

# **Lessons from the Neural Foundation of Entrepreneurial Cognition: The Case of Emotion and Motivation**

David A. Baucus  
University of Otago  
School of Business  
PO Box 56, Dunedin 9054, New Zealand  
[dave.baucus@otago.ac.nz](mailto:dave.baucus@otago.ac.nz)

Melissa S. Baucus  
University of Otago  
PO Box 56, Dunedin 9054, New Zealand  
[Melissa.baucus@otago.ac.nz](mailto:Melissa.baucus@otago.ac.nz)

Ronald K. Mitchell  
Texas Tech University  
PO Box 2101, Lubbock, Texas 79406-2101, USA  
[Ronald.mitchell@ttu.edu](mailto:Ronald.mitchell@ttu.edu)

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## ABSTRACT

Our objective in this chapter is to illustrate how entrepreneurs' brains are physiologically the same as any other person's brain, but in terms of experiences and knowledge they are different. Using neurophysiology and relevant concepts from neuroscience, we peer inside portions of the individual's brain to map the physiological processes involved in transmitting visual data from the periphery (environment) to conscious thought and behavior, with affective processes (emotion and motivation) modulating data flows along the way. We explain how cortical fields and subcortical nuclei (key parts of the brain) process and code neural representations, first as simple data points, but then as behaviorally relevant *percepts* (perceptions) and *concepts* (conceptualizations) that carry *affective value* acquired through structures specialized for emotion and motivation. We also explain how these abstract building blocks of thought—percepts, concepts and affective valuations—decouple from external stimuli owing to repeated activation (experience) and come together with real-time data in the default mode network, with emotion and/or motivation enabling the entrepreneur to adapt behavior to a given context. An understanding of this 'standard complement' of physiological processes may allow researchers to explain similarities and differences among entrepreneurs and the opportunities they conceive. We offer 15 researchable premises that can be examined with current social-science methodologies and illustrate the implications of our approach (i.e., detailing how the brain generates behavior) for entrepreneurial cognition theory and research.

## INTRODUCTION

Are entrepreneurs like anyone else or are they different? Our objective in this chapter is to explain how entrepreneurs' brains are physiologically the same as any other person's brain, but in terms of experiences and knowledge, they are different. To achieve our objective, however, we need to take readers down the unfamiliar pathway of neurophysiology, from sensation to conscious thought—perception, conception and affective valuation—and into an attendant level of complexity some readers may find uncomfortable.

Our analysis holds implications for both research and teaching within the domain of entrepreneurship study. In tackling the question of whether entrepreneurs are different or the same – through the exploration of neurophysiology – we contribute to entrepreneurial cognition research by enabling future research to better focus on entrepreneurs' experiences and the implications for their perceptions, conceptions and affective valuations. When we assert that “physiologically entrepreneurs' brains are no different than the brains of others” we implicate current conceptualizations of the entrepreneur. We are therefore constrained to disagree in part with, for example, the “unique person” conception of the entrepreneur used by Shane & Venkataraman (2000) (that may overemphasize the role of individuals with incomplete experience-based knowledge in contrast to the standardized perfect-information/ rational-man of neoclassical economics); and instead we offer, and support with an extensive analysis of brain physiology, a conception of the entrepreneur that permits the existence of unique life experiences on one hand while emphasizing a ‘standard complement’ of neurological processes on the other. Thus we argue that a conceptual middle-ground exists for examining similarities and differences among entrepreneurs and phenomena such as opportunity conception.

We reason further that if we better understand the physiological workings of the brain, we can target ways to more effectively teach entrepreneurship. Our assertion that “entrepreneurs' brains are physiologically the same as others' brains but experientially they are different,” offers a compelling rationale for efforts expended by society to teach and learn entrepreneurship – especially experientially. We make the argument in this chapter that a better understanding of how episodic memory actually works in the brain (how it's used by humans in general and also by entrepreneurs specifically), and how episodic memory informs conceptual reasoning, might lead us to validate, refine, or develop pedagogies that rely first upon creating and engaging students in certain entrepreneurial experiences and then using these new memories to conceive opportunities.

Our analysis in this chapter is motivated by the need to resolve what we perceive to be a false dichotomy in the entrepreneurship literature, which erroneously pits nature (entrepreneurial traits) against nurture (entrepreneurial experiences) to explain entrepreneurs' behaviors. The deliberate practice stream of research in the expert information processing theory literature helps with this resolution by suggesting that expertise within a domain results from the combination of so-called “mental hardware” of the brain (e.g., hard coding: that produces learning rates, forgetting rates, speed of processing, and memory), with the “mental software” of the brain (e.g. soft coding: that contributes knowledge bases and problem-solving processes) (Charness, Krampe, & Mayer, 1996: 53). In this chapter we seek to map the terrain in the brain where soft coding meets hard coding. This mapping task is consistent with and may help to further amplify recent developments in cognitive psychology and entrepreneurial cognition research that integrate action, embodiment and social situation in explanations of entrepreneurial cognition (cf. Mitchell et al, 2011; Smith & Semin, 2004)

Our analysis is further motivated by findings which suggest a paradox of sorts in entrepreneurial cognitions themselves. On one hand, entrepreneurs as a group have been found to have cognitive patterns that are distinct from those of non-entrepreneurs – even across countries and cultures, suggesting a “universal culture of entrepreneurship” (Mitchell et al.,

2000: 988). On the other hand, within the group of entrepreneurs – *depending* upon culture – entrepreneurs have been found to have cognitive patterns that are distinct from each other (Mitchell et al., 2002). Theory is needed to explain how entrepreneurial cognitions can at once be the same, yet different. Our explanation of “why physiologically entrepreneurs’ brains are no different than the brains of others but experientially they are,” offers such theory.

As suggested in the first paragraph: to accomplish our task we must invite the reader to engage complexity. Yet the bewildering intricacy of the brain remains far too complicated for more than a highly-specific analysis of just a few cognitive processes by way of illustration. Thus, in this chapter we utilize the sight-to-feeling pathway (what happens in the split seconds between seeing and feeling) as this illustration, with entrepreneurial affect (emotion and motivation) as a focal point. In the following sections we therefore: (1) provide additional background to frame our research problem and illustration within entrepreneurial cognition, (2) offer definitions for key terms grounded in (structures-functions) physiology and justify our working from clear definitions, (3) introduce several fundamental principles of systems neuroscience that underlie our analysis, (4) describe the seeing-to-feeling pathway: starting with the ventral visual stream, (5) explain the hierarchical processing of episodic memory, with a link between percepts and concepts, (6) introduce emotion and then motivation to the exploration, and (7) discuss the implications of the analysis for entrepreneurial cognition research.

## **BACKGROUND**

As we have noted in our Introduction, the research problem that is our objective in this chapter is to explain why physiologically entrepreneurs’ brains are no different than the brains of others; but experientially they are. Researchers have addressed some aspects of this problem over the last decade by refining the definition of the entrepreneur to refer to a thinking, feeling human being (Baron, 2004; Grégoire et al., 2010; Mitchell et al., 2002; Mitchell & Shepherd, 2010), not necessarily a rational economic agent, but an actual person whose behavior derives from a standard complement of neurological processes (Baron et al., 2012; Baron & Tang, 2011; Haynie et al., 2010; Tang et al., 2012), and whose choices may be susceptible to cognitive heuristics and biases (Busenitz & Barney, 1997; Keh et al., 2002; Simon & Houghton, 2002). These researchers argue both that these distinctly human attributes affect the entrepreneurial process (Mitchell & Shepherd, 2010), and events – experiences – in this process affect the individual (Morris et al., 2012).

In this regard, emotion has emerged as a “hot topic,” and a proposed umbrella concept, subsuming the entrepreneur’s affective evaluations of many types of experiences (Baron, 2008; Cardon et al., 2012). Researchers have, for example, explored the impact of emotions on opportunity evaluation and exploitation (Foo, 2011; Grichnik et al., 2010; Welpé et al., 2012), creativity (Baron & Tang, 2011) and level of effort (Foo et al., 2009). Others have focused on the impact of specific emotions such as optimism (Hmieleski & Baron, 2009), passion (Breugst et al., 2012; Cardon et al., 2005), happiness (Hahn et al., 2012) or grief (Patzelt & Shepherd, 2011; Shepherd et al., 2009), as well as on coping behaviors and emotional intelligence (Foo et al., 2004; Rhee & White, 2007).

Such work has advanced the study of entrepreneurship through the rendering of the entrepreneur as human; but efforts to date to integrate affective evaluations into the entrepreneurial cognition research literature have been described as fragmented and limited (Grichnik et al., 2010). Significant challenges exist in identifying theoretical foundations from which to work (often requiring the use of disparate literatures); and in our observation, researchers have struggled to define core concepts (e.g., cognition, affect, motivation, emotion and stress) as well as relationships among these concepts. The research challenge has been magnified owing both to the subjectivity of entrepreneurial cognition as the phenomenon of interest, and to the currently unmet need for the use of common terminology: two research

complications that risk placing the topic beyond the scope of science (LeDoux, 2012). Thus, for example, it is very difficult if not impossible to study directly the subjective experiences of entrepreneurs' "feelings" or to distinguish among neural states corresponding to the glut of labels entrepreneurs may apply to introspective assays of their own feelings (e.g., angry versus frustrated; excited versus anxious; fearful versus stressed; or sad versus inept). Without a deeper more-accessible map of how cognitive processes work within humans as physical beings, the emerging research stream risks coming to resemble an amorphous construction of all things neural, built upon a shaky foundation that is an admixture rather than a coherent core.

We believe there are research premises that can be obtained from the in-depth analysis of the eye-to-brain pathway, to valuation, to behavior transmission physiology. Accordingly, as a specific and detailed illustration of the role of brain physiology in the complex processes involved in entrepreneurial decisions, actions, behaviors, etc., in this chapter we trace the path of episodically acquired data and their emotional/motivational valuation: from photons striking the retinae, the brain identifying and categorizing stimuli, the integration into episodic memory imbued with semantic meaning, and the judging of familiar vs. novel, toward the production of emotional and/or motivational value, all within a few hundred milliseconds. We therefore seek to contribute to the entrepreneurial cognition literature by offering a neuroscience-based analysis of entrepreneurial cognition, with particular interest in entrepreneurial cognition, which we have defined as: *all of the computations that support the acquisition and comprehension of episodic experiences in the brain, expressly including the affective evaluations of emotion and motivation*. Thus, in this chapter we are concerned with the "episodic processing" and "affective evaluation" portions<sup>1</sup> of entrepreneurial cognition, that is, with the neural substrate (e.g., cortical fields and subcortical nuclei) of entrepreneurial experiences and their emotional/motivational valuation. Study of this neural foundation of entrepreneurial cognition can have important benefits.

As Buzsáki (2004: p. 446) suggests: "Features of the physical world do not inherently convey whether [for a brain, or for an entrepreneur for that matter] (emphasis added), a situation is familiar or novel, whether a stimulus is pleasant or repellent, etc. These attributes are added to the information conveyed by sensory inputs by a process referred to as cognition." Thus we argue that it is not the case, as some would argue according to the Cartesian tradition that ignored the importance of the body and situation (e.g. as did Descartes, Locke, Hume, Kant), that emotions impact cognition as some outside influence that impinges only upon the mind as an inner entity of some kind (van Gelder, 1995: 380): an "isolated mind" (Gallagher, 2009, p. 35). Rather, we argue, and seek to better describe how the neurophysiological foundation of emotion is an essential part of cognition, and is critical for explaining the making of appropriate choices. Thus we argue that the notion of cognition subsumes all the unconscious and conscious processes that turn sights and sounds into neural representations that allow the individual to make sense of the world, form goals, and select suitable behaviors for a changing world, and that the study of the physiology informs a more-thorough explanation of the entrepreneur and entrepreneurial cognition: especially of emotion and motivation.

Our illustration objective, therefore, is that by articulating the computations that take place as environmental data travel from peripheral sensory circuits to structures subserving episodic memory, as well as those computations associated with the affective modulation of neural activity, we can generate research premises for the further advancement of embodied cognition research within the socially-situated entrepreneurial cognition research stream (Mitchell et al, 2011). We begin our analysis with some definitions; follow with an introduction

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<sup>1</sup> A more comprehensive definition would include *all* of the computations that support the acquisition and comprehension of episodic experiences in the brain, expressly *including* semantic processing. But for the sake of limiting the already almost-bewildering level of necessary complexity, semantic processing is *not* included in this illustration.

to systems neuroscience; then trace the flow of data through the visual “what” pathway to the Inferior Temporal Cortex (ITC) where percepts (i.e. perceptions) are identified: known as the ventral visual pathway. We then explain how this information projects to the hierarchical Medial Temporal Lobe (MTL) memory system responsible for episodic memory. Following this, we identify and describe the structures in the MTL which selectively gate for affective data, process spatial data, affix a time stamp, transform percepts into concepts and enable novelty detection. The discussion then turns to how the valuation of data occurs through the physiological stress response of emotion and the real-time computation of value supporting motivation; and we discuss the implications that the physiology of this sight-to-emotion/motivation pathway have for entrepreneurial cognition research.

{Insert figure 1 about here.}

We therefore argue that the contribution from incorporating neuroscience research into entrepreneurial cognition (and possibly more generally into management) studies will more likely come from informing research questions that can be addressed with familiar and highly-developed social-science methodologies, rather than from relying on (for example) fMRI machine output and identifying which parts of the brain are active when the subject does “x.” We argue this on both practical and theoretical grounds. From a pragmatic standpoint, few management (entrepreneurship) researchers presently have access to imaging technologies and have the training necessary to conduct the sophisticated statistical analyses required for processing voxel data (e.g., very large samples of regularly-spaced data points on a three-dimensional grid). (We note that neuroscience researchers do this kind of research well and we believe it to be sufficient to simply follow their lead to advance entrepreneurship research.) From a theory-building standpoint, we intend to demonstrate how, by our tracing the pathway from sight to emotion/motivation and to behavior, likely premises can be isolated for future research attention. In this chapter, we therefore utilize an in-depth analysis of neural structures to generate likely premises for entrepreneurial cognition research.

### **THE NEED FOR DEFINITIONS**

In our observation, some entrepreneurship researchers are beginning to conduct neuroscience research, but perhaps without the advantage of fully grounding their work in analyses of neural structures and functions: the physical “substrate” or foundation of cognitive processes. We believe studies of neural phenomena, in particular such important areas of study to entrepreneurship as emotions and motivation, with additional grounding in the anatomical and physiological analyses that describe the structure of specific brain areas (i.e., cortical fields and subcortical nuclei) and the functions (i.e., computations) performed by these structures, can assist researchers to explain previously un- or under-explained variance in the impacts of both emotion and motivation on entrepreneurial-cognition-based outcomes (cf, Mitchell et al, 2007). Such a foundation in structures and functions has the potential to free researchers from the constraints of inevitable subjectivity previously attached to explanations of affective phenomena (cf., LeDoux, 2012) and to offer key insights for clearly defining and differentiating among concepts, and for conducting additionally revealing research into the cognitive processes of entrepreneurs. We therefore offer working definitions of the key terminology to be utilized (see Table 1) as a foundation for the discussion in this chapter.

{Insert Table 1 & 2 about here}

In the following sections of this chapter we will proceed to analyze key portions of the physiological foundation of embodied cognition, i.e. “how the body shapes the mind” (see Gallagher, 2005) to: (1) explain how Medial Temporal Lobe (MTL) memory structures support episodic memory, the rapid coding of one-time experiences (Hafting et al., 2005; Hargreaves et al., 2005; Kondo et al., 2008, 2009; Lavenex & Amaral, 2000; Lavenex et al., 2004; McHugh et al., 2007); (2) describe the amygdala and physiological stress response that weights experiences

and stimuli, those slivers of memories entrepreneurs label as emotionally significant (Herman et al., 2005; Kreibig, 2010; Sah et al., 2003; Tsigos & Chrousos, 2002); and (3) describe the flow of dopamine from the ventral tegmental area (VTA) to ventromedial striatum (a.k.a. nucleus accumbens - NAc) that supports motivation and value-based decision making (Öngür et al., 2003; Price & Drevets, 2010; Sesack & Grace, 2010; Voorn et al., 2004).

Such study offers a foundation for investigating cognitive processes (e.g., emotion and motivation); and we therefore believe that grounding entrepreneurship studies in neuroscience represents a logical and helpful addition to the ongoing entrepreneurial cognition research effort. To date, entrepreneurship researchers have embraced an agenda taken primarily from cognitive psychology, as illustrated (non-exhaustively) in analyses of cognitive biases, emotion-as-information, expert scripts and venture creation, and effectuation (e.g., Baron, 2008; Busenitz & Barney, 1997; Foo et al., 2009; Grichnik et al., 2010; Mitchell et al 2002, 2007). Work in neuroscience has the potential to advance the entrepreneurial cognition research agenda by articulating the structures and functions involved in processing information from periphery circuits to conscious thought (in the default mode network – DMN, as discussed below), with emotion and motivation (as focal cases) being shown to modulate the acquisition, processing and storage of information, as well as the selection of behaviors along the way.

### **KEY PRINCIPLES OF SYSTEMS NEUROSCIENCE**

As we illustrate in this chapter, researchers have the opportunity to ground more deeply entrepreneurial cognition-based explanations in certain established principles of systems neuroscience, expressed as follows: (1) structure drives function; (2) endogenous activity constantly occurs; (3) experience modulates cognition; (4) critical cognitive processes occur offline; and (5) building blocks of cognition exist: that is, far from the periphery, the brain codes for abstract representations more aligned with the meaning and quality of often seen, familiar and personally relevant percepts than the physical features of things out there (Albright, 2012; Buzsáki, 2004). In the following paragraphs we offer the following deeper explanation of each principle in turn.

#### **Structure Drives Function**

The brain is built a certain way. As Wallace and Kerr (2010) note, the anatomy and physiology of individual cells (see Douglas & Martin, 2007; Spruston, 2008) and the structure of the cortex are well described as follows. The cortex is arranged in a laminar, six-layer organization referred to as isocortex (Harris et al., 2011; Treves, 2003). This gray-matter sheath is populated with about 80% excitatory pyramidal neurons (the most abundant excitatory cell type in virtually every mammal studied; found in the human cortex, hippocampus and amygdala; and associated with advanced cognitive functions) and 20% local inhibitory interneurons (cells thought to stabilize and directly shape the function (computations) of local circuits) (Markram et al., 2004; Spruston, 2008), with excitatory and inhibitory neurons organized as duplications of a stereotypical microcircuit template (Markram et al., 2004). Adaptations of this template are tied to the functions performed by specialized neural structures and the requirements of cognition. We examine the laminar and template structure of cortical fields and subcortical nuclei and their functions at each step in our analysis of the brain's work and workload.

#### **Endogenous Activity Constantly Occurs: No Dormant Starting Condition**

Is the brain's workload externally or internally generated? Two views of brain function have existed since the early twentieth century: one posits that the brain is primarily responsive to environmental demands (suggesting an external workload) and the other holds that most brain activity is endogenous (suggesting primarily an internal workload) (Raichle, 2009). The former view has historically influenced neuroimaging studies and may also constitute an extant belief in entrepreneurship, as in an emphasis on studies of overt behaviors in pursuit of opportunities that

exist “out there.” (We note that the discussions (and debates) over entrepreneurial discovery and creation may take some of their shape from such beliefs (cf, Alvarez & Barney, 2007)).

Nonetheless, internal demands are not insignificant. For example, metabolic analyses show that the brain maintains an enormous level of energy consumption, estimated at 20% of the body’s total oxygen and glucose resources (Raichle, 2010). As much as 80% of this energy is consumed through neuron signaling (Sibson et al., 1998), which suggests that it is therefore functionally significant endogenous activity, defined as ongoing and independent of the presence or absence of stimuli or observable behaviors (Snyder & Raichle, 2012). Energy consumption ascribed to environmental demands is estimated at less than 5% (Raichle & Gusnard, 2002; Raichle & Mintun, 2006). Hence, we assume that the idea of the “dormant” brain is not credible.

### **Experience Modulates Cognition**

If the brain is always working, but is not necessarily always heavily engaged with the environment, what is it that might be driving the massive internal activity that continuously occurs? Numerous explanations for the existence and function of endogenous brain activity have been posited over the years. Some researchers report that this activity plays a functional role in maintaining an excitatory-inhibitory balance in neural systems (Raichle & Gusnard, 2002; Wehr & Zador, 2003) enabling neurons to detect and respond to sensory stimuli on a millisecond timescale and speed information transfer (Deco et al., 2011; Kayser et al., 2010). Others argue endogenous activity plays a critical role in maintaining normal brain function, with disruptions of this activity linked to a variety of pathologies and to the degenerative effects of aging (Damoiseaux et al., 2007; Greicius et al., 2004; van den Heuvel & Hulshoff Pol, 2010). Thus, both brain balance and brain maintenance consume brain energy; but all of the energy?

Of course, the function of endogenous activity remains the subject of ongoing research, but sufficient evidence exists to also implicate *experience* in modulating cognition. How experience drives brain activity may also be explained physiologically. Endogenous activity originates in the electrophysiology of neuron spikes and spike correlations (Buzsáki & Draguhn, 2004; He et al., 2008), and this activity is either noise or neural code relaying information through functional networks. Harris (2005) argues synchronous and repeated activation of neurons during sensory stimulation and behavior enables neuron ensembles (i.e., cell assemblies – groups of neurons that function to sustain a memory trace – Hebb, 1949) to decouple from external events. Thus neurons are thought to maintain activity owing to repeated experiences *without* sensory stimulation, and (importantly) can be triggered by internal processes alone, for example by thought.

It follows that endogenous brain activity carries on meaningful tasks and, for example plays important roles in: (1) continuously sharing information (van den Heuvel & Hulshoff Pol, 2010); (2) maintaining ongoing internal representations (abstractions) of the external world; and (3) modulating neural activity during stimulus presentation (Harris, 2005; Kayser et al., 2010). Thus we can see how the brain learns to preferentially respond to and process familiar and relevant stimuli: how experience modulates cognition. We can also draw the inevitable conclusion that there likely is a so-called “offline” element to cognition.

### **Cognition Takes Place Offline**

Offline cognition matters. A critical discovery in analyses of endogenous activity is that resting-state neuron networks exist, defined as functionally related brain areas with high levels of correlated endogenous activity during rest (Raichle et al, 2001; van den Heuvel & Hulshoff Pol, 2010). Resting-state networks consist of structures with a common function and subserve known processes such as motor function, vision, audition, language and offline cognition in the



“default mode network,” or DMN, a set of brain regions that remain active when an individual is not externally focused, and when the brain is supposedly at rest – that is, offline.

The DMN exhibits heightened neural activity at rest and decreased activation from a “resting state” baseline during externally-focused tasks: negatively correlated with attention. Thus, this endogenous network comprises an offline “default” mode of cognition to which humans inevitably return when not externally engaged. The DMN subserves, or helps to further or promote, episodic recall and autobiographical memory (Greicius et al., 2003), self-referential thought (Gusnard et al., 2001; Whitfield-Gabrieli et al., 2011), emotion processing (Immordino-Yang et al., 2009), semantic processing (Binder et al., 1999; Wirth et al., 2011), as well as problem solving and episodic future thought (Buckner & Carroll, 2007; Gerlach et al., 2011; Szpunar et al., 2007).

### **Building Blocks of Thought Exist**

At the highest level of processing, the entorhinal cortex and hippocampus developed to support episodic (percepts) and semantic (concepts) memory (Buzsáki & Moser, 2013), while other structures compute affective valuations relevant to emotion and motivation: amygdala and orbitofrontal cortex respectively. These representations comprise abstractions aligned more with the meaning or quality of that which is often seen, familiar and personally relevant than physical attributes of something out there. In other words, the brain turns dimensionless, man-created concepts (e.g., entrepreneur) into rich representations informed by experience, with meaning derived from statistical regularities (i.e., learned associations) in the environment, and value ascribed to physiological processes, described below. These abstractions comprise the building blocks of thought and, combined with sensory data, ongoing representations of the world in the DMN that support adaptive behaviors. This systems neuroscience characterization of cognitive activity—as ongoing, offline and supported by abstract building blocks (representations) of thought—may align with and refine the concept of “the mind” employed in other literatures.

### **Summary**

For entrepreneurial cognition researchers, an understanding of the foregoing principles is the first step in laying the foundation for a more exacting physiological explanation of selected entrepreneurial cognition processes/outcomes. The next step in our analysis proceeds with a discussion of the ventral visual “what” pathway (Figure 1) and the distinction between sensation (i.e., of mere photos and sound waves) and perception.<sup>2</sup> The discussion and explanation offered in this next section – and in subsequent sections and subsections – is preceded by a brief explanation or map of the section (which appears in italics), and which is offered as a mechanism for the reader to receive a high-level explanation of the material that then appears in detail within that section.

{Insert Figure 2 about here}

### **THE VENTRAL VISUAL STREAM**

*When the individual views the world, visual stimuli enter the brain as mere data points (an orientation and spatial frequency) without meaning. This information undergoes associative processing) as it flows through the ventral visual stream (a.k.a – “what pathway”) and is recognized as behaviorally relevant perceptions (hereafter percepts) in the inferior temporal cortex (ITC). These meaningful percepts are organized categorically (e.g., people, places and things); encompass personally familiar people; are the product of both what was seen (real-time*

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<sup>2</sup> Note: A parallel dorsal visual stream (a.k.a. “where” pathway) exists and is associated with motion and location of external objects. While the functional characterization of the dorsal stream has been extensively debated, this material remains beyond the scope of our analysis and an unnecessary complication in our view. We track the steps in the ventral visual stream as a means to clarify the processing of stimuli to perception.

*data) and experience-based imagery; and suggest particular behavioral responses (though conscious thought, “this could be an exciting opportunity” and connections to behavior occur elsewhere). Moreover, the recognition of meaningful percepts can occur (for faces) in under 100 milliseconds.*

All sensory data, except olfaction (sense of smell), enter the brain through the thalamus, a structure that gates data transfer to sensory cortices: an initial barrage of excitatory input is rapidly followed by feedforward inhibition that squelches spiking responses in sensory neurons. The thalamus thus increases the temporal precision of firing patterns in sensory cortices and decreases noise: it has a function (Gaberet et al., 2005). As illustrated in Figure 2, we trace the path of visual data from the retina in the eye onward, to clarify the functions performed by other structures in the ventral visual stream, dubbed the “what” pathway, as well as those in the medial temporal lobe (MTL) memory system.

These functions comprise the initial computations in human cognitive processes, those that transform mere data points (encoded in individual V1, V2, V4 neurons) into high-level percepts recognized and stored in the inferior temporal cortex (ITC), then projected to the MTL (Lavenex & Amaral, 2000) and integrated into episodic memory (i.e., the rich and unique recollection of personal experiences or events from a person’s life – Tulving, 1972, 1983), as well as transformed into abstract conceptions of the world—percepts become concepts (Quiñero, 2012). We detail the: (1) computations that take place along the way; (2) content of episodic memory (e.g., percepts & concepts) entrepreneurs may tag as emotionally significant; and, thereby enable the description of (3) the essential role of affective valuation in cognition.

We note that episodic memory is defined as memory possessing emotional value: neutral events are not processed and consolidated into long-term memory. Episodic memory also comprises one interpretation of “experience” from neuroscience. With the potential to offer new insights about the elements of experience (e.g., scenes, objects, orientations, perspectives, self, and other people) the entrepreneur may leverage episodic memory to envision a business venture. Neuroscientists suggest that the individual flexibly recombines bits and pieces of memory to pre-experience the future through mental simulation, a cognitive trial-and-error process used to select actions with the greatest potential for producing desired outcomes (Addis et al., 2009; Schacter et al., 2008). Thus, the ability of the potential entrepreneur to identify and exploit an opportunity may depend on her ability to “see” the idea and its potential, combined with how she anchors her mental simulation (e.g., a product idea, garage startup concept, desired customer profile, or the benefits of being one’s own boss). Of course, not all such starting points lead to success. This is partly due to what happens as sensory data transform into behaviorally relevant percept, concepts and affective valuations.

### **From Sensation to Perception**

The “what” pathway is characterized as a hierarchical, recurrent and highly interactive network that processes object quality (Kravitz et al., 2013). Receptive fields, onset latencies and selectivity for complex stimuli increase as data travel from the V1 to the ITC, which is indicative of a hierarchical structure of neural flow. Nonetheless, anatomical data indicate that both feedforward and feedback projections exist among stages; and extrinsic projections to memory, valuation and cognitive systems occur at varied stages (Kravitz et al., 2013). These complex patterns of connectivity help explain the categorical structure of percept data (e.g., clustered by faces, scenes and tools), and the pathways through which top-down influences occur (i.e., how attention is controlled by internal/endogenous factors such as goals).<sup>3</sup>

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<sup>3</sup> Top-down (endogenous) processing is distinguished from bottom-up (exogenous) processing by the source of initiation, with bottom-up processing arising from external stimulus such as a loud noise, a shout, a flash of light, etc.; and top-down processing arising from the individual’s desire to achieve some goal or objective.

We therefore offer the following explanation. Neurons in the V1 (the primary visual cortex) have receptive fields selective for minute details of stimuli, with individual cells coding for both the orientation at a point in space and spatial frequency (i.e., sharp edges versus matt surfaces) of stimuli at that location (DiCarlo et al., 2012). Wide diversity exists in the two-dimensional tuning of cells, thereby enabling V1 neurons to respond to the same details of all stimuli, consistent with V1's function as the gateway for visual data into the cortex. The V1, however, does not yield camera-like representations of the world.

Higher-level visual fields (e.g., V2 and V4) perform associative integration functions (e.g. encoding various combinations of input from the V1) to form more complex object representations: they aggregate the output of prior stage feature detectors, while exhibiting successively larger receptive fields and greater tolerance (i.e., invariance) to variations in size, position and context (Hegdé & Van Essen, 2007; Kravitz et al., 2013; Rust & DiCarlo, 2010). Functional clustering occurs owing to heterogeneous wiring of the “what” pathway and processing requirements of stimuli. Researchers posit that categories of visual stimuli, requiring large populations of neurons and recurrent processing, cluster in areas affording the necessary connectivity and computing power, as in the fusiform face area (the part of our human visual system specialized for facial and/or object recognition) and scene-selective parahippocampal place area (where scene/place coding and recognition occur) (Kravitz et al., 2013).

### **More than Meets the Eye: Modulation by Experience**

Object recognition occurs in the ITC within about 150 milliseconds, but as Albright (2012: 227) explains: “It should come as no surprise that what you see is not determined solely by the patterns of light that fall upon your retinae.” Retinal input accounts for only about 20% of V1 activity (Muckli & Petro, 2013) and coding in the ITC is posited to be the joint product of current input and repeated experiences. Neurons in the ITC exhibit plasticity into adulthood. Experience-dependent learning steers ITC neurons to respond to familiar stimuli and with greater sparseness: fewer neurons carry better information for directing perceptually guided behavior to well-known objects. It is through recurrent pathways that top-down attentional effects (e.g., the goals of an individual) influence the entire state of the “what” pathway and filter irrelevant distractors.

### **Implications for Entrepreneurs**

What does this mean for our understanding of entrepreneurial cognition? Stated simply, we learn from this structural account of how signals move from the retina to “matchmaking” (coding for light patterns + experience) in the ITC, that the structures and functions in the visual “what” pathway support the transformation of sensations into behaviorally relevant percepts/perceptions, such that what the entrepreneur sees is modulated by experience. Neurons are tuned to familiar people, places and things: object identification. Based on the fundamental structure of the ventral visual system and prior research (Mitchell & Shepherd, 2010) into “images of opportunity,” we therefore suggest the following premise:

*Premise 1: It is likely that entrepreneurs rely on behaviorally relevant percepts—part stimulus driven and experience-guided imagery of familiar people, places and things—to envision a business venture.*

Our analysis of the ventral visual stream aligns with this conjecture, as neurons in the ITC are part stimulus-driven and part experience-tuned to respond to probable things (Albright, 2012). The modulation of perception occurs implicitly, out of habit, and supports refined perceptions (e.g., a doctor's diagnosis of patient symptoms). It enables the craftsperson to leverage perceptual abilities to start a business, but likely hinders her recognition of innovative business opportunities. Our analysis now turns to MTL structures (Figures 2 & 3) and an analysis of the

further hierarchical processing of high-level percepts into integrated episodic memories and concepts.

{Insert Figure 3 about here}

### **HOW EPISODIC MEMORIES ARE PROCESSED**

*Here we describe how percepts from the ITC, as well as all other sensory and endogenously generated data comprising an experience, converge on the medial temporal lobe (MTL) memory system and are integrated into whole episodic memories. Each structure in the MTL performs a specific function, as in gating, spatial processing, distinguishing coups from miscues, associative pattern completion and novelty detection. The types of processing that occur provide insights into the cognitive abilities and composition of episodic memory (experience) that entrepreneurs may use to “envision” a business opportunity. The MTL is also well-recognized as the place at which percept inform concepts: the nexus between experience and semantic comprehension*

Researchers describe the inferior temporal cortex (ITC) as the pinnacle of the visual “what” pathway and the long-term repository of visual memory. The ITC massively and reciprocally connects with medial temporal lobe (MTL) memory structures—defined as including the perirhinal-parahippocampal cortices, entorhinal cortex, and hippocampal formation (dentate gyrus, hippocampus (CA3 & CA1) and subiculum (Lavenex & Amaral, 2000)). The MTL supports: (1) rapid recording of one-time episodic experiences; (2) associative learning (plasticity) in cortical systems; as well as (3) memory consolidation and recall. We analyze the flow of data through the MTL, while explicitly linking structures and functions (Figure 3).

#### **Affectively-Weighted Information Passes**

*The perirhinal and parahippocampal cortices (PRPH) provides a powerful illustration of the importance of affective valuation in cognitive processes in the brain. This structure, a pair of cortical fields, gates noisy and otherwise nonessential details (e.g., nameless faces seen on the street), while permitting emotion-laden data to pass through. In other words, high value (positive or negative) content pertaining to venture performance or a promising opportunity gets preferentially processed into episodic memory.*

Information from the ITC visual field—along with all other data comprising an experience—converges on the perirhinal and parahippocampal cortices (PRPH), the gateway to the MTL. Together these structures account for nearly two-thirds of the cortical inputs to the entorhinal cortex (ERC) (Insausti et al., 1987), where spatial and nonspatial (e.g., affective) processing occur (Hargreaves et al., 2005). However, anatomists characterize unimodal, polymodal and endogenously-generated data as hitting a “wall of inhibition” at the PRPH, an apt construal of this region’s function in the MTL (Curtis & Paré, 2004). This is because the PRPH operates as a gate that inhibits propagation of extraneous data to the ERC and hippocampal formation (strongly implicated in episodic memory), while allowing affectively weighted information to pass. That is, in the PRPH, noise and nonessential details (e.g., nameless faces seen on the street) are deleted, while emotion-laden data pass through.

Animal studies show that stimulation of the ITC excites as many as 42% of perirhinal (PRC) neurons compared to only 2% of ERC cells, a response characterized as rare and sparse (i.e., stimulus coding by a small percentage of neurons) (Curtis & Paré, 2004). The PRPH likely quashes activity owing to highly spontaneous, non-code firing in cortical circuits (i.e., noise) and redundancies or irrelevancies in data, a function that supports the selective and precise integration of memory elements in the hippocampal formation. Indeed, problems occur when too much information gets into the hippocampus. Failure of inhibitory control has been

implicated in overstimulation or epileptic activity in the ERC and hippocampal CA3 and CA1 fields (Curtis & Paré, 2004).

Nevertheless, inhibitory control by the PRPH partially lifts owing to input from the amygdala (strongly implicated in the physiology of emotion) and medial prefrontal cortex (mPFC) (supporting conscious thought, autonomic/emotional control, and flexible/adaptive behavior), to the PRC (see above) and the ERC (Kajiwara et al., 2003). For example, stimulation of the basolateral amygdala (BLA) has been found to activate approximately 15% of both PRPH and ERC neurons (Curtis & Paré, 2004). These authors speculate, owing to the accepted roles of the mPFC and BLA in reward-related behavior and emotion (Öngür & Price, 2000), that "...traffic through the rhinal cortices [PRC and ERC] varies depending on the emotional significance of current environmental contingencies" (Curtis & Paré, 2004: p. 106). From a neuroscience perspective we can see how due to the PRPH, high value (positive or negative) content gets preferentially processed into memory (first in the ERC, then hippocampal formation), illustrating how essential it is to better understand the role of emotion and motivation in cognition generally, and in entrepreneurship specifically. How does the ERC process spatial memory?

### **Spatial Processing: Map and Compass**

*The ERC processes contextual (affective and behaviorally relevant) data, but is best known for spatial processing: it acts as a map and compass. Researchers argue the ERC evolved to support spatial navigation (e.g., a mouse foraging for food), but now supports human episodic and semantic memory, with the implication that navigation in physical and mental space rely on the same basic algorithms. The ERC supports landmark-base and Path Integration (PI) navigation and these relate to episodic and semantic memory, respectively. We describe the ERC as a map and compass here (a foundation) and develop implications for entrepreneurial cognition in our discussion section.*

The entorhinal cortex (ERC) constitutes one of the more interesting structures in the brain owing to its function in orienting the individual to the world, with computations tied to short-term synaptic plasticity – the tendency for the brain to change its connections in response to changing stimuli. Most people know that synaptic plasticity—cellular-level changes in dendritic spine architecture—supports long-term memory (Lamprecht & LeDoux, 2005). Less well known is that short-term plasticity can occur on the dynamic timescale of behavior (i.e., milliseconds) in the performance of neural computations (Abbott & Regehr, 2004; Fujisawa et al., 2008). Short-term plasticity in the ERC supports real-time processing of spatial data, but it may not retain memory for more than minutes or seconds (Almeida et al., 2012).

As shown in Figure 2, the entorhinal cortex (ERC) consists of two parts: the Lateral Entorhinal (LEA) and Medial Entorhinal Areas (MEA), executing nonspatial and spatial processing respectively (Hargreaves et al., 2005). The LEA processes nonspatial data about context, such as the emotional/behavioral significance of stimuli (i.e., people, places or things) consistent with its inputs from the olfactory and frontal cortices, insular cortex (involved in taste, emotion, homeostasis), and from subcortical amygdala and hypothalamus involved in triggering the physiological stress responses of emotion (de Quervain et al., 2009; Herman et al., 2005; Kreibig, 2010).

The (dorsocaudal) MEA operates as a generalized, context-independent representation of spatial environments, with an internal map of rigid spatial relationships that register comparable distances across environments and thereby offers a neural metric for distance (Jeffery & Burgess, 2006; Moser & Moser, 2008). Grid cells in layer II code for regularly spaced external locations (Hafting et al., 2005; Moser & Moser, 2008; Sargolini et al., 2006), while cells in layers III, V and VI are directionally-tuned based on head direction (Sargolini et al., 2006), with the combination of layers forming an internal map and compass. This structure supports two

types of navigation. Grids anchor to landmarks that permit navigation via goal-directed paths, with landmarks functioning as key decision points (i.e., go here, turn there) (Janzen & van Turennout, 2004; Maguire et al., 1997; Rosenbaum et al., 2004). Path Integration (PI) navigation uses self-motion cues to track linear and angular movements and continuously update representations of self-location, orientation, and distance relative to defined (past) reference points (Etienne & Jeffery, 2004; McNaughton et al., 2006).

In sum, the entorhinal cortex (ERC) processes contextual and spatial information, with the LEA and MEA together delivering data about affective value, landmarks, self-location, orientation, and distance data from reference points to the hippocampal formation for coding in episodic memory. Thus, the entrepreneur may recall specific details from an episodic memory: a scene, where s/he was standing, direction s/he was looking, location of prominent spatial features, objects and other people. S/he may project forward by flexibly combining similar elements of memory to envision a business venture, and this suggests our second premise:

*Premise 2: It is likely that entrepreneurs rely on specific details from episodic memory to envision a business venture.*

Next, the entorhinal cortex provides the major inputs to the dentate gyrus which enables the pattern separation skills found in most mammals, including humans.

{Insert Figure 4 about here}

### **Separating Coups from Miscues**

*Entrepreneurs acquire episodic experiences daily, with these experiences populated by the same people, places and thing. The question arises, “How does she distinguish this time from last time or tragedy from triumph. The dentate gyrus (DG) transforms highly overlapping episodic memories – relying on adult neurogenesis to affix a time stamp -- into sparse, orthogonal representations for storage in hippocampus. The entrepreneur may rely on temporal differences in episodic memories (subtle changes) as signals of opportunity.*

The dentate gyrus (DG) is anatomically notable as the primary entry point into the hippocampus proper (fields CA3 & CA1), where episodic memories are stored (and recalled) and the highest level of associative processing occurs. All DG granule cells (small, densely packed and uniformly sized cells located in the DG granule layer) project to CA3 pyramidal cells (Seress, 2007). In this section we examine the function of the DG as a filter or gate further reducing noise (Hsu, 2007) and a pattern separator for the efficient (i.e., sparse and orthogonal) storage of episodic memories in the extremely small hippocampal region: CA3.

To accomplish this task, the DG functions as a gate by producing both recurrent and feed-forward inhibition (Hsu, 2007). For instance, anatomical data show that a higher percentage of inhibitory interneurons exist in the DG compared to the cortex (i.e., 50% vs. 10 to 20%, respectively) (Acsády & Káli, 2007) and, through strong recurrent inhibition, spontaneous non-code firing in the DG is very low (0.1 - 0.01 spikes/s). DG granule cells are thus extremely quiet (Jung & McNaughton, 1993). When these cells participate in data transfer, interneurons respond very fast to suppress noisy non-code activity in a competitive manner (Acsády & Káli, 2007), so only patterns of ERC activation that are consistently and repetitively presented (i.e., familiar or the focus of attention) pass through to hippocampal CA3 region (Hsu, 2007).

DG granule cells drive feedforward inhibition in the CA3 region as well. Researchers report that a single granule cell contacts an estimated fifteen CA3 pyramid neurons, with each CA3 neuron receiving about fifty excitatory inputs. In contrast, granule cell axons synapse on CA3 inhibitory interneurons four times more frequently than CA3 pyramidal cells (Acsády & Káli, 2007) and CA3 pyramidal cells may have as many as 30 to 60,000 terminals within the CA3 network (Amaral & Witter, 1989; Li et al., 1994). Activation of more inhibitory than

excitatory neurons in the massively recurrent CA3 region suggests that DG granule cells may induce a net inhibitory effect in the CA3: they quiet background noise and permit the faithful transmission of information concerning what happened out there (Acsády & Káli, 2007; Amaral et al., 2007; Kondo et al., 2008). Thus, the DG dampens the transmission of noise and sharpens firing patterns for storage in the hippocampal CA3.

Nevertheless, the DG is most often characterized by its pattern separation function: it transforms highly overlapping representations (i.e., memories involving common contexts, people and objects) into highly dissimilar, nonoverlapping representations (Bakker et al., 2008; McHugh et al., 2007; Treves et al., 2008). Researchers hold that the DG performs this function through adult neurogenesis, the generation of new granular cells throughout the individual's life (Clelland et al., 2009; Deng et al., 2010; Eriksson et al., 1998).

Ninety-five percent of granule cells in the DG are generated during child development and do not divide thereafter, but the DG also contains neural progenitor cells that generate the remaining 5% of adult-born neurons (Nakashiba et al., 2012). Young adult-born granule cells are particularly responsive during a critical window after genesis; they may become tuned to events that occur during that time; and participate in the reinstatement of those precise memories (Alme et al., 2010). They orthogonalize memories according to time, in essence, affixing a temporal stamp. Recent evidence suggests that young adult-born DG granule cells contribute to ongoing pattern separation, while older granule cells support the rapid recall of memories through pattern completion (Nakashiba et al., 2012).

In sum, the DG transforms noisy and overlapping inputs into sparse, orthogonal code for storage in hippocampal CA3. It projects familiar data, most likely aligned with emotion-laden remembrances, but distinguishes *this time* from *prior times*. We therefore theorize that the entrepreneur depends on the DG to distinguish unsettling miscues from triumphant coups in a common context and thereby learn from successive experiences, and we suggest:

*Premise 3: It is likely that entrepreneurs rely on temporal differences in episodic experiences (i.e., between this time and prior times) to envision and conceive a business opportunity or venture.*

Pattern separation is essential to learning and memory (Bakker et al., 2008) and is likely critical to entrepreneurial cognition but, of course, it is not the only thinking skill required. Complete episodic memories come together in the hippocampal CA3, a neural field that permits the highest levels of associative processing and supports perceptual and conceptual reasoning, most likely used by entrepreneurs to envision the future and conceive (i.e., become aware of and semantically comprehend) a new opportunity and/or venture.

### **All the Pieces Come Together**

*The hippocampus is comprised of several neural fields (the CA3, CA1 and subiculum for our purposes), with the hippocampal CA3 as the place where whole episodic memories are processed and stored. The CA3 is described as highly recursive and supporting autoassociative recall, so a single environmental stimulus, word or thought can enable the entrepreneur to recall a past memory or vision a business opportunity or venture.*

It is reasonable to suppose that the entrepreneur experiences an event in a context with physical properties: her location in space (having an orientation and perspective); gaze direction and observed scene being duly noted; spatial relationships among landmarks and salient objects having registered; others moving, doing, saying observed; and affective responses to what happened experienced. These all come together as a coherent representation (i.e., as a whole episodic memory) for storage and recall in the hippocampal CA3 field, an area structured for forming new associations among ongoing experiences and permitting the sparsest code among small ensembles of pyramidal neurons.

The distinctive feature of the CA3 is that pyramidal cells mainly connect to other CA3 pyramidal cells to form a dense, recurrent network (Amaral & Witter, 1989). Any neuron is two or three synapses (junctions through which firing impulses pass) away from about four-million other CA3 neurons. Thereby, it can form arbitrary associations among any or all elements of an episodic memory and whole episodic memories can be stored in one unified network (Lavenex & Amaral, 2000; Treves & Rolls, 1994).

The CA3 has been described in computational models as supporting autoassociative pattern completion of whole memories (Marr, 1971; Rolls, 1996; Treves & Rolls, 1994). In other words, a single fragment, degraded or noisy cue can elicit the recall of a whole memory past or present (Leutgeb & Leutgeb, 2007; Marr, 1971; Rolls, 1996). The importance of autoassociative pattern-completion cannot be overstated: particularly as it relates to the recall of one-time, single-trial learning experiences (e.g., characterizing entrepreneurial processes), those which do not repeat and for which only partial or vaguely-remembered cues are available. Entrepreneurs may also depend on this property to envision (i.e., mentally simulate) a business venture from fragments from memories or ongoing experiences, a potentially critical insight. We therefore suggest:

*Premise 4: It is likely entrepreneurs rely on auto-association in episodic memory (the ability to retrieve a memory from only a tiny sample of itself) to envision a business venture from only fragmentary cues.*

### **Percepts Inform Concepts**

*The CA3 is also recognized as the juncture between percepts and concepts or, in other words, where the entrepreneur's experiences inform his or her semantic comprehension of a business opportunity. Environmental cues are observed as statistical regularities that attach semantic properties (belongs to this category) and the meaning to concepts: "the entrepreneur" or "opportunity" derives meaning from the individual's experiences.*

Thus far we have analyzed the hierarchical processing of visual data into high-level percepts from retina to ITC, and explained the generation of sparsely-coded, highly-personal episodic memories in the CA3. Structures described along the way gated, inhibited, extracted, sharpened and modulated the available data (through experience and affective processes), such that percepts in the ITC and episodic memories in the CA3 emerge from raw sensory data. We have illustrated how neurons become more and more selective and invariantly responsive to that which is familiar, often seen, and personally relevant. We have argued that these percepts and memories constitute abstractions removed from actual sensory stimuli, possessing semantic properties and subjective meaning (Albright, 2012; Quian Quiroga, 2012). Anatomists and computational neuroscientists alike argue the CA3 field resides at the juncture of transformations of percepts into concepts: the nexus between experience and semantic comprehension (Lavenex & Amaral, 2000; Quian Quiroga et al., 2008; Rolls, 1996) and compelling evidence supports the logic.

Quian Quiroga and colleagues, for instance, show about 14% of hippocampal neurons respond selectively and invariantly to objects, landmarks and persons, but the relationship is not a single neuron coding for a specific individual or landmark. These neurons, coined "concept cells," commonly respond to a small number of (often related) stimuli and small ensembles of neurons respond to categories of stimuli (e.g., landmarks – Eiffel Tower, Washington Monument or Tower of Pisa) and remain silent otherwise (Mormann et al., 2008; Quian Quiroga, 2005, 2012; Suthana & Fried, 2012). Moreover, concept cells that respond selectively to a person's image also respond to the person's written name and synthesized pronunciation of her name, showing independence of internal representations from visual stimuli. Thus, it has been suggested that CA3 concept cells and cell ensembles code for category, do not require visual cues, and can be triggered by mere thought (Quian Quiroga, 2012).



The meaning attached to concept cells is thus thought to be derived as follows. Learned associations between stimuli arise from *statistical regularities*<sup>4</sup> in the observer's environment (e.g., person + place = barista), regularities that prove beneficial for predicting and interpreting future sensory inputs (Albright, 2012). These associations are stored in memory and recalled as needed. Quian Quiroga and colleagues report that a time delay (i.e., latency) exists in the firing of CA3 neurons relative to the ITC. ITC neurons fire at about 100-150 ms after stimulus onset, but hippocampal neurons fire at 300-400 ms, an amount of time substantially and suspiciously greater than required for hierarchical processing through the MTL (Mormann et al., 2008). These authors argue lateral (associative) processing takes place in the CA3 during this delay and learned associations are used to define semantic properties (e.g., belongs to this category) and meaning of a concept: meaning that likely includes emotional or motivational value. For instance, a business venture may be defined by market or job creation; an entrepreneur by how she thinks, feels and behaves; and "entrepreneurship" as a concept that may carry positive or negative value for an individual depending on learned associations.

Concept cells and categorical coding align with the theorized role of the MTL in the consolidation of long-term semantic memories (Bayley & Squire, 2005) adding further credence to the proposed nexus of percepts and concepts. We are left with the conclusion that episodic memory may consist of richly coded percepts—of scenes, objects, orientations, perspectives, self, and other people—and concepts of things familiar, often seen and personally relevant. The implication is that these abstract representations with subjective meaning and value comprise the building blocks of declarative memory (Quian Quiroga, 2012) and offline self-reflective thought about the future in the DMN (our conjecture): not objective physical details of things seen "out there." This implication supports arguments in the literature which suggest that "creation of new ventures is a process by which entrepreneurs come to imagine the opportunity for novel ventures, refine their ideas, and, after an initial investment, justify their ventures to relevant others to gain much-needed support and legitimacy (e.g., Alvarez & Barney, 2007; Cornillisen & Clark, 2010: 539; McMullen & Shepherd, 2006)." We therefore suggest:

*Premise 5: It is likely that, prior to actual formation, an entrepreneur's reliance on combined episodic memory and self-reflective thought, enables a business opportunity or venture to be comprehended as an abstract representation/business concept.*

And:

*Premise 6: It is likely that interdependencies exist in the entrepreneur's ability to use (1) value-weighted percepts to envision and (2) statistically informed concepts to semantically comprehend a business opportunity or venture—prior to formation.*

So where does emotion, and motivation enter the picture? What are the neural processes that move cognition from conceptualization to affect and motivation? Enter CA1.

### **The Detection of Novelty**

*In this subsection, we introduce a new concept (prediction error  $\equiv$  the difference between that which was expected and what just happened) and describe the role of the hippocampal CA1 as a novelty detector that enables the entrepreneur to compare familiar features of the world with real-time data from ongoing experiences. Both emotion and motivation are implicated in the CA1's role in novelty detection.*

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<sup>4</sup> Statistical regularities refer to observed patterns in the person's environment (observations/data points), as in repeated pairings that inform conceptual meaning. We note that this Small-N (maybe N=1) reasoning from unique life experiences likely amplifies unexplainable variance in empirical analyses and thereby complicates efforts to refine our understanding of the *entrepreneur* as a research concept from noisy data.

Our discussion of MTL structures thus far has focused on the refinement of cortical inputs into meaningful sparse code for memory storage. We should also note that the hippocampus participates in both encoding *and* retrieval, and it dynamically shifts from one to the other on the timescale required to support behavior. Researchers describe the hippocampal CA1 field as a novelty detector, rerouting neural activity from memory retrieval to encoding (Duncan et al., 2012). This novelty detection process moves cognition beyond the familiar representations and conceptualizations in the CA3.

With perhaps as few as 4 million neurons based on a 1 to 3.7 cell count ratio, nonhuman primate to human (Jabès et al., 2011; Seress, 2007)—the CA3 temporarily registers and records all the day-to-day events that may become episodic memories over an individual’s lifetime. Thus the entrepreneur, for example, relies on this structure to meet with a potential client: “I parked over there; we met over lunch; we talked about production; you requested a proposal for improving efficiency.” She will meet with the client again this week and use the pattern completion capacity of the CA3 to seamlessly advance the ongoing agenda. A single cue (e.g., voice on the phone) elicits the recall of details from the prior meeting and she will use episodic memory to form expectations, plan and envision (even script) this week’s meeting—an illustration of episodic future thought. Our entrepreneur will continue to rely on memory retrieval as long as experiences match her expectations, but when sensory data (e.g., scowl on the client’s face) signal a mismatch, the CA1 will reroute neural activity, i.e., engage in novelty detection and encoding functions.

{Insert Figure 5 about here}

Anatomical data support the CA1’s role as a novelty detector or comparator of highly-processed, familiar representations of the world transmitted from the CA3 with real-time data from ongoing experiences directly from the ERC (Duncan et al., 2012). The CA1 gates (or compares and allows/inhibits) the flow of information and switches hippocampal function from retrieval to encoding of novel data, in part defined as unexpected data (i.e., a prediction error) used to update representations about the individual’s changing world (Ito & Schuman, 2012; Kumaran & Maguire, 2007).

The CA1 receives two streams of data: one through the ERC-DG-CA3-CA1 pathway as described above, while the other projects data directly from the ERC to the CA1 (Figure 5). CA3 sends highly-processed, associative information about well-known people, places and things, and constitutes the primary excitatory *familiarity* signal to the CA1. The ERC in contrast transmits real-time data and (when signaling novelty) can strongly inhibit or regulate activity in the CA1 (Dvorak-Carbone & Schuman, 1999). The CA1 is thus well positioned to detect novelty or prediction error: i.e., differences between that which was expected and what has just happened. It is at this point that the role of affective valuation enters the picture.

Specifically, affective value plays an essential role in the way CA1 gates information, with affect in this case attached to novel (unexpected) stimuli, as follows. Direct inputs from the medial entorhinal area (MEA) and lateral entorhinal area (LEA) terminate in discrete CA1 fields, a topographical organization that hints at a behaviorally relevant function. MEA fibers send spatial data to proximal CA1 neurons close to the CA3, while LEA axons convey nonspatial data to the distal CA1 cells adjacent to the subiculum (Ito & Schuman, 2012).

Additionally, CA1 neurons are also primary targets for dopamine-releasing projections from the ventral tegmental area (VTA) (Ito & Schuman, 2012; Lisman & Grace, 2005) with dopamine (DA) strongly implicated in signaling behavioral relevance (Ito & Schuman, 2012; Lemon & Manahan-Vaughan, 2006; Lisman & Grace, 2005). Researchers argue the detection of novel data in the CA1 activates VTA neurons which release dopamine that preferentially impacts LEA inputs, those carrying nonspatial (e.g., object quality and affect) information about what exists out there. DA enhances high-frequency signals (suppresses low-frequency signals)

that inhibit CA1 pyramid cells from firing in response to CA3 inputs (Dvorak-Carbone & Schuman, 1999).

Thus, CA1 acts as a filter for preferential encoding behaviorally relevant (i.e., novel) information (Ito & Schuman, 2012). The CA1 then transmits real-time data to the amygdala, strongly implicated in triggering the physiological responses of emotion (Fudge et al., 2012) and back to the ERC for further processing. Data streams from the cortex to the ERC and from the CA1 to the ERC are posited to cross paths, with the ERC acting as an interactive hub for incoming and outgoing data (Canto et al., 2008), possibly – in the case of the entrepreneur – prompting her to pause and revisit novel data. Baron (2008: 335), for example, suggests that both dispositional and event generated affect primes mood-relevant memories, or cue reactions to objects, ideas, people, etc., which in turn have effects on basic cognitive processes such as perceptions, judgments, decisions, memories, and so on, thereby influencing such entrepreneurial processes as opportunity recognition and capacity to respond effectively to highly dynamic environments, among other outcomes. We therefore suggest:

*P7: The likelihood of entrepreneurs effectively responding to novelty (i.e., prediction error) as an environmental cue to opportunity, and thereafter successfully forming a business venture, is moderated by affective processes, and implicates both emotion (physiological response and label) and motivation.*

Our analysis thus turns to emotion and motivation as useful phenomena to illustrate the research potential offered by a neuroscientific rationale for the importance of entrepreneurial emotion and entrepreneurial motivation, in entrepreneurial cognition research.

## **EMOTION**

*In this section, we argue that emotion may be most productively defined as a stress response – initiated by the sympathetic nervous and neuroendocrine systems – and experienced as a physiological reaction in the body that informs the entrepreneur about what is relevant. The weights and labels attached to stimuli vary across individuals, over time, and with experience. We importantly note that the stress response associated with entrepreneurs' emotions is objectively measureable and can be linked to verbal reports (i.e., labels) entrepreneurs attach to their experiences.*

Two lines of reasoning exist in the study of emotion in neuroscience: one focuses on emotions as “natural kinds” or feeling states that exist in nature independent of the perceiver, while the other explains emotions in terms of structures and functions (see LeDoux, 2012; Lindquist et al., 2012 for reviews). These approaches differ in their grounding in mainstream neuroanatomy and ability to support additive research.

### **Emotions as Natural and Universal**

Natural kinds researchers characterize emotions as discrete feeling states (e.g., fearful, angry, happy or surprised), universally expressed and recognized (in facial expression studies) around the world, conserved across species, and dubbed basic or natural emotions hardwired in the brain (Ekman, 1992a & b; Ekman, 2011; Izard, 2007). This approach has been widely applied in research, owing to the simplicity of attaching a name to a subjectively-defined state; and it may typify the theoretical underpinnings of some studies in entrepreneurship concerning, for example traits-based entrepreneurship research.<sup>5</sup> Still, problems exist in this neuroscience literature.<sup>6</sup>

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<sup>5</sup> Mitchell, 1994: 25 explains as follows: “Psychological characteristics-based research focuses on a very broad range of psychological characteristics including (not exhaustively) the need to control and direct, self-confidence, a sense of urgency, good health, comprehensive awareness, realism, superior conceptual ability, needs for status, objectivity in interpersonal relations, emotional stability, attraction to challenge, level of creativity, need for

In brief, and specifically with respect to emotion, deficiencies in “natural kinds” research include the lack of agreement about the numbers, names and defining characteristics of basic emotions, as well as their neural structures and functions (see LeDoux, 2012). Little evidence exists to tie discrete emotions to dedicated circuits (but see Vytal & Hamann, 2010) and the idea of emotions as discrete states does not align with the analog character of processes giving rise to emotions, those involving the widespread diffusion of hormones and neuromodulators with long lasting but imprecise influences on neural systems. As we have explained in the foregoing foundational descriptions, the physiology of emotions is anything but discrete and objectively grasped. Thus, “natural kinds” research remains suspect and unable to sustain additive research, as evidenced by challenges to the most basic question: do natural kind emotions exist? Advocates of this approach must defend their work after forty years (e.g., Ekman, 2011).

### A Structure-Function Account

The second research stream (focusing on structures and functions) dates to the early Twentieth Century and the discovery that the hypothalamus controls the autonomic nervous system, as well as later evidence that damage to the amygdala can leave subjects with diminished fear and aggression (LeDoux, 2000, 2003a; Sah et al., 2003: historical reviews). Early anatomists established the amygdala and hypothalamus as central to emotion processes (structure); and fear conditioning studies of the 1970s - 1980s began to clarify function. For example, researchers paired an emotionally neutral conditioned stimulus with an aversive unconditioned stimulus, for example a tone (CS) and foot shock (US). After one or more trials, a tone acquired value, was found to signal danger and triggered a physiological reaction capable of provoking a behavior (avoidance) (LeDoux, 2003a). Based on this research, and more recent studies (LeDoux, 2012: extensive review), researchers have therefore argued that the function of emotion is not to produce “feelings,” but to enable an “organism to survive and thrive by detecting and responding to challenges and opportunities” (LeDoux, 2012: p. 654), and which we term stressors.

**Emotional triggers.** In the structure-function stream, emotions are characterized as a stress response to various stimuli in the individual’s life: pleasant or aversive, real-time or temporally distant, and oftentimes the unexpected (e.g., see the previous CA1 discussion). Everyday stressors may include the thought of rising from a warm bed on a cold morning, a number on bathroom scales, pinched toes in new shoes, attention from a certain other person, the density of traffic on the day’s commute, stock market vagaries, gas prices and career choices. Regrets past and worries future (e.g., mortality) enter the person’s thoughts as well. Specifically as an entrepreneur, she affectively weights (positive or negative), for example, factors such as the independence, benefits and costs of starting/owning a business, financial investments, debt obligations, monetary gains or losses, customer demands and complaints, hiring or firing decisions, competitor actions, accounting requirements, investor presentations and the possibility of success or failure. Physiological reactions in the body (triggered by the amygdala and related structures) inform the person about what is relevant and steer her through daily decisions (e.g., where to lunch, how to price or whom to trust) and weights are attached to

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achievement, belief in an internal locus of control (belief in the ability to control the environment through individual actions), risk-taking propensity, and more (Coulton & Udell, 1976; McClelland, 1965; McClelland & Winter, 1969; Rotter, 1966; Welsh & White, 1981)..

<sup>6</sup> Problems also exist in the entrepreneurship literature. Mitchell 1994: 25 further explains: “Examples of subsequently disconfirming research on the most commonly cited psychological traits: the need for achievement, belief in an internal locus of control, and risk-taking propensity (Sexton & Bowman-Upton, 1991) illustrate the present level of confusion in this research stream. The difficulty arises because the factors that describe entrepreneurs “. . . also tend to describe successful people in many areas, such as business, art, music, and education” (1991, p. 9).”

stimuli that vary across individuals, over time, and with experience (e.g., rollercoasters lose their thrill value with repetition).

**A specialized structure for emotion.** The amygdala complex, at the center of emotion processing, consists of ~ 13 nuclei clustered in anatomical studies as the: (1) basolateral (BLA) complex; (2) cortical group (not a part of our analysis); and (3) centromedial group (Sah et al., 2003; Spampinato et al., 2011). The BLA complex is the primary input site into the amygdala and is posited to assign a valence (i.e., affective value) to stimuli through associative coding of stimuli and physiological data (Cardinal et al., 2002; Sah et al., 2003). The BLA processes data locally and projects to the centromedial nuclei, described as a primary output station (Sah et al., 2003).

**Emotion ≡ a physiological response.** How does the stress response occur? The amygdala receives sensory data from the thalamus, cortex (e.g., ITC) and MTL structures, while physiological inputs arrive from the hypothalamus and brainstem structures. These data can trigger an automatic stress response: for example, unprocessed sensory data (e.g., firing activity signaling a 98 mph fastball closing in on a batter's head) project directly from the thalamus to the amygdala to trigger an automatic defensive behavior such as ducking (but see Kravitz et al., 2013). Alternatively, cortical areas and MTL structures (Sah et al., 2003) convey highly processed information about an episodic experience (something "out there"), as well as endogenous data concerning physiological discomfort (pain), sociopsychological happenings (rejection and uncertainty) or thoughts (starting or failing in business) that knock the individual out of homeostasis (de Quervain et al., 2009; Herman et al., 2005; Kreibig, 2010; McGaugh, 2002; Tsigos & Chrousos, 2002). The amygdala then triggers a peripheral reaction.

Specifically, centromedial nuclei project to the brainstem to activate the sympathetic nervous system, thereby initiating the characteristic physiological stress response: heightened attention, catabolic release of energy from fat cells into the bloodstream, increased blood pressure, galvanic skin response, and the acceleration of cardiac and respiratory output to fuel brain, heart and muscle (Tsigos & Chrousos, 2002). The amygdala also projects to the paraventricular nuclei (PVN) of the hypothalamus to initiate a hormonal cascade through the Hypothalamus-Pituitary-Adrenal (HPA) axis leading to the release of adrenal stress hormones: glucocorticoids, epinephrine and norepinephrine.

This combination of autonomic nervous system and hypothalamic neuroendocrine system comprises the efferent limbs through which the brain influences all peripheral stress responses (Tsigos & Chrousos, 2002) and those engaged in classical fear-conditioning studies in which a neutral stimulus [conditioned stimulus (CS)] acquires emotional value when paired with a biologically significant event [unconditioned stimulus (US)] (LeDoux, 2000). For the individual, then, external and internal stimuli (thoughts) produce physiological responses registered in the brain and reflectively interpreted as "feelings." The individual then names these feeling as specific emotions, with a time course to the applied labels (Kirkland & Cunningham, 2011). In this manner, emotion arises and a task comes to be viewed as onerous, a coworker as kind, or thought of becoming an entrepreneur as exciting or terrifying and so forth.

**Widespread modulation.** Additionally, the amygdala modulates memory and cognition though both indirect and direct means (LaBar & Cabeza, 2006; McGaugh, 2002). For instance, it heightens arousal through interactions with noradrenergic and dopaminergic brainstem and midbrain nuclei, such as the ventral tegmental area (VTA) mentioned earlier (Cardinal et al., 2002). Centromedial nuclei projections and blood-borne epinephrine-feedback to the brainstem (de Quervain et al., 2009; Roozendaal et al., 2009) trigger the widespread distribution of excitatory dopamine and norepinephrine through the brain and thereby prime circuits for activation (Sah et al., 2003).

Heightened-levels of norepinephrine (plus glucocorticoids and acetylcholine) in the hours after an emotionally charged episode (Paré, 2003) may account for evidence showing that BLA activation strengthens memory by tuning auditory receptor fields to a specific tone; increasing visual stimulus representation, so larger neuron populations store more data; as well as synchronizing frequencies in visual circuits to select behaviorally relevant stimuli (Chavez et al., 2009; Murty et al., 2010). As noted earlier, amygdala activation also modulates the PRPH to selectively convey affectively weighted data to the ERC (Curtis & Paré, 2004) and may elicit frontal lobe-mediated semantic processing in support of emotional memory encoding (LaBar & Cabeza, 2006; Murty et al., 2010).

**Targeted / direct connections.** The amygdala also enhances memories of emotionally arousing experiences via direct projections to other brain regions in a narrow window around the time of an emotional event (de Quervain et al., 2009; Roozendaal & McGaugh, 1997; Roozendaal et al., 2009). Researchers report norepinephrine (widely distributed in the brain) and glucocorticoids (crossing the blood-brain barrier) converge on and activate receptors in the BLA, which then projects to the MTL and cortex (Joëls et al., 2011; Majak & Pitkänen, 2003; McGaugh, 2002; Murty, et al., 2010; Paz et al., 2006; Sah et al., 2003). The amygdala receives inputs from MTL structures including rhinal cortices and hippocampus and projects back to these same structures (Majak & Pitkänen, 2003; Sah et al., 2003) creating reciprocal pathways for emotional memory enhancement (Murty et al., 2010).

These reciprocal connections boost and synchronize BLA output and the BLA sends “massive” projections to MTL structures (specifically the rhinal cortices) that amplify firing rates between MTL structures (Curtis & Paré, 2004; Paz et al., 2006). The amygdala is reported to reduce the threshold for hippocampal long-term potentiation and increase the expression of genes critical in mediating synaptic plasticity. Thus through these processes, emotion-laden memories are more vividly and longer remembered (LaBar & Cabeza, 2006; McGaugh, 2002; Murty et al., 2010; Paz et al., 2006; Roozendaal et al., 2009). Now (within the structure/function paradigm), having provided a quite-detailed (for a social science article) map of the “structure” of emotion processing, the question of function also can be addressed.

**The function of emotion.** Neuroscience research leaves little doubt about the modulatory influence of emotion on cognition and memory, but what functions do emotions serve? We offer two answers. First, research on emotion most constructively focuses on the selective processing and valuation of stimuli, rather than a feeling state. Fear studies illustrated the conditioned negative value of stimuli in detecting a threat or danger (LeDoux, 2000). This negative-valence conception broadened to encompass the amygdala’s role in positive affect, reward and novelty (Bermudez & Schultz, 2010; Ito & Schuman, 2012), then expanded further to recognize the amygdala’s role as a *relevance detector* that responds to stimuli (e.g., pain) deemed important to the organism’s wellbeing (Ousdal et al, 2012; Simons et al., 2012). Emotion thus weights events, experiences, and outcomes, and thereby influences even daily choices (e.g., where to eat, what to wear, which way to work and when to do a task). In the case of entrepreneurial cognition, it is to be expected that emotion serves to steer the entrepreneur down an unfamiliar path of realizing a business. We thus suggest:

*P8: It is likely stressors and the physiological stress response produced within entrepreneurs (duration and magnitude) prominently describe the process of exploiting a business opportunity (how it “feels” to the entrepreneur).*

*P9: It is likely the labels entrepreneurs apply to stress responses vary over time and with experience, as well as affect the probability of venture success.*

And:

*P10: It is likely that the affective weighting of stimuli (emotion) in part explains why entrepreneurs choose one business opportunity or venture over another, as well as paths taken (choices) in exploiting a business opportunity.*

We also note that episodic memory refers to rich and unique recollections of personal experiences from a person's life, happenings at a particular time and place, with affective value sufficient to elicit feelings of reexperiencing the past (Tulving, 1972, 1983). Emotions serve the valuable function of delineating self-relevant, self-defining moments that contribute to the formation of the individual's cohesive identity (Conway, 2009; LeDoux, 2003b). To the extent the entrepreneur travels unfamiliar paths, unexpected outcomes will happen; she will remember emotion-laden happenings longer and more vividly than neutral experiences; and those experiences will likely (in part) come to define her as an entrepreneur. We therefore suggest:

*Premise 11: It is likely that concepts such as “entrepreneur” and “opportunity” as comprehended by the individual are informed by statistical regularities, prediction errors, and affective valuations derived from episodic experiences in the opportunity identification and exploitation processes.*

The implication of emotion-driven assistance with venture creation suggests a linkage to entrepreneurial motivation, which we address next.

{Insert Figure 6 about here}

## MOTIVATION

*Here we describe the physiology of motivation, including the online valuation of stimuli and how motivation connects with behavior. For entrepreneurs, the mid-brain dopamine system supports both the refinement of expert skills / habits and adaptive behavior. It is at this point in our analysis that abstract building blocks of thought—percepts, concepts and affective valuations—come together with real-time data from ongoing experiences in the medial prefrontal cortex (mPFC - part of the default mode network) in support of conscious thought and entrepreneurs' adaptive behaviors—those beyond simple instrumental learning.*

The Merriam-Webster Dictionary defines motivation as: the act or process of giving someone a reason for doing something. In neuroscience, the term *motivation is defined as the dopamine-modulated state of arousal consonant with anticipation that precedes and guides reward-seeking behaviors toward desired outcomes* (Düzel et al., 2009; Isoda & Hikosaka, 2011; Schultz, 1997, 2010). In contrast to classical stimulus-stimulus conditioning explanations of emotion in which stimuli acquire value (described above); neuroscience researchers describe motivation as engaging instrumental (i.e., action-outcome or reinforcement) learning (Berridge, 2007; Cardinal et al., 2002; Kelley, 2004; Salamone et al., 2012). Thus, the idea asserted in our analysis of motivation is that appetitive and abstract (e.g., money) stimuli do not arrive in the brain with inherent value: these stimuli acquire value through experience (Knutson et al., 2005; Miyapuram et al., 2012; Schultz, 2010; Seymour et al., 2007); are wanted (Berridge, 2007); require effort to obtain (Salamone et al., 2012); and reinforce successful actions leading to consummation. This process is thought to be an evolutionarily old means for coding action-outcome memory that supports adaptive behaviors and—by implicating more recently evolved systems (e.g., medial prefrontal cortex – mPFC)—gives rise to more sophisticated applications of motivation in value-based decision making (Rolls, 2004; Wallis, 2012), effort-related choice (Salamone et al., 2012), goal-directed action (Balleine & O'Doherty, 2010) and choice among immediately available or temporally delayed rewards (Cardinal et al., 2002).<sup>7</sup>

<sup>7</sup> To place this discussion in context, some neural processes exist across species and are referred to as evolutionarily conserved (LeDoux, 2012) owing to their utility or function (e.g., survival circuits). The basic notion of action-

In this section, we describe the distributed network of structures involved in coding the value of stimuli (amygdala – AMG and orbitofrontal cortex – OFC) and those involved in mediating behavior (dorsolateral striatum – dLS, ventromedial striatum vmS, hippocampus – HIP, hippocampal ventral subiculum – vSB, medial prefrontal cortex – mPFC and Ventral Tegmental Area – VTA), as further illustrated in Figure 6. We continue to focus our analysis primarily on the processing of visual data from the visual “what” pathway (see Kravitz et al., 2013). To accomplish this task, we address first, how value is represented neurologically; and then following this, we discuss the Midbrain Dopamine System (MDS) to explain how value is connected to behavior thereby addressing: how habits and expert skills form, adaptive behavior occurs, as well as dopamine’s role in motivation.

### **The Representation of Value in the Brain**

The amygdala, as described previously, is responsible for coding the value of stimuli. It initiates the characteristic autonomic stress response and hormonal HPA cascade associated with emotion (Tsigos & Chrousos, 2002) and codes stimulus-physiology associations: the neural representation of emotional value. Researchers describe the amygdala as receiving visual data (e.g., from the ITC) and projecting back to the ventral visual stream to orient the individual to emotionally significant stimuli. Researchers implicate the amygdala in the preferential processing and storage of long-lasting (lifetime) memories, and possibly stable preferences, but this structure is thought to lack the flexibility to adjust “stored” values on the timescale of behavior (Kravitz et al., 2013; Padoa-Schioppa, 2011; Rolls, 2004).

In this paragraph we therefore describe the neural computation of motivational value in the orbitofrontal cortex (OFC) which, in contrast to the amygdala, computes the value of stimuli in real time as the individual makes value-based choices (Padoa-Schioppa, 2011). In other words, the OFC relies on real-time value computations rather than “stored” values, to facilitate choice decisions. The OFC, situated on the ventral frontal lobe surface (directly behind the eyes), receives data from most sensory systems and functions as a secondary sensory cortex representing stimulus value, e.g., hedonic pleasure (Grabenhorst & Rolls, 2011). Value in the OFC is encoded at the neuron level (as linear increases in firing rates) and constitutes a common unit of measure for comparing disparate choice options (Padoa-Schioppa, 2011: review). This representation is described as subjective (e.g., varying with satiation) and abstract (i.e., simultaneously coding for multiple dimensions on which options are compared, such as identity, hedonic quality, quantity, risk, ambiguity, fairness, and temporal delay). OFC representations also display transitivity, range adaptation (e.g., coding choices on a café menu or high-end car showroom) (Padoa-Schioppa, 2011) and some neurons code for prediction error (Grabenhorst & Rolls, 2011). We also note that while the OFC computes stimuli values, it only weakly connects to motor areas essential for instrumental learning (Carmichael & Price, 1995). This leads us next to consider how instrumental learning occurs: that is, through reinforcement in the midbrain dopamine system, which connects value to behavior.

### **Connecting Value to Behavior**

Researchers describe the midbrain dopamine (DA) system as a broadly distributed “reinforcement network” enabling the individual to move with purpose toward “wanted” outcomes (i.e., motivated behavior) (Berridge, 2007; Kelly, 2004). This network, centered on the striatum, serves a central role in connecting stimulus value to behavior: it supports instrumental learning (i.e., habit formation and refinement of expert skills) as well as flexible adaption (Foerde & Shohamy, 2011). How does it work physiologically?

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outcome coding is thought to exist across species (e.g., even simple life forms retreat from toxins), while the human forebrain (cerebrum and subcortical nuclei) enables higher-order value-based decision processes.



Anatomical studies show that cortical neurons from the OFC and mPFC, as well as limbic structures—basolateral amygdala (BLA) and hippocampus (HIP) (specifically the ventral subiculum – vSB)—project functionally-segmented information to distinct regions within the striatum, regions described as specialized by function or neurophysiological processes. The dorsolateral striatum (dLS) predominantly receives sensorimotor information; ventromedial part takes in limbic (i.e., affective and behaviorally relevant) data; while areas in the middle receive higher-order associational information (Voorn et al., 2004). Thus, a dorsolateral to ventromedial gradient exists in the striatum, with researchers implicating dorsolateral (dLS) and dorsomedial (dmS) regions as mediating instrumental learning, with a region-specific shift in coding occurring as learning slows and habits develop and refined skills consolidate (Yin et al., 2009).

**Habits and expert skills.** Researchers argue the neural representation of habits and expertise are coded as firing patterns in the striatum—like the coding of episodic experiences—and these firing patterns change with practice (Knowlton & Foerde, 2008). Habits and refined skills are expressed in more efficient neural processing and decreased neural activity (i.e., greater fluency and less cognitive effort) as illustrated in the case of a novice painter learning to cut a straight line with a fully-loaded paint brush. First attempts require extensive cognitive and perceptual effort as she watches the brush angle, bristle pattern, hand position, movement fluidity, and resulting painted line. She talks her way through each brush stroke (e.g., “watch your elbow”), evidence of the cognitive effort expended. Over time, perceptual representations of experience sharpen (i.e., sparse coding), such that neurons encoding critical details continue to fire; but those coding for less useful information drop out, and the total number of active neurons decreases. Expertise permits the rapid and automatic shifting of attention to successive elements of the task, so less cognitive effort is required and (through practice) expert performance is implemented through the smooth execution of automatic sensorimotor programs (Knowlton & Foerde, 2008).

A gradient thus exists in the acquisition of habits and expertise, with an initial phase of rapid improvement, followed by more gradual improvements as the new firing patterns are consolidated. Actions become automatic, resistant to interference and durable as a region-specific shift in neural activity takes place in the striatum. The associative dmS is preferentially active during training, while the sensorimotor dLS takes over as improvement slows and actions become automatic (Poldrack et al., 2005; Yin et al., 2009).

**Adaptive behavior.** In contrast, inputs from the OFC, mPFC, BLA and hippocampus (vSB) project heavily to the ventromedial striatum (hereafter nucleus accumbens, NAc): a structure closely related to other DA-innervated limbic areas; defined as a component of the “extended amygdala;” and location in which affect value links to adaptive action (Kelly, 2004; Price & Drevets, 2010). The NAc plays a crucial role in “why” explanations of behavior (in contrast to prior analyses of “what” gets coded) and is implicated in the experience of pleasure. The NAc is described as a hedonic hotspot and target of psychostimulants such as cocaine and amphetamine (Berridge & Kringlebach, 2013).

As previously described, the OFC network processes multi-modal sensory data into real time representations of stimulus value under varying physiological conditions, but does not directly connect to behavior. The mPFC, in contrast, integrates contextual and value data into conscious thought in the DMN (Raichle et al, 2001); modulates autonomic/emotional control (Gabbott et al., 2005); and permits flexible, adaptive control of behavior (Euston et al., 2012).

The mPFC network encompasses areas on the medial (i.e., midline) surface of the frontal cortex and those along the medial edge of the orbital cortex (Price & Drevets, 2010). It exhibits a ventral-to-dorsal functional gradient (Euston et al., 2012) in which affective (valuation data) and highly-processed sensory data converge (in support of behavior); and it extensively overlaps with the anterior cingulate cortex (ACC) (Price & Drevets, 2010). The ventromedial prefrontal

cortex (vmPFC) receives data from mid-brain limbic structures (e.g., OFC, BLA, insula vSB, and ERC) and is posited to mediate physiological-emotional activity, while the dmPFC receives multisensory data from widespread cortical areas and supports motor control (Narayanan & Laubach, 2006) and goal-directed actions (Gabbott et al., 2005). Researchers hypothesize that the vmPFC and dmPFC together enable the individual to adapt emotional and behavioral responses to a given context (Euston et al., 2012), while the ACC has been implicated in conflict monitoring, prediction error detection and the valuation of actions, including the cost of actions (Botvinick et al., 1999; Carter et al., 1998; Quilodran et al., 2008; Rudebeck et al., 2008).

The function of the mPFC in motivation remains the subject of ongoing research, but the nature of neural projections to this structure has prompted speculation. Some researchers posit that the mPFC enables the individual to predict the likely outcomes of actions, good or bad (Alexander & Brown, 2011; Quilodran et al., 2008). Others suggest it enables the individual to infer rules from statistical regularities (i.e., learned associations) in the environment, with adaptive behavior tied to learning novel rules in changing environments (Durstewitz et al., 2010): a potentially critical insight for entrepreneurs. In the broadest account, the mPFC codes (on a timescale of behavior) for "...rich contextual representations that take into account not only sensory cues but also actions and time" (Hyman et al., 2012: p. 5086); enables the individual to recall best actions and emotional responses from past experiences (Euston et al., 2012); and allows her to simulate, through cognitive activity in this area of the brain, possible actions to select those with the greatest potential for producing desired outcomes (Addis et al., 2009; Schacter et al., 2008).

In sum, the mPFC maintains ongoing cognitive representations that permit adaptive choices beyond those available in a simple instrumental (i.e., action-outcome) learning model. The individual can adjust her behavior to a boardroom or ballgame—or using the adaptive processes just described, can peek ahead, compare rewards today to those down the road and make adaptive choices under uncertainty. For example, the motivation to become an entrepreneur, where processes that require choices beyond a simple learning model are strongly implicated (Alvarez & Barney, 2007; Baron, 2008), is therefore likely to be supported by the foregoing neurological-systems.

**Dopamine's role in motivation.** The two components of motivation—arousal prior to reward and reinforcement of reward-seeking behaviors upon the timely delivery of rewards—depend on the circulation of dopamine throughout the MDS (Schultz, 1997). In brief, contextual and value data from widespread cortical fields (OFC and mPFC) and limbic structures (ERC, HIP, BLA) converge on the NAc (nucleus accumbens), which projects to the ventral tegmental area (VTA) (Floresco, 2007; Grace et al., 2007). The VTA, in turn, sends dense dopaminergic projections back to the NAc and other relevant structures: the mPFC for our purposes.

Dopaminergic neurons in the VTA exhibit tonic (irregular pacemaker-like activity) and burst (spike) firing (Grace et al., 2007; Lodge & Grace, 2006). The ongoing tonic release of dopamine from the VTA modulates diffused extracellular DA levels in structures like the mPFC, thereby preparing (arousing) the person to respond to motivation-relevant stimuli (Floresco et al., 2003). Tonic DA activity is punctuated by burst-firing to the NAc, a signal that carries information about reward value (specifically better than expected rewards). These two DA firing patterns are believed to elicit the hedonic sensations of liking and wanting (Berridge, 2007), facilitate learning from prediction errors (Schultz, 1997) and sustain behaviors sufficient to overcome time- or work-related costs of pursuing delayed rewards (Salamone et al., 2012).

How does dopamine support both instrumental learning and adaptation? Physiological studies suggest the hippocampal vSB (limbic) and mPFC (cortex) compete for control over the NAc, with the vSB steering behavior toward reward-dependent (instrumental learning) and the mPFC driving behavioral flexibility (Floresco, 2007; Goto & Grace, 2008). Increased burst and

tonic firing (signaling reward) sustains action-outcome learning (of habits/refined skills), while the cessation of DA to the NAc (when actions no longer yield *expected* outcomes) induces behavioral flexibility through the mPFC, a component of the DMN (Goto & Grace, 2008).

In summary, our neuroscience explanation of motivation suggests that the values of choice options are computed as real time, subjective and abstract representations. The MDS supports habit/skill formation, with learning represented as efficient neural processing and decreased neural activity. Adaptive behavior centers on the NAc, as well as the convergence of mid-brain limbic and multisensory data in the mPFC, with adaptation (in part) described as learning novel rules (through statistical regularities) in changing environments. Tonic and burst dopamine from the VTA drives both instrumental learning and adaptive behavior, with the entrepreneur's pursuit of a business opportunity or venture influenced by both action-outcome (reward) and higher-order cognitive processes. Thus, with respect to the implications of a neuroscientific analysis of entrepreneurial motivation, we suggest:

*P12: It is likely that the individual's choice to become an entrepreneur, a "why" decision—as well as choices along the way—are a function of affective influences, a combination of:*

- *real-time, subjective and abstract computations of the choice option values;*
- *short-term dopamine-reward signaling in instrumental, action-outcome (reward) experiences;*
- *stable (long-term) affective weightings (emotion-based preferences) processed in the self-reflective medial prefrontal cortex (and beyond simple instrumental learning).*

*P13: It is likely the uncertainty entrepreneurs experience in the pursuit of a business opportunity or venture, arises as much from within the person (owing to inefficient neural coding) as from the environment (and is resolved as they gain experience/expertise).*

*P14: It is likely that the processes of pursuing a business opportunity or venture is characterized (in part) as inferring novel rules (about effective action/behaviors) from statistical regularities in unfamiliar environments.*

And:

*P15: It is likely that the entrepreneur's adaptive abilities in pursuit of a business opportunity or venture arise from self-reflective processes in the DMN (anchored by the mPFC), beyond instrumental learning, and informed by percepts (envisioning), concepts (semantic comprehension) and affective valuations (emotion and motivation processes).*

## **DISCUSSION**

in this chapter we have traced the neurophysiological pathway involved in transmitting visual data from the periphery to conscious thought and behavior – with affective processes (emotion & motivation) modulating data flows along the way – with the purpose of illustrating that entrepreneurs' brains are no different than anyone else's, but they are different based on accumulated experiences and knowledge contain in the abstract representations – percepts, concepts and affective valuations that inform conscious thought and behavior. We view our analysis as essential to advancing entrepreneurial cognition as a science, for instance, as in resolving nature vs. nurture dichotomy; mapping hardware to software; explaining similarities

and differences among entrepreneurs; and discerning how entrepreneurs conceive (become aware) of opportunities.

We have offered fifteen premises in this chapter as researchable assertions informing research into *opportunity* and *venture formation* that can be addressed with current social-science methodologies. In P1 through P4, we highlight the importance of experienced-based imagery and episodic memory in envisioning a future business venture; in P5 we connect statistical regularities to the conception/semantic comprehension of business opportunities; and in P6 we emphasize the interdependence of the entrepreneur's abilities to envision and semantically comprehend a business opportunity or venture. In P7 through P10, we propose that novelty (a form of prediction error) and emotion (physiological stress response + label) influence entrepreneurs' choices and venture success; P11 implicates statistical regularities, prediction errors and affective valuations in the person's understanding of terms such as *entrepreneur* or *opportunity*; while P12 through P14 highlight the influence of motivation, real-time valuations, instrumental learning, within-subject uncertainty, as well as dopamine signaling on the pursuit of a business opportunity or venture. P15 then suggests the entrepreneur's adaptive abilities to identify and pursue a business opportunity or venture arise from self-reflective processes in the DMN, beyond instrumental learning, and informed by percepts (envisioning), concepts (semantic comprehension) and affective valuations—the abstract building blocks of thought. As we previously argued herein, this approach stands as an alternative research strategy to reliance on (for example) fMRI imaging to identify which parts of the brain are active when the subject does “x, y or z.”

### **The Entrepreneur**

We now illustrate the implications of our work for theory and research in the science of entrepreneurial cognition, starting with an *analogy* relating to conceptions of the entrepreneur. In the absence of experience a necktie is a meaningless word. The formal definition may refer to a band of cloth worn around the neck, but a deeper understanding regarding a necktie arises owing to its path to existence. Imagine, for example, that you draft a line drawing, pass it to the next person who colors between the lines. One person after another adds shading for dimension, cuts and creases, and folds the paper into an origami necktie. The next individuals emulsify the paper, add a bonding agent and dye, make a fabric, and then cut and sew the material into a desired shape, and the tie is offered for sale in a shop. Then a person buys the tie, so it becomes “my” tie. He wears it to successful business meetings and it becomes my “lucky” tie. Through the years the necktie acquires a soup stain, frayed edges and a lifetime of meaning associated with people, places and other statistical regularities in its owner's life. Thus, this particular necktie becomes unlike any other necktie and with meaning linked to the man's identity, much more deeply informing a dictionary conception of a necktie.

We argue that the designation entrepreneur for *the person* follows a similar route to existence. Here again, a simple definition may lack dimension, while individual experiences breathe life into the conceptual understanding of what it means when a thinking human being becomes an entrepreneur. The term entrepreneur lacks depth of understanding in the absence of experience (cf, Morris, et al, 2012), but imagine the following physiological pathway. First, and from unique life experiences, cortical structures and subcortical nuclei gate, inhibit, extract, amplify, sharpen and otherwise modulate sensory data—as in our necktie example. Then, sensory circuits tune (through experience) to familiar and personally relevant percepts and percepts merge into emotion-laden episodic memories. Percepts next align with concepts—some distinctive of the entrepreneur—and the concept “entrepreneur” acquires meaning through statistically-predictable regularities in the person's life. This concept carries positive or negative value based on associations. Percepts, concepts and affective valuations come together as

abstracted building blocks in ongoing representations of the world in the DMN that shape how she (as a distinctive entrepreneur) thinks, feels and acts: one exemplar or data point.

The challenge for researchers in comprehending the concept of the entrepreneur goes as follows. At one extreme, the entrepreneur is defined as human; all humans share a common complement of neural processes; and (in the absence of anomalies) all entrepreneurs rely on the same physiological processes of cognition: e.g., percepts, experience-based imagery, concepts, statistical regularities, prediction errors, physiological stress responses (of emotion), real-time valuations of motivation, instrumental learning, and dopamine signaling. At the other extreme all entrepreneurs accumulate unique life experience (small-N data) that inform subject-specific variations in percepts, concepts, valuations, and so forth. Cognitive processes remain the same, while exemplars exhibit wide intersubject differences—some related to entrepreneurial cognition and others mere noise. What should researchers do?

We argue that entrepreneurial cognition as a science is best served by advancing a common conception of the *entrepreneur*, a middle ground between ‘all the same’ and ‘all unique,’ to identify research questions (and streams) capable of sustaining additive research, those that unravel how experiences, percepts, concepts and affective valuations embody the entrepreneur, as well as explain systematic variance in cognitive abilities (e.g., envisioning, associative processing, and conceptual reasoning), including affective processes (e.g., physiological stress response, construal of predictions errors, and real-time computations of motivation value) in and among entrepreneur exemplars—as well as relative to other human beings. Our analysis contributes to the advancement of knowledge by refining our understanding of the entrepreneur *with common neurological processes* and by identifying premises that point to promising questions that may sustain additive research, while perhaps excluding distracting intersubject noise from scientific discussions.

### **Entrepreneurial Process**

Implications exist for how the entrepreneurial process may work as well. Earlier in the chapter we introduced the notion of episodic future thought: how the individual might flexibly recombine bits and pieces of memory to pre-experience the future through simulation, a mental trial-and-error process used to select actions with the greatest potential for producing desired outcomes (Addis et al., 2009; Schacter et al., 2008). Thereby the individual is not locked into the here and now, but can disengage from ongoing sensory stimuli to mentally travel back in time or forward to an envisioned a state of the world that does not yet exist: for example, a new opportunity or business venture. Where the potential entrepreneur anchors her envisioned venture remains unknown theoretically, but our analysis suggests that the content of episodic memory (and future thought) may include richly coded percepts of scenes, reference points (landmarks), prominent spatial features, objects, self, self-location, orientation (perspectives) and other people—as well as concepts of familiar, often seen and personally relevant things. Some starting points are likely more promising than others.

Buzsáki and Moser (2013) further explain how the opportunity/venture formation process may work from a neuroscience standpoint. The entorhinal cortex (ERC) and hippocampus (HIP) developed for spatial processing and navigation, with higher-order episodic and semantic memory capabilities layered on top, but relying on the same basic algorithms used in Path Integration (PI) and landmark-based (map-based) navigation. These authors argue that PI navigation likens to episodic memory and the exploratory acquisition of new experiences, while semantic memory (e.g., of objects, contexts and events) equates to map-based navigation in a static world, a known environment that can be easily articulated. In other words, navigation in physical and mental space can be viewed to be fundamentally the same. Applied as an explanation for a likely entrepreneurial process, the sequence might proceed as follows.

The potential entrepreneur starts out with an ongoing representation of the world in her head, a map-based creation of a known world that can be easily articulated and navigated. She envisions a business venture to meet a need (a business for a missing product or service), a mental simulation that initially remains described as sketchy, essentialized or sparsely populated. This person explores the mental space of starting this business through the acquisition of new and challenging experiences, the fundamental way she learns and adapts. Indeed, the process of identifying an opportunity may require her to gain sufficient experience, form associative connections (in the HIP) to translate percepts into concepts until she reaches a point she can sufficiently imagine and conceive the opportunity (Cornellisen & Clarke, 2010). Semantic comprehension (again, beyond the scope of our analysis in this chapter) in such a case may equate to the proverbial Aha! moment. Comprehension informs next actions and our potential entrepreneur exploits the opportunity by gaining experiences and familiarity in a *new* well-articulated terrain of an emerging business: products/services, customers, employees, locations, and revenues. This process may include inferring rules from statistical regularities in the new environment (Durstewitz et al., 2010). Key insights exist in this scenario: (1) experience comes before semantic comprehension; and (2) the heavy lifting of identifying and exploiting a business opportunity may occur offline in the DMN.

### **Opportunity: The Geometry of Semantic Memory**

An intriguing insight from our analysis is that a kind of geometry may exist in semantic memory that parallels the analysis of episodic memory but extends beyond concepts derived from percepts (i.e., personal experiences). Researchers widely hold that semantic memory is organized categorically and hierarchically. This structure may also be pyramidal with broad concepts encoded by some neurons (i.e., pyramid base), others encoded for associative information (e.g., person + camera = photographer), and rich details of specific percepts encoded by still others (i.e., the peak) (Lin et al., 2006). As previously noted, concept meaning derives from statistical regularities in the individual's experiences (Quian Quiroga, 2012) and according to Buzsáki and Moser (2013: p. 131), “neuronal mechanisms that evolved to define the spatial relationships among landmarks can also serve to embody associations among [semantic representations of] objects, events and other types of factual information.”

Together, these insights imply that a structure exists in semantic memory (knowledge in the brain that supports thought), maybe resembling a high-dimensional topographical map of sorts, with unknown implications for how entrepreneurs can systematically identify and exploit opportunities. We believe entrepreneurs in some way rely on category structures, statistical regularities, landmarks and the hierarchy (or pyramid) of broad semantic concepts to specific episodic experiences. Opportunity conception may be theorized to occur through articulating, searching, or altering these structures. In this respect, neuroscience may align with metaphor (Cornellisen & Clarke, 2010) in the imagining and enacting of new opportunities and ventures.

### **Affective Valuation**

From a physiological standpoint, affective valuation in either emotion or motivation signals behavioral relevance essential to cognition. Furthermore, the valuation of stimuli—identified, belonging to a category, informed by experience-guided imagery, preferentially selected, familiar, often seen, personally relevant, with semantic meaning derived from statistical regularities, and deemed novel, unexpected, threatening or wanted, etc.—appears to be crucial to and inseparable from cognition. We therefore assert based on our analysis that affective valuation plays a critical role in all questions of judgment, when no “correct” answer exists based on external circumstances. In this respect, our neuroscientific analysis makes a contribution to the decades-old question about judgment under uncertainty (cf. Knight, 1921), with even the threshold question in entrepreneurship research, “Why would anyone choose to become an entrepreneur?” better informed by an affect-implicated answer.

## **Emotion**

Our analysis further suggests (and explains why, from a physiological position) that inherent problems exist in studying emotion as a label attached to introspective assays of a person's feelings. Autonomic and neuroendocrine systems may elicit hormonal or physiological reactions with distinct signatures, but the notion remains speculative. Our research suggests that these systems developed for self-preservation and respond to sociopsychological stressors as they would to a predator, with crude distinctions in physiological signals possible at best. Cues sent to the brain remain vague and subject to interpretation (misinterpretation), so the names applied to "feelings" likely vary across time with stimuli even flipping in valence: a failed venture may evoke embarrassment and later carry a positive connotation of crucial learning experience, or an even more negative connotation as a truly terrible experience.

The definition of emotion as a physiological stress response, often induced by prediction errors, affords the opportunity to measure reactions to specific entrepreneurial experiences. Researchers may, for instance, consider using performance sports (biofeedback) technologies to capture real-time physiological data (e.g., heart rate, blood pressure, respiration rate, skin temperature and galvanic skin response data) while potential entrepreneurs pitch business ideas to angel investors or a similar scenario in which prediction errors may occur—and compare these with verbal reports (i.e., labels subjects apply to the stress response). The centrality of prediction errors in emotion research remains unknown and the correlation of physiology to verbal report may inform emotional labeling and the impact on entrepreneurial outcomes.

## **Motivation**

Our analysis of motivation has centered on the link between valuation and behavior, with the midbrain DA system implicated in explanations for learning habits and expert skills, as well as for supporting adaptive behavior. We emphasize that motivation involves the real-time valuation of options critical to judgment-based decisions, like the "big" choice of becoming an entrepreneur, or the many "small" choices made in the process. For example, from a motivational standpoint, the individual chooses between rewards today versus those later, with dopamine enabling her to wait (Salamone et al., 2012). The occasion exists to study the valuation of options, costs of actions, and influence of differences in the person's ability to see further down the road (i.e., temporal or psychological distance) on perceived risk or value of delayed rewards. An extensive literature exists in neuroscience concerning how economic and judgment-based decisions occur, and hence we do not proceed beyond this reference to it.

## **Conclusion**

We believe value exists in grounding entrepreneurship research in neuroscience, with this chapter detailing the role of neurophysiology in episodic processing and affective valuation to support the assertion that entrepreneurs' brains are physiologically the same as any other person's brain, but in terms of experiences and knowledge they are different. We have endeavored to illustrate the potential advantage of including discussions of neural structures and functions in entrepreneurial cognition research and offered premises from which beneficial future research may proceed. Still, we concede that our work is neither comprehensive nor definitive, as neuroscience researchers continue to refine our understanding of neurophysiology. We also largely excluded any discussion of semantic processing (a key research stream for investigating knowledge structures and opportunity) owing to the already overwhelming detail for non-neuroscience readers, while we underspecified our descriptions of key neural processes for neuroscientists, a necessary compromise in cross-disciplinary research in our view. We accept that alternative views exist on key concepts such as emotions (e.g., natural kinds) or the role of context in opportunity and venture formation. Nonetheless, our approach (detailing how the brain generates behavior) stands in contrast to the alternative as previously described: that of

taking a man-created word or concept (e.g., emotion) and searching for an explanation, oftentimes outside the individual.

In our view, neuroscience renders the entrepreneur as human and, more importantly, as accessible owing to the explanations possible through its structure-function paradigm; and (we hope) offers a foundation for additive research with well-defined (although cross-disciplinary) concepts and consequent research questions, some prompted through “premises” herein. We view the entrepreneur as an ideal research subject given this person’s adaptive nature and (as we observe) the affectively treacherous path she follows. The research challenge is then to view the “entrepreneur” as more than a lifeless moniker dangling like a necktie; distinguish between the entrepreneur as a research concept (defined as human, w/highly-developed brain and common neural processes) and exemplar (embodiment of experiences, percepts, concepts and valuations); and design research questions informed by the research concept to explain variance among exemplars. It is here we hope researchers will discover a key to unlock previously inaccessible doors to understanding, not the least of which might be in better explanations: of differences among entrepreneurs, franchisees, and nonentrepreneurs; differences between male versus female and young versus older entrepreneurs; distinctions among opportunity conception: recognition, discovery, and creation; and the more-exact role of embodiment in socially-situated entrepreneurial cognition research.



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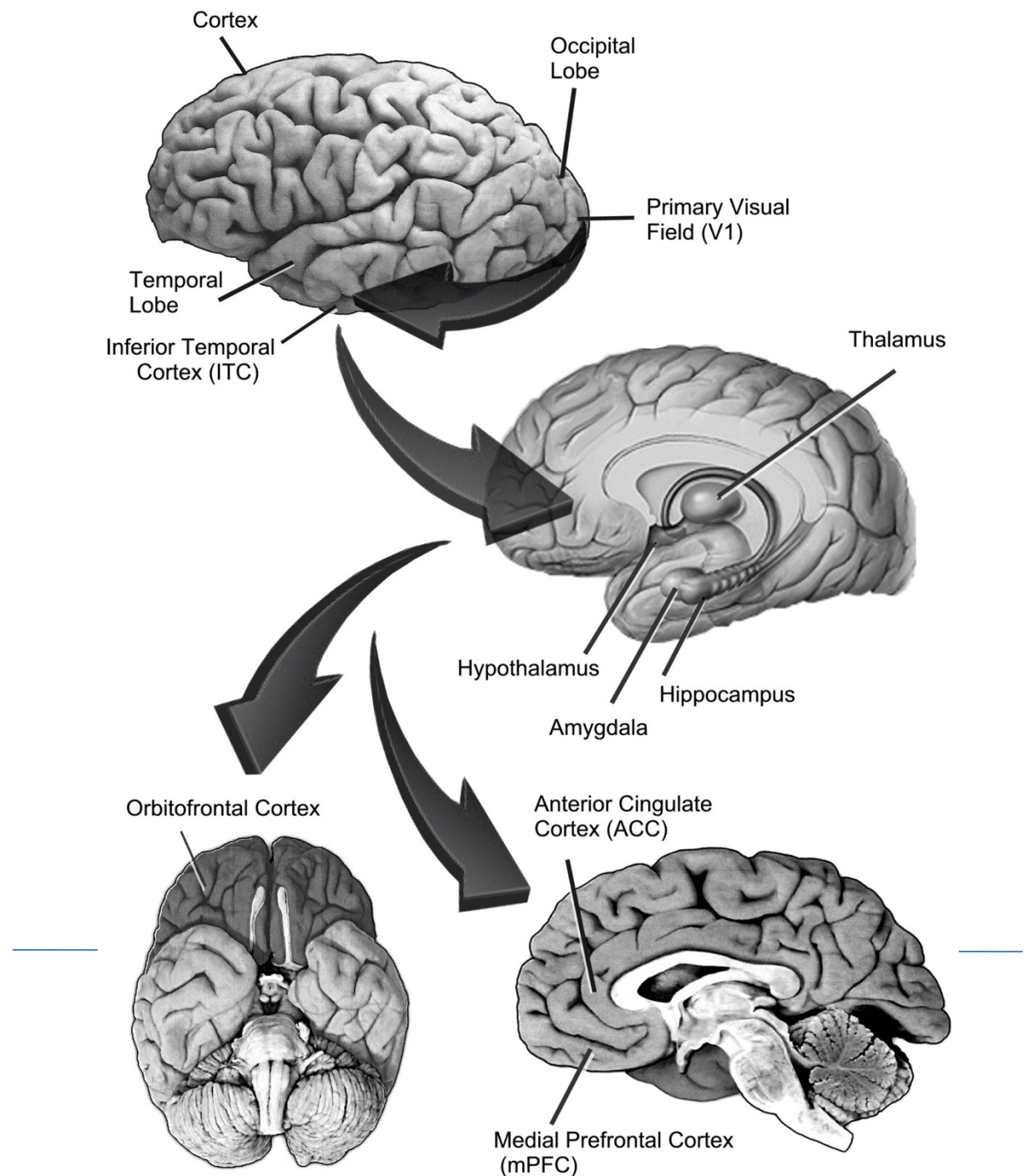
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**Figure 1: Simplified Flow of Visual Sensory Data from the Periphery to Conscious Thought**



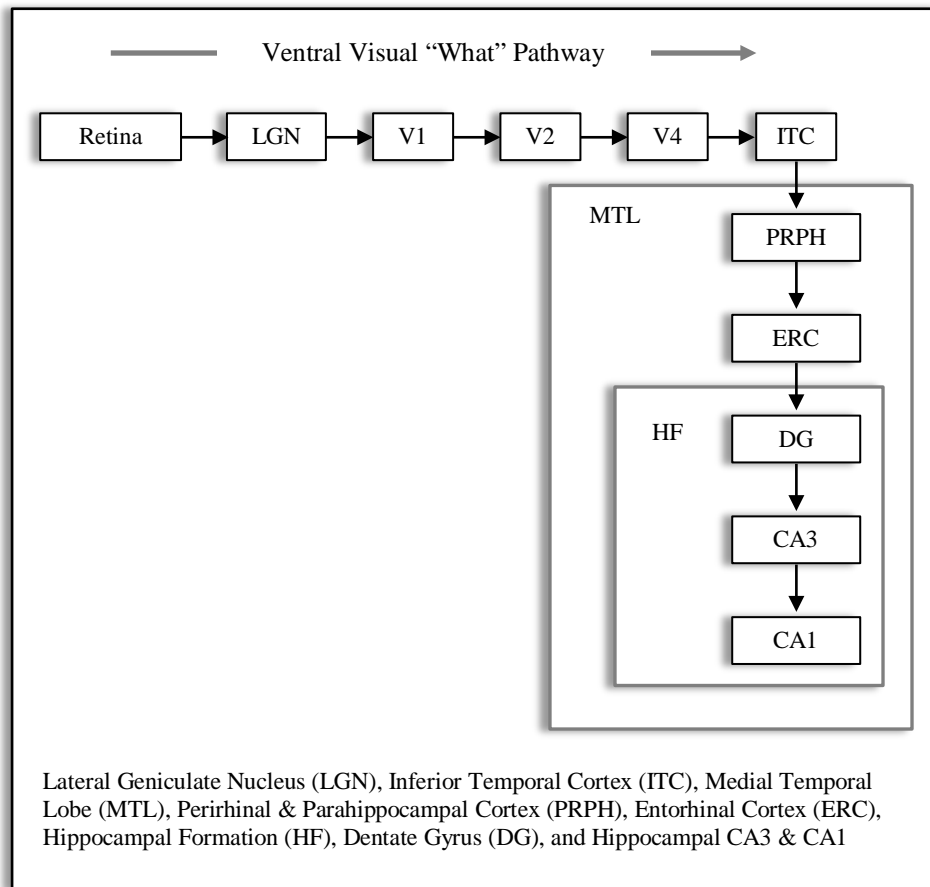
Simplified flow of sensory (visual) data from the periphery to conscious thought: primary visual field (V1) to Inferior Temporal Cortex (ITC); to Hippocampus & Amygdala (and Hypothalamus – triggering a physiological reaction); to Orbitofrontal Cortex (OFC), Medial Prefrontal Cortex (mPFC) and Anterior Cingulate Cortex (ACC); Cortex ≡ outermost layer of the cerebral hemispheres of the brain. Diagrams adapted from Pyramis Studios, 2007.

**Table 1: Definitions**

<b>Entrepreneur</b>	An individual with the same neural structures as anyone else and whose behavior derives from the standard complement of neurological processes. No neurological advantage need exist. This person's adaptive abilities derive from conserved survival circuits that support functions such as the affective valuation of stimuli, prediction, and episodic future thought.
<b>Cognition</b>	The umbrella concept subsuming all the unconscious and conscious processes, expressly including semantic processing and affective valuations (i.e., emotion and motivation), that turn sights and sounds, mere photons and air wave fluctuations, into neural representations that allow the individual to make sense of the world, form goals, and select suitable behaviors for an ever changing world.
<b>Affective Valuation</b>	The modulation of activity in neural structures from periphery sensory and memory circuits to conscious thought in the DMN, either through direct axonal connection or release of hormones in the body and neurotransmitters in the brain. Valuation derives from the preferential processing of some environmental stimuli (e.g., people, places and things) over others, with prediction errors (e.g., pleasant surprises, missteps or miscues) implicated in inducing the modulation of neural activity. Subsumes emotion and motivation.
<b>Emotion</b>	Emotion centers on the amygdala and activation of a visceral stress response through the hypothalamus, sympathetic nervous system, and stress hormones: glucocorticoids, epinephrine (a.k.a., adrenaline) and norepinephrine released from the adrenal cortex. An event happens that elicits the coincident neurotransmitter release in the brain and physiological reaction in the body—both modulating information processing. Emotion serves a purpose (function) of tagging behaviorally relevant stimuli or experiences (i.e., beneficial or harmful) that require a response, so “emotion” may be best defined and measured by a specific stimuli (or an experience) that induces a stress response, the valence (i.e., positive or negative) of the response, and the evoked behavior.
<b>Motivation</b>	Motivation refers to a dopamine-modulated state of arousal consonant with anticipation that proceeds and guides reward-seeking (a.k.a. goal-directed or approach) behaviors toward desired outcomes. Appetitive (e.g., food and water) and abstract (e.g., money) stimuli alike acquire subjective reward value as a function of the individual's experiences with these stimuli. The two components of motivation, 1) arousal prior to rewards and 2) reinforcement of reward-seeking behaviors upon the timely delivery of rewards, occur through the operation of the midbrain dopamine (DA) system centered on a distributed network of DA-modulated structures, with special emphasis on the Orbitofrontal Cortex (OFC), Ventral Tegmental Area (VTA) and Ventromedial Striatum (a.k.a. nucleus accumbens – NAc). Motivation may be best studied as a specific stimulus with reward value and an evoked behavior.

**Table 2: Anatomical Abbreviations**

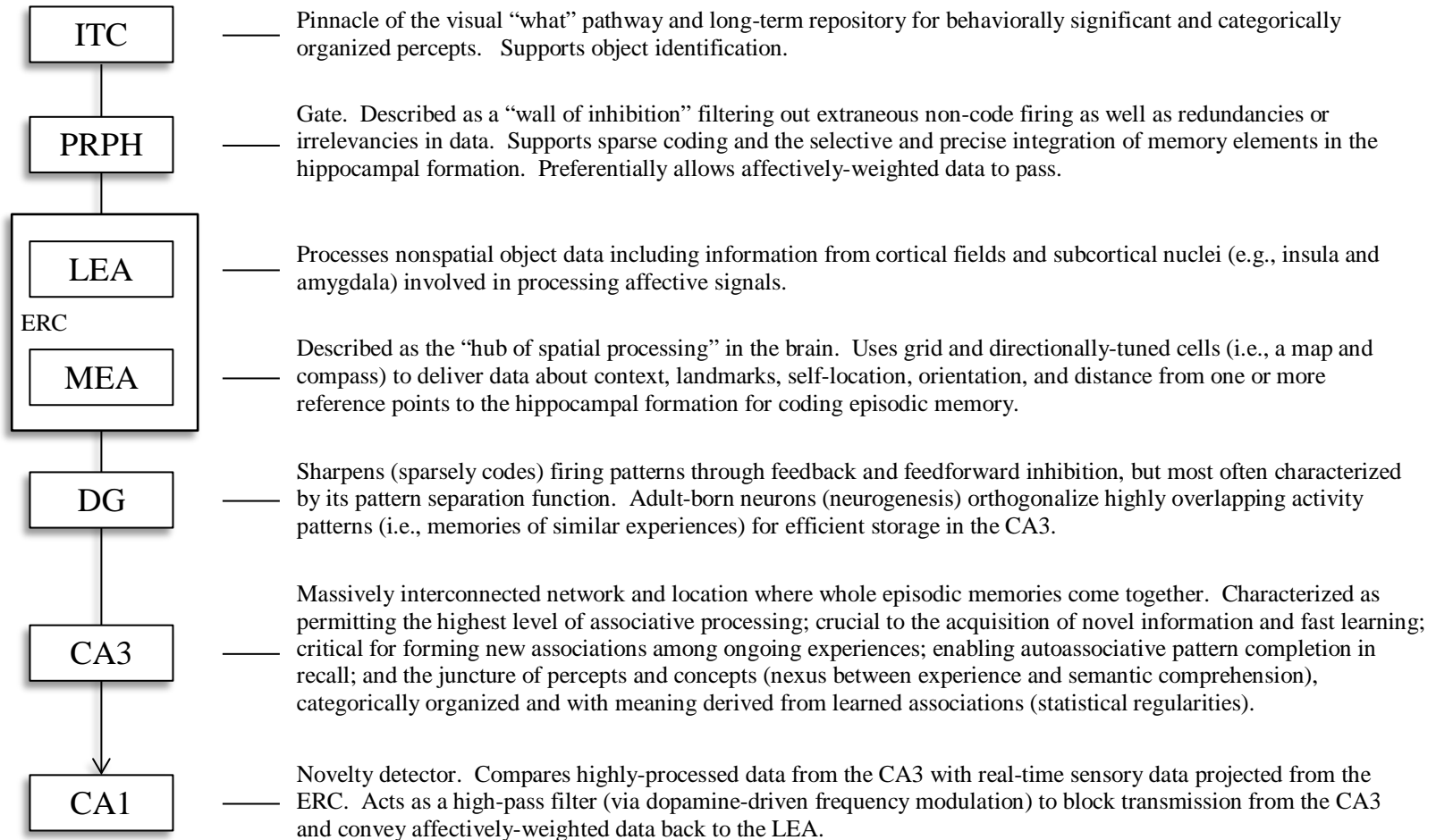
ACC	Anterior Cingulate Cortex
AMG	Amygdala
BLA	Basolateral Amygdala
CA1 & CA3	Hippocampal fields ( <i>CA - Cornu Ammonis</i> )
DA	Dopamine
DG	Dentate Gyrus
ERC	Entorhinal Cortex
dIS	dorsolateral Striatum
DMN	Default Mode Network
dmS	dorsomedial Striatum
dmPFC	dorsomedial Prefrontal Cortex
HIP	Hippocampus
HPA	Hypothalamus-Pituitary-Adrenal Axis
ITC	Inferior Temporal Cortex
LEA	Lateral Entorhinal Area
MDS	Midbrain Dopamine System
MEA	Medial Entorhinal Area
mPFC	medial Prefrontal Cortex
MTL	Medial Temporal Lobe (memory system)
NAc	Nucleus Accumbens (a.k.a. vmS)
OFC	Orbitofrontal Cortex
PRC	Perirhinal Cortex
PRPH	Perirhinal and Parahippocampal Cortices
PVN	Paraventricular Nuclei of the Hypothalamus
V1, V2 & V4	Visual Processing Fields
vmPRC	ventromedial Prefrontal Cortex
vnS	ventromedial Striatum (a.k.a. NAc)
vSB	ventral Subiculum
VTA	Ventral Tegmental Area

**Figure 2: Visual “What” Pathway and Medial Temporal Lobe Memory System**



### Figure 3: Structures and Functions of the Medial Temporal Lobe (MTL)

Inferior Temporal Cortex (ITC), Perirhinal & Parahippocampal Cortex (PRPH), Entorhinal Cortex (ERC), Lateral Entorhinal Area (LEA), Medial Entorhinal




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Area (MEA), Dentate Gyrus (DG), and Hippocampal CA3 & CA1

**Figure 4: Hippocampal Formation**

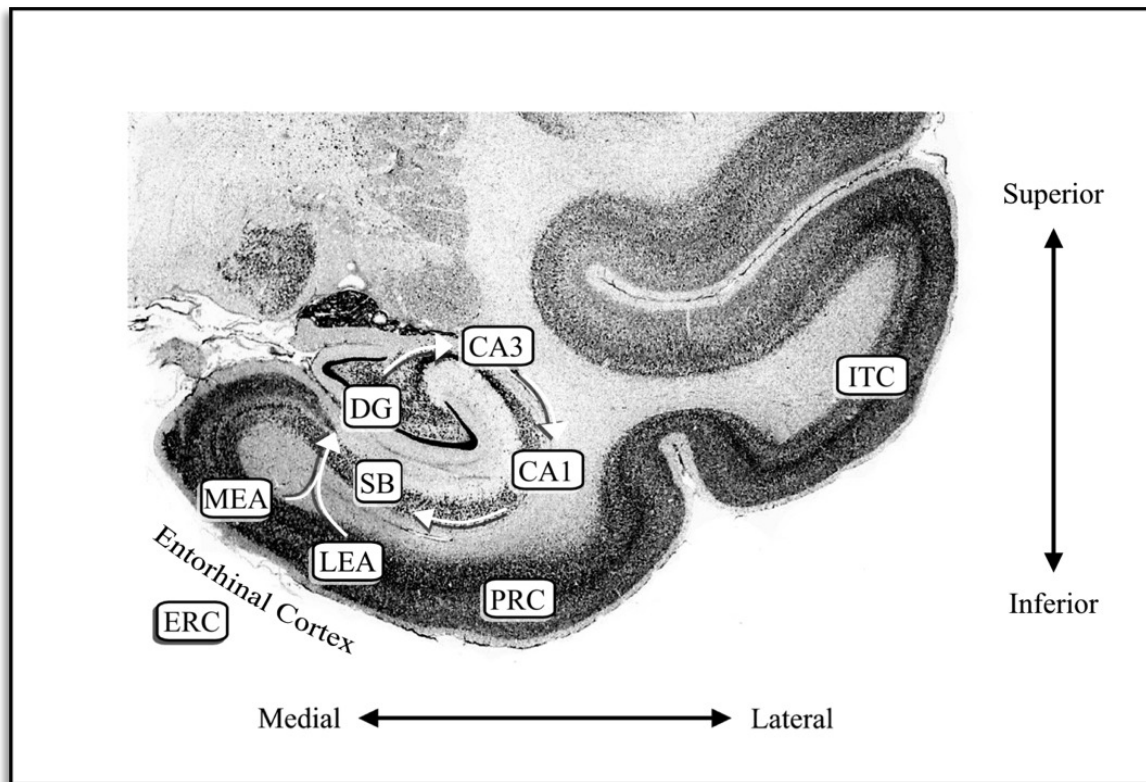
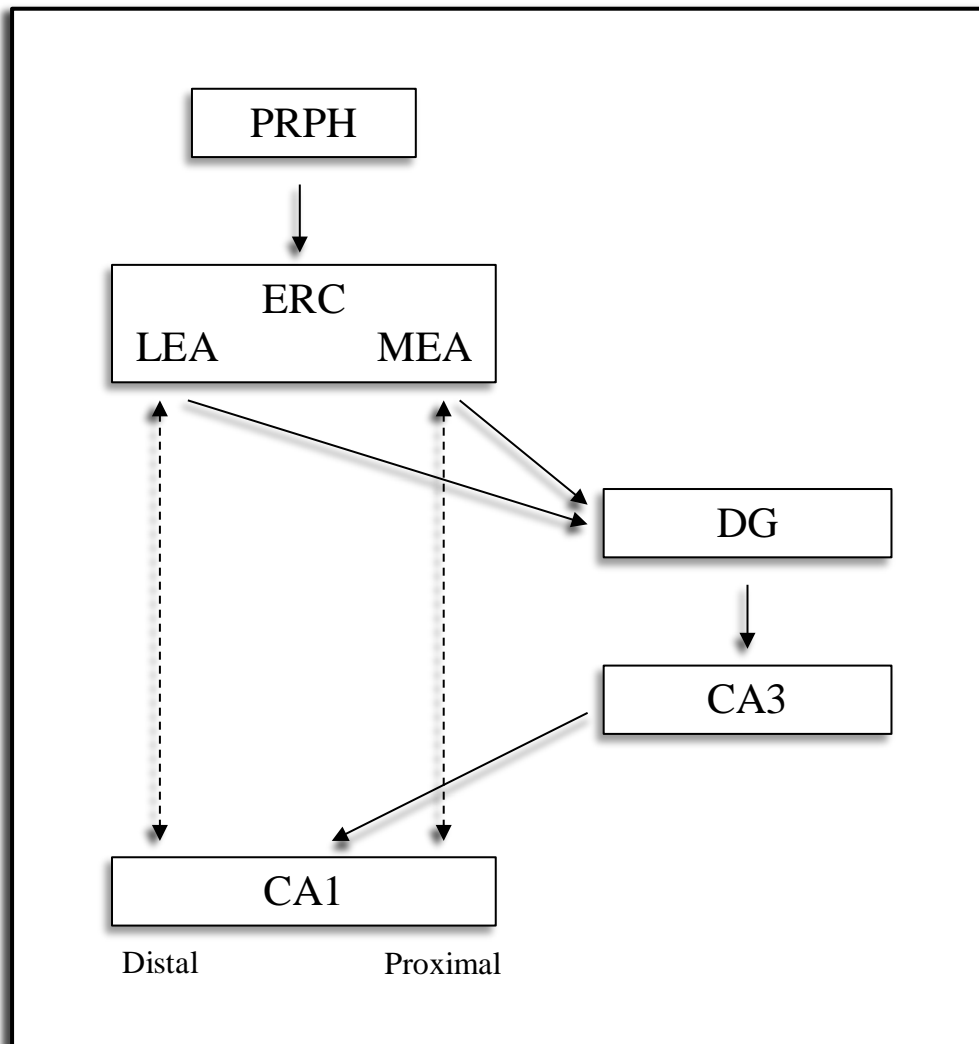


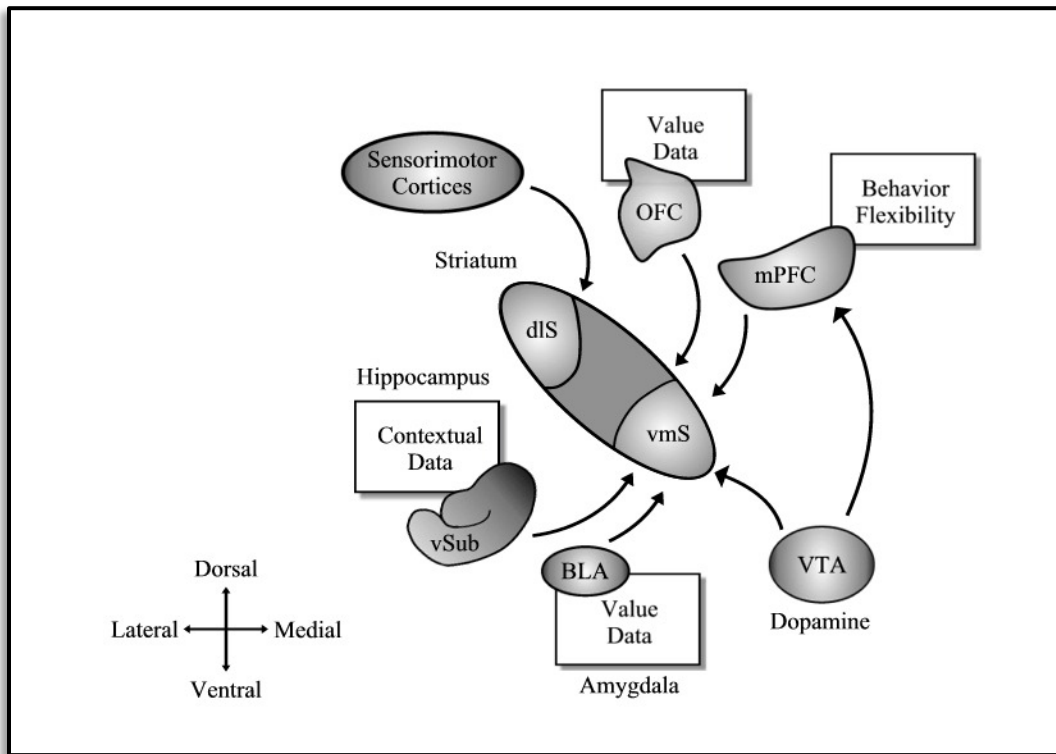
Diagram of the hippocampal formation tucked into the medial wall of the temporal cortex: Dentate Gyrus (DG), Hippocampal CA3, Hippocampal CA1, and Subiculum (SB). Other prominent structures in our analysis include the Inferior Temporal Cortex (ITC), Perirhinal Cortex (PRC), Entorhinal Cortex (ERC), Lateral Entorhinal Area (LEA), and Medial Entorhinal Area (MEA). Adapted from Brainmaps.org.

**Figure 5: Hippocampal Formation Wiring Diagram**



Perirhinal & Parahippocampal Cortex (PRPH), Entorhinal Cortex (ERC), Lateral Entorhinal Area (LEA), Medial Entorhinal Area (MEA), Hippocampal Formation (HF), Dentate Gyrus (DG), and Hippocampal CA3 & CA1

**Figure 6: The Striatum and Midbrain Dopamine System**



Orbitofrontal Cortex (OFC), Medial Prefrontal Cortex (mPFC), Dorsolateral Striatum (dIS), Ventromedial Striatum (a.k.a. Nucleus Accumbens - NAc), Hippocampal Ventral Subiculum (vSB), Basal Lateral Amygdala (BLA), Ventral Tegmental Area (VTA).