1. Introduction

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This handbook presents an exploration into the nascent field of neuroentrepreneurship. At this point, the general body of entrepreneurship research has examined global, national, local, individual, and cognitive levels of entrepreneurship. With the advancement of technology and neuroscience-inspired methodologies in other business and economics fields, it was inevitable that entrepreneurship researchers would venture even deeper into the realm of the curious entrepreneurial brain. However, where to begin?

As with the other social sciences, the study of entrepreneurship uncovers many seemingly conflicting behaviors in its subjects. We see entrepreneurs coming from various backgrounds, experiences, and environments in virtually every culture, with a complexity that stretches the limits of the deep and narrow study that is common in academic research. Even focusing on a “narrow” area such as cognition quickly becomes complex due to perceived and unperceived influences (chemical and physical) in the brain of the entrepreneur, along with his or her interpretations and reactions to those influences before any action is ever taken.

It is not difficult to conclude that entrepreneurship is a “mindset,” a concept that is wide currency today. We no longer teach about entrepreneurship, we attempt to teach the entrepreneurial mindset (see for example Kriewall and Mekemson, 2010). Though we do this without ever really defining what we mean by “mindset,” or how to measure it properly. The cognitive and neuroscience fields may offer us exactly what we need: the deeper structures that characterize entrepreneurial thinking and behavior. Only now do we have the technology to seriously begin to explore this and to offer definitions.

Over the past decade, researchers have revealed an increased interest in studying these perceived and unperceived influences and responses. This is partly because of the brain-based tools that are increasingly accessible through neuroscience avenues (See Krueger and Welp, 2008; Stanton et al., 2010; Krueger and Day, 2010). Indeed, like their neuroresearch cousins in economics, marketing, and other behavioral sciences, entrepreneurship researchers have tentatively begun to step into this

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research space. However, faced with hurdles such as a lack of familiarity with and training in neuroscience research design and implementation, along with interpretation of reactions in the brain to stimuli in laboratory experiments, this can be daunting.

Experimental studies in entrepreneurship research in their own right, however valuable, are still relatively uncommon. Most social scientists simply do not have training or experience using functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), or positron emission tomography (PET). Neuroscientific studies are conducted in a laboratory setting and require trained specialists to set up and run the equipment and then to assist with the interpretation of the results. As much as we might want to become masters of the neuroentrepreneurship laboratory domain as well, this type of research may stretch the limits of many entrepreneurship researchers' current methodological capacities. We strongly encourage you to reach out to neuroscientists and cognitive scientists to develop and execute sound, generalizable research.

We present the chapters in this handbook as examples of approaches that some of the pioneers in this new field of neuroentrepreneurship have taken or plan to take. The authors of these chapters reflect the breadth of expertise that entrepreneurship scholars can draw upon. Within this handbook, you will find technical chapters that explain the various types and methods available to researchers. You will find examples of the types of hypotheses that can be tested with these methods, and you will find specific examples of theories in a variety of areas such as risk, decision making, and cognition that can be fruitfully tested through these methods.

Before we get started, it is important to consider some philosophical issues with which one must wrestle within the realm of brain-based research. In fact, neuroscientists do not conclusively know if and how the brain correlates to the mind. Per Mary Harrington (2011, p. 38), *The Design of Experiments in Neuroscience*, she writes: "In my opinion, figuring out how mind arises from brain is the largest and most enduring question in neuroscience."

Regarding neuroentrepreneurship, are we interested in the entrepreneurial mind, the entrepreneurial brain, or possibly both? Within this handbook, we are interested in the mind and/or brain of someone who is entrepreneurial. We do not know whether there is a type of mind or a type of brain that is entrepreneurial. In fact, we may find no evidence for this. Early entrepreneurship researchers thought that there would be measurable personality traits that could predict who would be entrepreneurs, but found no evidence for such. Skeptics believe that neuroentrepreneurship researchers are going down a similar path. Still, none of us can deny that there is something different in the mind, if not the brain of entrepreneurs.

It is entertaining to imagine something similar to the “sim-man” in medical education, to have a “simulated entrepreneur brain” created after hundreds of thousands of brain scans and other experiments with entrepreneurs that could then be studied under various environments and treatments. Could this lead to artificial intelligence – simulated entrepreneurs’ brains and predicted simulated responses? Imagine a virtual test database rooted in theories around various constructs found in the entrepreneurial experience, such as failure, autonomy, altruism, loss, or success. Researchers could then test a wide variety of hypotheses using data from actual entrepreneurs when they become more easily accessible for studies.¹

As interesting as the possibility of building a sim-entrepreneur is, it is also important to remember that such designs will always be rule-governed and controlled by instructions, without the physiological constraints that exist in actual humans (Epstein, 1984). However, that does not stop scientists from trying to create a brain-like computer. For instance, scientists in Japan are taking a new “beyond Turing” approach, presenting a “multilayered seed structure” that filters sensory input, “learns by itself,” and writes its own programs to solve problems (Ghosh, et al., 2014). Perhaps within the next few decades we could have a sim-entrepreneur that might recognize opportunities and create solutions?

It may seem impossible to re-create brain-based scenarios of past entrepreneurial successes or failures. However, in the competitive world of pop music, major labels have algorithms that they run on songs that have been hits previously – in an attempt to re-create that success. Songs are not entrepreneurs, but given developments such as these, could entrepreneurship be just another field waiting to be understood deeply enough for us to make use of tools such as the sim-entrepreneur?

ENTREPRENEURIAL MIND, ENTREPRENEURIAL BRAIN?

Instead of a reductionist approach, we take a nomological stance that the mind is not the same thing as the brain, but that the mind arises from the brain. In Chapter 3, Colosio, Bellavitis, and Gorin present the field of psychophysiology that explores this relationship between mind and brain (body), between chemical and electrical signals, and physiological activity such as increased heart rate, movements, emotions, or risk-seeking behavior. Do these signals cause the activity or does the activity cause the signals? Where does the mind fit in?

A reductionist would say that behavior could be fully explained by the neural activity in the brain.² In Chapter 5, Ward, Reeck, and Becker

discuss several variations of reductionist theory and its criticisms. Kurthen (2010) presents a thorough analysis of several philosophical positions: reductionism (materialism where “the mental reduces to the cerebral” and parallelism where there is “no interaction between the mental and cerebral”), dualism (epiphenomenalism where “mental events are caused by physical events” and not vice versa), and Kurthen’s own position: non-reductive physicalism (where “the mental is asymmetrically dependent on the cerebral, without being reducible to it . . . mental events are ‘realized’ by cerebral events” (p. 8)).

An example: “. . . while it seems obvious that my intention to raise my arm causes my arm to raise, it is not part of our commonsensical understanding (unless we are neuroscientists) that my intention to raise my arm causes my brain to build up a certain pattern of activation in the primary motor area of the cerebral hemisphere contralateral to the arm to be raised. But this is exactly what would have to be the primary effect of my intention, if it should also manage to cause my arm to raise” (Kurthen, 2010, p. 6).

An interesting research question would then be: do chemical and/or electrical signals in one part of the brain, as might be activated in some type of experimental entrepreneurial treatment, appear to affect other parts of the brain and somehow affect a mental response occurrence? This is an example of a question that, while seemingly elementary in the world of neuroscience, could be a first step toward application in neuroentrepreneurship experiments. As a neuroentrepreneurship researcher, you might design your methodologies and perhaps interpret your results differently depending upon your philosophical assumptions about mind–brain causation. Rather than intentionally, what if Kurthen’s arm raised as a result of an errant electrical impulse in the brain, or in response to a fight-or-flight activation where “intent” may exist at some instinctual level. It could be “realized” by the cerebral, but not necessarily perceived at a consciousness level. Is this important to know for neuroentrepreneurship research? Or is it enough to know that there is concurrence, whichever way?

If direction is important, this would speak to a need for a basic notion of causation. Kurthen (2010) argues that “[n]euroscience can only demonstrate concurrence, but if lawlike [nomological] concurrence is all we need for stating causation, then neuroscience can give evidence for causation” (p. 18). This type of groundwork can serve a valuable role, enhancing and informing our theory and research methodologies in neuroentrepreneurship. Harrington (2011, p. 48) explains that hypotheses related to the “proximate causation of the phenomena” would answer “how” questions, and those related to “ultimate causation” would answer “why” questions.

This brain–mind relationship represents a different presentation of causation than what we find in traditional social science research, but it is not new. For instance, Fodor (1983) references mental faculty theories, the beginnings of which go back to antiquity. These are “theor[ies] of the structure of the causal mechanisms that underlie the mind’s capacities” (p. 24). Quoting Spearman (1930): “[t]he general intention (in faculty theories) [. . .] is to represent the countless transient mental experiences by a small number of relatively permanent – particularly innate – different principles” (p. 26).

Neuroscience has shown how amazingly complex is the brain and its parts, functions, and interrelationships. Yet it is the nature of theory building to reduce the complexity to somewhat manageable heuristics, another type and process of reductionism. In Chapter 5 Ward, Reeck, and Becker demonstrate how this integrates with neuroentrepreneurship theory-building and research design methodology.

Liu et al. (2014) conducted an experiment partially funded by the National Institute of Health that examined “neural and behavioral correlates of face pareidolia.”³ In their article entitled “Seeing Jesus in toast . . .” the authors found that those who were able to distinguish faces in random pixels exhibited a higher level of communication activity between different parts of the brain than those who could not see faces in the same random set of pixels. Along similar lines, perhaps instead of there being entrepreneur-specific location characteristics of the brain (that is, the BOLD patterns resulting from fMRI scanning⁴), there may be levels of electrical and chemical pattern characteristics that cause or facilitate the entrepreneur to recognize an opportunity. Or perhaps it is all of the above combined.

These types of questions will need to be answered before we get to the point where we can create a simulated entrepreneur. Direction, or causality, would also need to be addressed and controlled for. Carter and Shieh (2010) note that: “activity in the visual cortex increases not only when human subjects are exposed to visual stimuli, but also when subjects are told to *imagine* visual stimuli” (p. 24, emphasis theirs). Stokes (2013)⁵ presents an in-depth discussion of the possible relationships between seeing, perceiving, and cognition, and how a person’s relationship with a given perceived phenomena changes with familiarity. While seeing is not necessarily believing, what one believes may influence what one sees. Whether this is due to conditioning (learning), or some innate “cognition-to-perception” ability would also be grounds for testing.

If opportunity recognition produces the same responses as facial recognition, then random pixels might correspond to an environmental context that the entrepreneur sees but others do not. Could imagining

itself (if not entrepreneurial imagining) be the representation of a type or series of chemical and electrical patterns? Would it be enough to know that such activations were concurring or does, going back to our previous discussion, direction (causality) matter? These are potentially rich areas for neuroentrepreneurship research.

In a recent concrete example (no pun intended), Robinson and Hayes (2012) tested the proposition that experience and social and institutional factors explain patterns of opportunity recognition. They shot video of a broken-down, graffiti-ridden, boarded-up storefront on a corner in Harlem, New York. Then they showed the footage to entrepreneurial individuals familiar with the area and some who were not (as a control) to test if and how they perceive entrepreneurial opportunity within that location. Since the perception and recognition of an opportunity would vary across individuals and cultures, imagine the electrical and chemical variances and/or patterns that might occur. A controlled neuroentrepreneurship experiment such as this would be another fertile area to apply neuroexperimental research methods such as those represented in this handbook.

THIS HANDBOOK

As you peruse the various chapters in this handbook, it is our hope that you the reader will find guidance and inspiration in designing neuro-based experiments to enhance your own research. The rest of this book is organized as follows:

Chapter 2: for anyone reading this volume, Pérez-Centeno provides a helpful overview of the various ways in which neuroscience methods can contribute to entrepreneurship research. As neuroscientists who are also entrepreneurship scholars are rare, this chapter brings together a helpful integration of the two fields. To do this, Pérez-Centeno first provides an overview of existing brain-based entrepreneurship research. Especially helpful is how the chapter walks the reader through basic experimental design to entrepreneurial cognition and brain-based research, and then an overview of strengths and limitations.

Then, Pérez-Centeno provides an in-depth, critical review of the neuroentrepreneurship literature. Specifically, the chapter covers strengths, limitations, and opportunities for better understanding the field and specific neuroscience methods (fMRI, EEG, and so on) applicable to entrepreneurship research. The chapter then concludes with an agenda for future research, along with several possible research questions.

Chapter 3: Colosio, Bellavatis, and Gorin make two significant contributions in their chapter. First, they outline a variety of physiological

and neurological processes that are potentially relevant to entrepreneurial decision making. This can help neuroentrepreneurship researchers work through and formulate research questions. For entrepreneurship scholars who are unfamiliar with physiology and/or neuroscience, this section would be helpful as a primer.

Their second main contribution is to outline the various ways in which these physical processes can be measured. Especially for entrepreneurship researchers who do not have a background in physiology or neuroscience, this section is helpful. The authors provide a useful outline of which techniques and tools are best for measuring which processes, along with a brief overview of the relevant benefits and limitations.

Chapter 4: De Holan and Couffe provide an overview of the potential for entrepreneurship research using electroencephalogram (EEG), a neuroimaging technique. For scholars who are specifically interested in this technique, or are considering this as one of several options, this chapter is useful. Specifically, the authors make the argument that research using EEG technology can be used both as a useful triangulation tool, as well as a central one. They then break down in detail specifically how EEG can be used, along with strengths, limitations, and ideas for future research.

Chapter 5: for scholars who are specifically interested in research using fMRI, a neuroimaging technique, this chapter provides first an excellent primer and then a deep dive into fMRI that is both useful and accessible for social scientists. Specifically, this chapter has several main contributions. First, the authors present the primary benefits and limitations of using neuroimaging techniques in general. For neuroentrepreneurship scholars considering neuroimaging techniques generally, and fMRI specifically, these sections are essential.

Ward, Reeck, and Becker then go on to define and describe fMRI in detail. Specifically, they discuss the types of hypotheses and designs in fMRI studies and how they can be useful for neuroentrepreneurship research as well as the benefits and limitations of each type of design. These discussions can help to set up neuroentrepreneurship scholars for success.

Particularly useful is the presentation of data analysis that is both general and specific to fMRI studies. Several of the techniques, such as regression analysis, should be familiar to entrepreneurship scholars. For the techniques that are not necessarily familiar, the authors identify these clearly.

Equally important is their section on communicating fMRI results. Even the most experienced researchers may inadvertently and unintentionally report results that do not accurately reflect the research when the methods used are unfamiliar. We strongly suggest that researchers using fMRI studies review again the communication section before drafting the results.

Chapter 6: Pérez-Centeno builds upon the presumption that a fusion between entrepreneurship and neuroscience is justified by the methodological and technological advantages facilitated by the former. He first suggests that the joint use of neuroscience tools such as laboratory experiments and brain-driven technologies are propitious to entrepreneurship research because they allow a deeper level of analysis: the entrepreneurial brain. Second, focusing on one of these tools – laboratory experiments – he unveils nine principles to take into account in good design of an experiment within the structure of a brain-driven entrepreneurship study.

Chapter 7: Day and Boardman present part of a stream of research that seeks to identify the intangible return-on-investment calculations that an individual makes in his or her decision to become an entrepreneur. This research pares down 33 cost and benefit decision variables to a handful of constructs that significantly explained the variance in their model. Then, specific to the point of this handbook, they present several hypotheses to test the model using neuroexperimental methods. These internal calculations in the mind of the pre-nascent entrepreneur may not be intentional but rather generated by the subconscious, and then “realized” by the cerebral. If however, there were such a thing as an “entrepreneurial brain” it would follow that electrical and chemical impulses came together at such a time (or maybe time and time again) to affect the mental to evaluate an opportunity that it identifies.

Chapter 8: Shaver, Schjoedt, Passarrelli, and Reeck make several main contributions in applying neuroscience methods to entrepreneurial decision making and risk. Specifically, they discuss the differences between neuroimaging and electrophysiological methods, and when to use both. Importantly, the authors complement the Colosio, Bellavatis, and Gorin chapter (Chapter 3) in providing an overview of the various methods relevant to neuroentrepreneurship. They also complement the Day and Boardman chapter on entrepreneurial return on investment (ROI) (Chapter 7) by providing a deeper dive on a specific aspect of Day and Boardman’s broader concept.

As experimental design is integral to neuroentrepreneurship research, the authors provide an excellent refresher on the topic. Specifically, the chapter contains overviews of method selection, methodology, and study design, along with technological and human factors. Then, the chapter walks readers through specific experimental designs relevant to neuroentrepreneurship. Particularly useful are the multiple examples of experiments that are both applicable to entrepreneurial risk and measurable using neuroscience.

Chapter 9: Sud provides an overview of experimental design, discusses brain plasticity, then advocates for an intervention-based approach

to this research. The chapter concludes with specific examples of intervention-based neuroexperiments to explore entrepreneurial cognition.

Chapter 10: Treffers features a helpful discussion on neuroentrepreneurship research design, focusing on entrepreneurial cognition and affect. She first presents an argument for the use of neuroscience methods to explore these phenomena. Then, this chapter provides an in-depth review of the relevant neuroscience literature. Finally, the primary contributions of this chapter involve a presentation of five neuroentrepreneurship designs that relate to entrepreneurial cognition and/or affect.

Chapter 11: Pérez-Centeno covers seven neuroscience technologies and four criteria to guide the appropriate selection of a neuroscientific tool for a given research question.

Finally, in Chapter 12: Guillory, Boardman, and Day provide a quick overview of the topics discussed in previous chapters, and then place this in context. Specifically, we discuss the benefits and limitations of neuroentrepreneurship research, and lay out what researchers should assess when deciding to devote the time and resources to pursuing this field of study.

NOTES

1. See, for example, the ASA Experiment Manager (pdf), http://human.cbtc.utoronto.ca/tutorials/ANT-PDFs/ASA_Experiment_Manager.pdf.
2. For an analysis see Sullivan, J. (2009), "The multiplicity of experimental protocols: a challenge to reductionist and non-reductionist models of the unity of neuroscience," *Synthese*, **167**, 511–39.
3. "Face pareidolia is the illusory perception of non-existent faces" (Liu et al, 2014).
4. BOLD stands for blood-oxygen-level dependent, which is explained in more detail in Chapter 5 of this handbook.
5. See also Mathen (2005) for a discussion on seeing, doing, and knowing.

REFERENCES

- Carter, M. and J. Shieh (2010), *Guide to Research Techniques in Neuroscience*, Burlington, MA: Elsevier.
- Epstein, R. (1984), "Simulation research in the analysis of behavior," *Behaviorism*, **12** (2), 41–59.
- Fodor, J. (1983), *The Modularity of Mind*, Cambridge, MA: The MIT Press.
- Ghosh, S., K. Aswani, S. Singh, S. Sahu, D. Fujita, and A. Bandyopadhyay (2014), "Design and construction of a brain-like computer: a new class of frequency-fractal computing using wireless communication in a supramolecular organic, inorganic system," *Information*, **5** (1), 28–100; Doi:10.3390/info5010028.
- Harrington, M. (2011), *The Design of Experiments in Neuroscience*, 2nd edn, Los Angeles: Sage Publishing.

- Kriewall, T. and K. Mekemson (2010), "Instilling the entrepreneurial mindset into engineering undergraduates," *The Journal of Engineering Entrepreneurship*, **1** (1), 5–19.
- Krueger, N. and M. Day (2010), "Looking forward, looking backward: from entrepreneurial cognition to neuroentrepreneurship," in Z. Acs and D. Audretsch (eds), *Handbook of Entrepreneurship Research: An Interdisciplinary Survey and Introduction*, 2nd edn, New York: Springer, 321–57.
- Krueger, N. and I. Welp (2008), "Experimental entrepreneurship: a research prospectus & workshop," *United States Association for Small Business and Entrepreneurship Conference Proceedings*, 1070–80.
- Kurthen, M. (2010), "Pushing brains: can cognitive neuroscience provide experimental evidence for brain-mind causation?," *Psyche*, **16** (2), 5–22.
- Liu, J., J. Li, L. Feng, L. Li, J. Tian, and K. Lee (2014), "Seeing Jesus in toast: neural and behavioral correlates of face pareidolia," *Cortex*, **53** (April), 60–77.
- Mathen, M. (2005), *Seeing, Doing, and Knowing: A Philosophical Theory of Sense Perception*, Oxford: Oxford University Press.
- Robinson, J. and R. Hayes (2012), "Opportunity recognition in inner-city markets: An exploratory study," *Journal of Developmental Entrepreneurship*, **17** (2); doi: <http://dx.doi.org/10.1142/S1084946712500112>.
- Spearman, C. (1930) *Psychology Down the Ages*, vol. 1, New York: MacMillan.
- Stanton, A., M. Day, and I. Welp (eds) (2010), "Introduction," in *Neuroeconomics and the Firm*, Cheltenham: Edward Elgar.
- Stokes, D. (2013), "Cognitive penetrability of perception," *Philosophy Compass*, **8** (7), 646–63.
- Sullivan, J. (2009), "The multiplicity of experimental protocols: a challenge to reductionist and non-reductionist models of the unity of neuroscience," *Synthese*, **167**, 511–39.