approaches (e.g., fMRI) could provide information not only about whether a particular design-thinking-based approach works, but also how (or why) it does. Knowing the underlying neural mechanisms involved in a particular design thinking approach could provide valuable insights for developing new and effective pedagogical and practical methods. Further, advances in neuroimaging at the single participant level (a.k.a. Precision neuroscience; Saggar et al. 2019) could be immensely useful in tailoring design thinking practices to each individual.

In order to realize this promise, the studies that are undertaken in the field of NeuroDesign need to go beyond the paradigm of the current studies on neuroscience of creativity and design thinking and include elements that will orient the findings to practical use in day to day design thinking application. In this chapter, we outline specific gaps that need to be addressed and potential avenues for exploration to move the field of NeuroDesign towards the application of neuroscience-driven design thinking in the real world.

2. Neuroscience experiments to research Design Thinking

Neuroscientific research examines brain functioning through highly controlled lab experiments in which participants perform a pre-defined set of cognitive tasks. This allows us to investigate activation of specific brain regions by examining changes in brain activity/connectivity. Measuring such changes in activation/connectivity can putatively inform about which brain regions are active when performing certain cognitive tasks. For recent examples of finding neural correlates of design thinking based practices, see Saggar et al. 2015 for assessing neural correlates of figural creativity or Shealy & Gero 2018 for examining neural correlates of brainstorming. Neuroimaging paradigms could provide valuable insights about the underlying neurocognitive process of thinking in design. Understanding and observing neurocognitive processes of designers has a great potential to inform design practices. However, there are several disciplinary gaps between applying neuroscience-derived insights into design thinking practice.

3. Disciplinary gaps between Neuroscience and Design

Neuroscience and Design Thinking have differing purposes. Neuroscience aims to understand the brain functioning that enables specific modes of thinking and behaving. Design Thinking aims to apply these specific modes of thinking and behaving to an external objective such as profit, beauty, utility or even justice. This difference in purpose creates several gaps. These differences are outlined in Table 1.

Table 1 shows the difference in the nature of Neuroscience and Design Thinking

	Neuroscience	**Design Thinking**
Purpose:	Understanding thinking (in design, i.e. creativity)	Enabling and utilizing thinking in design (e.g. creativity)
Question:	Hypothesis testing	Design challenge
Condition for answer:	Falsifiable	Satisfactory
Reasoning:	Deductive	Abductive
Predominant thinking:	Analysis	Synthesis
Experimentation mode:	Controlled experiment	Prototyping to reach real-world conditions
Practical considerations:	Scientific terminology Costs of brain imaging Scientific methods	Design terminology Costs for materials Design methods

3.1. Question gap

Neuroscience is situated within the empirical science paradigm of hypothesis testing and theory formation. It seeks to understand and model how the human brain functions when performing various cognitive, creative, affective, social as well as unconscious activities. It asks deep reasoning questions about how our neural mechanisms influence who we are and how we behave. Designers, on the other hand are situated within the constructivist paradigm. They ask generative - what if - questions that seek to both answer and shape how the world ought to be. A neuroscientist aims to understand the complex nature and dynamics of our brain, while a designer would consider ways to apply this thinking for an external purpose such as profit, beauty, utility or justice.

For example, McKim (1980) outlined how to think visually to create beauty, utility and ultimately profit. Similar, Adams (2001) described practices of how to overcome blocks to creative thinking. The effects in thinking developed through creative exercises can be observed by neuroscientists (Saggar et al 2015).

3.2. Culture gap

Another gap is the culture gap of what each discipline values and how this value is manifest through everyday practice. The two cultures phenomenon has been expressed by Snow (1993) between science and writing. Neuroscience focuses on empirical proof through hypothesis testing and well designed and controlled experiments utilizing tightly defined cognitive tasks. The result of a neuroscience study is considered scientific when it is accompanied by empirical evidence that can be replicated or falsified by others. In contrast, design outcomes aim to create a satisfactory condition to the challenge at hand. This can be accomplished through many different solutions without a single right answer. The search for a satisfactory solution is pursued through abductive reasoning which is not necessarily empirically grounded or even explicitly communicable. There is an artistry in design which clashes culturally with the technical rationality of neuroscience.

3.3. Reasoning and thinking gap

The nature of reasoning in the design thinking discipline differs from that in the neuroscience discipline. Neuroscience follows a deductive and inductive reasoning that allows for new knowledge to be created based on a strong foundation of what is already known. Design follows an abductive reasoning pattern that seeks to create variations that are an amalgamation of both concept and knowledge, and seeks to test, iterate and refine on these variations through real-world trial-and-error. The gap between neuroscience and design is that too much focus on deductive reasoning and analytical thinking in design will not result in a novel satisfactory solution, while abductive reasoning and synthesis in neuroscience will not result in an answer that contributes to the body of scientific knowledge.

3.4. Approach gap

The approach gap consists of how knowledge is produced in both disciplines. As mentioned above, neuroscientific experiments require tightly controlled lab settings. In contrast, thinking in design includes experimenting of failing fast, prototyping and leaping or learning forward. These are different learning approaches. This gap becomes apparent when researching design thinking through neuroscience. Thinking of the designer incorporates real-world experience and insights and flexibility and fluency in thinking and approach. Therefore, when researching design thinking through neuroscience, trade-offs need to be made. Either the complexity of real-world practice needs to be reduced, in turn reducing ecological validity, or a higher degree of freedom in activities needs to be allowed which could putatively reduce the observability and scientific reproducibility to generate testable insights about the neural correlates of that design activity. These conflicting approaches present an important and challenging gap that needs to be bridged.

3.5. Practical gaps

The last gap is a practical gap incorporating costs, jargon and methodology. Experiments in neuroscience can involve costly procurement, operation and maintenance of brain imaging instruments. However, recent technological developments have decreased the cost making brain imaging more accessible (Gero 2019). This could allow designers to utilize brain imaging techniques. However, it is important to understand both the language and methodology within a discipline to form a successful bridge between it and practice. When executing brain imaging study, designers need to understand the language used in the neurosciences to build on this large body of knowledge. Understanding the language will also help in understanding methodological approaches and how to collect, analyze and interpret data. This may be a steep learning curve for designers. However, without it, it will be difficult for designers to contribute and utilize the existing knowledge of neuroscientific studies to advance thinking in design. On the other side, neuroscientists need to understand the language and methodology of designers to generate value. If neuroscientists will simply persist in their methodology, they will provide explanation of design thinking, but will not contribute by creating knowledge that improves design thinking practice. To add value to thinking in design both sides need to understand the current technological limitations and methodological perspectives including the complexity involved in designing and developing meaningful solutions that serve the needs of people in real-world conditions. For this to happen, the practice of learning is key to bridging the gap between the two disciplines.

5. Practice of learning to bridge the gap of neuroscience and design

Neuroscience and design thinking share a similar concern, which is to study, support and augment the ability of people to learn. For bridging the gap between the two (un)learning is essential. However, this kind of learning requires empathy for each other. Empathy to understand another field and culture requires one to detach from one's own worldview and to reframe the world from the other's point of view. The best way to understand one another is to experience the practice of the other. Embodied learning could be facilitated by doing or being involved in neuroscience research and design thinking practice. It is a process of socialization as described by Nonaka & Takeuchi (1995). For example, learning is best accomplished by practicing neuroscience in design thinking and utilize design thinking to creatively find new interesting questions and design neuroscientific experiments. This approach has been stated by Einstein and Infeld (1967) as making true advances in science. The first step is to offer each other a helping hand and start collaborating to bridge the neuro-and-design gaps. In this collaboration there are two modes of learning, a constructivist approach by practicing and reflecting, and a positivistic approach of scientific discovery.

5.1. Learning by practicing

Neuroscientists can learn and develop their creative capability through participating in the creative thinking activities in design, while designers can learn and develop their scientific curiosity and analytical thinking through partnering with and practicing neuroscientific research. It allows each discipline not only to observe indirectly the thinking of people, but also it provides an environment to think about thinking, a reflexive practice of thinking about one's own design or neuroscience practice. This intersection allows the researcher and designer to develop their ambidextrous thinking as described by Faste (1994). In this sense, a neuro-designer is a creative scientist or a scientific creative who is able to bridge the gaps.

5.2. Learning from research

Scientific research is an activity with the main focus of producing knowledge. Neuroscientific experiments can help to understand the underlying thinking in relation to specific practices. Insights on brain activation and structural developments can provide knowledge, which one can act upon to improve one's thinking. This by itself can help to develop practice of learning in science and design. To enable this learning in the intersection of neuro-and-design, we propose a framework that can help address the gaps between neuroscience and thinking in design.

6. A framework to address the gaps

Neuroscience and design thinking have the potential to inspire and enable each other. The emerging intersection of neuro-and-design, Neurodesign has the potential to bridge the gaps by understanding the neurocognitive processes in design thinking through scientific observation and improving the thinking in design through synthesis and informed intentional action. To enable this intersection several gaps outlined above need to be addressed through the practice of learning.

6.1. Bridging the Question gap

The Question gap can be overcome by understanding the similarities of neuroscience and design thinking. Both start with an attitude of questioning and curiosity. Both the scientific problem finding or designer need finding require the gathering of information about the environment and the contextual frame. This has been described in science, arts and design (Getzels & Csikszentmihalyi, 1976; Arnold 1959; Einstein & Infeld 1967). Creative thinking is at the core of this process of defining the research question, hypothesis or design challenge. The bridging of the Question gap could be achieved by creating a question formation toolbox that could be used by both design practitioners as well as neuroscientists to drive hypothesis generation.

6.2. Bridging the culture gap

Overcoming the culture gap is probably one of the most difficult tasks. Culture has to do with shared beliefs and values (Schein & Schein 2016).. Overcoming and accepting other beliefs and values that may challenge one's own value system requires letting go. A first step that may be helpful is to accept that different body of knowledge exists. The scientific body of knowledge is about how the universe "works". Design has a different body of knowledge as described by Vincenti (1993). The body of knowledge of design is constructive or productive knowledge. The knowledge of how to manipulate the world. Through designing, building and evaluating engineers and designers create knowledge about how the world could be. While these are two types of knowledge, they are not mutually exclusive. When designing and executing experiments designers produce something new while scientists can observe the process and outcome and empirically test it through interesting experiments. This allows us to examine the thinking in design neuroscience and utilizing the thinking in design through design practice to create real-world solutions that serves the needs of people.

6.3. Bridging the reasoning and thinking gap

The focus on analytical thinking in science and synthetic thinking in design can be overcome through developing the ability for both types of thinking. This has been called as ambidextrous thinking by McKim (1980) and Faste (1994). It is important to know when each type of thinking is required and being able to flexibly move between the two. The meta-ability is to be able to change thinking modes by will (McKim 1980) thus allowing for individuals to work creatively and analytically when the task requires. There is a need to come up with novel and relevant experiments through creative study designs to advance theoretical knowledge as well as practice, and a need for thorough analysis to understand deeply observed concepts. Learning and developing these abilities will allow us to overcome the analysis and synthesis gap.

6.4. Bridging the approach gap

Experiments of neuroscience can be combined with design research approaches to examine both the neurocognitive process and context of these processes such as background of the person, chain of activities, outcomes such as products and environment of everyday practice.

Through the combination of capturing these different variables, experiments can be designed in the neuro-design intersection that could contribute to both neuroscience and design disciplines. Other design practice aspects that could be examined include team interactions based neurocognitive process (Mayseless et al. 2019), and the context of cultural environments of design thinking practices.

6.5. Bridging the practical gap

The practical gap pertains to the gap in the actual practice of the two disciplines which could involve issues of cost, time, language and methods. The biggest challenge faced by both designers and neuroscientists is a lack of time to pursue the bridge to another discipline. Designers are on a tight schedule to deliver on their projects and do not necessarily have the time to learn new tools, language and methods from neuroscience. Similarly, neuroscientists are on a tight schedule or running research projects to take time to learn new methods and ways of thinking from design. If NeuroDesign is to become an interface between the two disciplines, it needs to somehow overcome these practical issues. One way is to create explicit programs that create space for collaboration between the two disciplines through grant making and funding of collaborative design projects. Another is to create a research and development agenda that seeks to create micro-tools or micro-activities that enable neuroscientists to practice design thinking and designers to adopt findings from neuroscience during the course of their daily routines. These tools or activities could act as a translator between the practitioners of the two disciplines.

7. Conclusion

Neuroscience and Design Thinking might seem unlikely collaborators but could form a potent partnership that could not only inform neuroscience studies but also radically improve design practice. We call this partnership, NeuroDesign. In this chapter we presented the gaps that NeuroDesign as a discipline will need to bridge between neuroscience and design practice and suggested a framework for closing these gaps. The term NeuroDesign is such a term that requires new meaning without overemphasizing the neuroscience analysis or the design thinking synthesis and develop a new intersection that can improve the thinking in design, the ability to design and develop better solutions for our world.

References

Adams, J. L. (2001). Conceptual Blockbusting: A Guide to Better Ideas, Fourth Edition. Cambridge, MA: Perseus Publisher.

Altshuller, G. (2002). 40 Principles: TRIZ Key to Innovation. Technical Innovation Center Inc.

Arnold, J. E. (1959). Creativity in Engineering. In P. Smith (Ed.), Creativity, an examination of the creative process: a report on the third communications conference of the Art Directors Club of New York (pp. 33-46). New York: Hastings House.

Arnold, J. E. (1962). Useful Creative Techniques. In S. J. Parnes & H. F. Harding (Eds.), A source book for creative thinking. USA: Scribner.

Einstein, A., & Infeld, L. (1967). The Evolution of Physics. London: Touchstone.

Faste, R. A. (1994). Ambidextrous thinking. In Innovations in Mechanical Engineering Curricula for the 1990s: American Society of Mechanical Engineers.

Gero, J. S. (2019). From design cognition to design neurocognition. Paper presented at the CogSci 2019.

Getzels, J. W., & Csikszentmihalyi, M. (1976). The Creative Vision A Longitudinal Study of Problem Finding in Art. New York: John Wiley & Sons.

Mayseless, N., Hawthorne, G., & Reiss, A. L. (2019). Real-life creative problem solving in teams: fNIRS based hyperscanning study. NeuroImage, 203, 116161. doi:https://doi.org/10.1016/j.neuroimage.2019.116161

McKim, R. H. (1980). Experiences in Visual Thinking. USA: Brooks/Cole Publishing Company.

Nonaka, I. & Takeuchi, H. (1995). The Knowledge-Creating Company How Japanese Companies Create the Dynamics of Innovation. New York: Oxford University Press

Osborn, A. F. (1963). Applied Imagination Principles and Procedures of Creative Problem-Solving. USA: Charles Scribner's Sons.

Saggar, M. & Uddin, L. Q. (2019). Pushing the Boundaries of Psychiatric Neuroimaging to Ground Diagnosis in Biology. *eNeuro* **6,** ENEURO.0384–19.2019

Saggar, M., Quintin, E.-M., Kienitz, E., Bott, N. T., Sun, Z., Hong, W.-C., Chien, Y.-h., Liu, N., Dougherty, R. F., Royalty, A., Hawthorne, G., & Reiss, A. L. (2015). Pictionary-based fMRI paradigm to study the neural correlates of spontaneous improvisation and figural creativity. Scientific Reports, 5(1): 10894.

Schein, E. H., & Schein, P. A. (2016). Organizational Culture and Leadership. Hoboken, New Jersey: Wiley.

Shealy, T., Hu, M., & Gero, J. S. (2018). Patterns of Cortical Activation When Using Concept Generation Techniques of Brainstorming, Morphological Analysis, and TRIZ. https://doi.org/10.1115/DETC2018-86272

Snow, C. P. (1993). The Two Culture. New York: Cambridge University Press

Vincenti, W. G. (1993). What Engineers Know and How They Know It: Analytical Studies from Aeronautical History. USA: Johns Hopkins University Press.

Zwicky, F. (1948). The Morphological Method of Analysis and Construction. In Studies and Essays. (Vol. Courant Anniversary Volume.). New York, NY: Interscience.