Introduction: The emergence and stabilization of neuroeconomics as an interdisciplinary field

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1. Introduction

In this introductory chapter we sketch the context in which neuroeconomics has emerged and has stabilized as an interdisciplinary field at the intersection of economics, psychology and neuroscience. In doing so we recall where neuroeconomics came from, what developments made its emergence possible, what hopes and expectations were initially invested in it, and what directions and forms it subsequently took. In particular, we give an account of how the advent of new brain-scanning techniques gave an impetus to the emergence of two distinct styles of neuroeconomics: one that originates from behavioral economics, to which Ross (*This Handbook*) refers to as *behavioral economics in the scanner* (BES for short), and another that developed from the application of economic models and concepts to the study of neuronal behavior, to which Ross (*This Handbook*) refers to as *neurocellular economics*, NE for short (also *neural economics*, Montague and Berns 2002, or *economics of neural activity*, Vromen (*This Handbook*)).

The two styles emerged largely independently, at about the same time, and had totally different goals. This feature of its emergence could imply either that neuroeconomics, in fact, comprised two separate fields, each with its own goals, methods and domain of phenomena, or that the discipline was then at an early stage of development and, as a consequence, its goals, methodology and domain of phenomena were still being negotiated.[1] Lately, the two

[1] We understand a field as in Darden and Maull's (1977: 4) characterization: "A central problem, a

styles have been showing signs of convergence in terms of aspirations, methodology and views about the content of economic theory. Convergence on these aspects would seem to indicate that neuroeconomics is developing into a unified field and possibly approaching a stage of stabilization in which negotiation over goals, methodology and content is becoming less frequent (although elements of unity and disunity frequently coexist in successful cases of inter-field unification, see e.g. Marchionni 2009).

In keeping with this narrative, this introductory chapter is organized as follows. Sections 2 and 3 examine the emergence of neuroeconomics in relation to economics and neuroscience, respectively. Section 4 focuses on neuroeconomics as an interdisciplinary field with the potential to integrate economics, psychology and neuroscience. Section 5 culminates in the observation that the two styles of neuroeconomics are converging on a common trajectory. Section 6 offers a roadmap of the rest of the *Handbook*.

2. *Do Economists Need Brains?*

The emergence of neuroeconomics as a new interdisciplinary field was deemed significant enough for *The Economist* to publish an article in 2008 entitled, *Neuroeconomics: Do economists need brains?* As is usually the case with *The Economist*, the article was meant to be accessible to a large audience, it was witty, succinct, yet well informed and to the point. Not only did it give a fairly accurate account of what neuroeconomics is, it also succeeded in

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domain consisting of items taken to be facts related to that problem, general explanatory facts and goals providing expectations as to how the problem is to be solved, techniques and methods, and sometimes, but not always, laws and theories which are related to the problem and which attempt to realize the explanatory goals."

pinpointing the most controversial aspects. In a nutshell, the message was that the brain-scanning techniques being developed in neuroscience offered new opportunities to learn about how decisions are made in the brain, and that economists would have been ill-advised not to seize these opportunities. The hope was not only eventually to arrive at a more realistic economic theory – with improved descriptive and explanatory power – but also and even more ambitiously, to develop an analytical framework that would integrate all the behavioral sciences.

2.1. Behavioral economics in the scanner

It will be instructive to flesh out in detail what *The Economist* article argues and what is only tacitly assumed. It presents neuroeconomics as a natural outgrowth of behavioral economics, taking it one step further by investigating the neural underpinnings of the mental constructs (such as cognitive biases and heuristics) identified by behavioral economists. Given that behavioral economics purports to connect economics with psychology, and with all the recent advances in (cognitive) neuroscience, it is only natural to push this a step further and ask how the psychological mechanisms in the human mind are implemented in the brain.

Shifting the research frontier from the mind to the brain is all the more understandable, it is suggested, not only because "hard" neuroscience is held in higher esteem than "soft" psychology, but also because of the availability of new scanning techniques such as fMRI. The point is that earlier generations of economists did not peer into the brain for the simple reason that there were no available techniques for doing so. Even though pioneers of modern economics such as Edgeworth dreamt of a "hedonimeter" (Colander 2007) – a device that would enable economists to directly measure the desires of agents and the degrees to which such desires are satisfied – for a long time no such instruments were in the offing. Lacking reliable ways of discerning how we make decisions, economists reverted to *as-if* theorizing,

which makes no claim about the way the maximizing computations attributed to agents are actually executed in the agents' minds. Therefore, economic agents behave *as if* they are maximizing some goal function.

The emergence of experimental and behavioral economics on the one hand and the availability of new brain-scanning techniques on the other changed the situation dramatically. Economists had the opportunity to shift from theorizing about *Homo Economicus* to founding their research on what actually goes on inside our heads. For the first time ever, it was also possible to look directly into the brain to see what is going on in there when agents make decisions. At last, the move from *as-if* theorizing to *as-is* theorizing became feasible.

The Economist article was not naively optimistic about the prospects of neuroeconomics, however. It offered some caveats and acknowledged the presence of controversies. For example, it referred to the limits of MRIs in terms of identifying the loci of neural activity in the brain, which makes it clear why assuming that what is going on in the head can be directly read from MRI images is a dangerous illusion. The article also briefly discusses the well-known attack on neuroeconomics by economists Gul and Pesendorfer (2008) (this *Handbook*, Volume 1). Gul and Pesendorfer (2008) forcefully argue that there is no good reason for economists to look at how decisions are made in the brain. They do not deny that there might be room for improvement in economic theorizing and modeling, but they point out that brain data do not convey whether this is the case, or, if it was the case, how it would bring about improvements in economic theories and modeling. Given that economic theories and models do not speak out about how decisions are made, but merely concern what decisions are made, only behavioral data can reveal whether economic theories and models need to be improved. In short, economists do not need brain data to do their job. Even though it did not fully discard it, *The Economist* regarded Gul and Pesendorfer's claims as overly dismissive. However, in the light of some remarks by Nobel Prize winner Daniel Kahneman,

it suggested that their argument might be effective in blocking the venturing of economics into psychology, but that it was much less likely to block the venturing of economics into neuroscience (or brain science).

2.2 Proponents, Adversaries, and Skeptics

It is worth pointing out that Gul and Pesendorfer's principled argument contrasts sharply with some of the methodological concerns about how empirical research is conducted in neuroeconomics. It is one thing to argue, for example, that MRI scans are blunt instruments, that fMRI findings should be interpreted more carefully (than simply assuming that they reveal the brain at work), and that the samples typically used in neuroeconomics are too small to draw conclusions (cf. also Harrison 2008; *This Handbook*). These methodological concerns presuppose (or at least do not deny) that it might be worthwhile for economists to peer into the brain. It is something different to argue, as Gul and Pesendorfer do, that there is no need for economists to look into the brain in the first place. *The Economist* article seems to have failed to fully appreciate the scope of Gul and Pesendorfer's argument, which it took to be confined to psychology: in other words, it was an argument for "mindless" economics (as the title of Gul and Pesendorfer's paper would suggest), but not necessarily one for brainless economics. If we assume that brain science concerns the study of decision-making processes on the level of the brain, and if Gul and Pesendorfer were right in assuming that economists should not study decision-making, it follows that economists should also be disinterested in *brain sciences*. If economists were to rest content studying choices without going into the processes leading to them, as Gul and Pesendorfer argue, then they should equally refrain from delving into the neurological mechanisms underlying those choices.

The BES narrative, reflected in *The Economist* article, presents the decision of economists not to look into the brain as a forced move, an idea that is clearly at odds with Gul and

Pesendorfer's argument. According to the latter, the decision to steer clear of psychological and brain mechanisms is a principled and deliberate choice: economists decided to settle on questions that do not require the study of decision-making processes. They believed that simply studying the choices made would suffice for the purpose of economics, which Gul and Pesendorfer define as "… to analyze institutions, such as trading mechanisms and organization structures, and to ask how those institutions mediate the interests of different economic agents" (Gul and Pesendorfer 2008, p. 8). Given such a purpose, economists believe there is no need for them to look into why and how decisions are made by economic agents. They gladly leave it to others to study decision-making processes, either on the level of the human mind (psychology), or on the level of the human brain (brain or neuro-sciences).

Despite Gul and Pesendorfer's portrayal of economists, most behavioral economists do show an interest in decision-making processes. They want to know not only what decisions are made and their implications for processes at a higher level of aggregation, but also *how* these decisions are made. Put another way, behavioral economists are not looking for a decision theory that paraphrases descriptions of observed choices (as revealed preference theory does). They are looking for a decision theory that explains observed choices in terms of the decision-making mechanisms leading to those choices. This explains, at least partly, why they hoped and expected to learn a lot from neuroscience. By the time neuroeconomics was launched, several behavioral economists (notably Kahneman and Frederick 2002; later popularized in Kahneman 2011) had already put forward a two-system (or process) view of how human agents reason and make decisions. According to this view, two different systems are involved in human decision-making: the first, often called System I, operates largely unconsciously, quickly, autonomously, effortlessly, associatively and intuitively, is affect-(emotion-) ridden and works in a "hot" state; the other one, called System II, works largely

consciously, slowly and in a controlled manner, involves high effort and operates in a "cold" state.

Behavioral economists sympathetic to neuroeconomics have been dabbling in neuroscience to find evidence for the existence and operation of both systems, and especially evidence indicating that System 1 dominates human decision-making. The already-mentioned neuroeconomics manifesto of Camerer et al. (2005; reprinted in this *Handbook*; see also Camerer et al. 2004) claims that findings in neuroscience strongly imply not only that the two systems are indeed active in human decision-making, but also that System I is much more influential than standard economic theory would have us believe. Indeed, according to Camerer et al. (2005), the implication in neuroscience is that the system taken in standard economic theory (allegedly) to be the only one operating in human decision-making – System II – is merely a small component of it. It is further argued that the bulk of the work in human decision-making (as well as in economic behavior) is done by System I, in spite of the fact that what is going on in that system is hardly accessible to introspection.

Thus, behavioral economists sympathetic to neuroeconomics have been looking to neuroscience to find evidence in support of their theories and models vis-à-vis standard economic theory. It is exactly this use of neuroscience that Gul and Pesendorfer (2008) rally against: the use of "brain data" gathered in neuroscience to test and adjudicate between rival economic theories. Brain data cannot be used for this purpose, they argue, if only because standard economic theory endorses Revealed Preference theory, which does not pronounce on decision-making processes, only on observed choices. That is why behavioral data, and only behavioral data, can adjudicate between rival economic theories.

The *hope* of behavioral economists sympathetic to neuroeconomics, such as Camerer et al. (2005), is clearly that neuroscience can help in developing new economic theories (or

vindicating already existing ones) that are superior to standard economic theory both descriptively and explanatorily. The idea is that it is economic theory that ought to be improved and therefore should be the main beneficiary of neuroeconomics, with neuroscience as the main source upon which to draw to accomplish this. The belief is not that neuroscience cannot be improved on: the tacit assumption is rather that, compared to economics, neuroscience is already in good shape, at least good enough to be relied upon when it comes to improving economists' understanding of human decision-making. What is on the agenda is the development of more realistic economic theories. Camerer et al. (2005) distinguish between two different ways in which neuroscience could inform economics: via an incremental or a radical approach. In the short run, extra variables drawn from, or inspired by, neuroscience could be added to existing economic models so as to make them more realistic. However, the authors believe that in the longer run it will be necessary to deviate more radically from standard economic theory. The big challenge is to develop precise theories about how System I and System II interact in producing behavior.

3. Neuroeconomics: A Different Tale

It is perhaps not surprising that *The Economist* article followed the BES narrative: especially in the early years of neuroeconomics, Camerer et al.'s manifesto attracted the most attention in the economics profession. Theirs was not the first neuroeconomics manifesto, however (see Montague and Berns 2002; Glimcher and Rustichini 2003). Earlier efforts conveyed an altogether different view of what neuroeconomics was and what sort of contributions were to be expected from it. The hope from this alternative narrative, the second strand of neuroeconomics mentioned above that originates from within Neurocellular Economics (NE), is that conventional economic theories such as expected utility theory and game theory could shed light on neural activity in the brain. Just as standard economic theory was deployed long ago to enhance understanding of animal behavior (e.g. Tullock 1971), it could also be used to

enhance understanding of neural activity in the brain. In other words, from its very inception, two styles (or camps) were parading under the name of neuroeconomics (Ross 2008, Vromen 2007). Indeed, these camps could be presented as taking opposite stances on the relationship between economics and neuroscience.[2] Whereas BES takes recourse to "standard" neuroscience to transform and eventually revolutionize economics, thereby overturning standard economics, NE takes recourse to "standard" economic theory to revolutionize neuroscience, thereby overturning standard neuroscience.

As noted above, BES envisions economics as the main beneficiary of neuroeconomics, and neuroscience as the main source upon which to draw. With regard to NE, neuroscience is the main beneficiary of neuroeconomics, and economics the main source on which to draw.

4. Neuroeconomics as an interdisciplinary field

For all their differences, however, BES and NE share the view that the main contribution of neuroeconomics lies (or should lie) in helping its parent or contributing disciplines (be it economics or neuroscience) move forward. Indeed, neuroeconomics is often portrayed as an interdisciplinary endeavor (or as an "interdiscipline"; see Smith and Huettel 2010) in that it brings together several disciplines.

As O'Doherty and Camerer (2015) put it in their Editorial Overview:

[2] This "irony" is noted by Camerer et al. (2005): "Many neuroscientists are now using the most basic elements of rational choice theory to explain what they see. Ironically, they are taking up rational choice theory at the same time as more and more economists are moving away from rational choice toward a behavioral view anchored in limits on rationality, willpower, and greed (which we expect to be informed by neural detail)." (p. 54)

> "A distinctive and valuable aspect of this research is that it has adopted a strongly inter-disciplinary flavor: theories, constructs and experimental methods are borrowed, as they prove useful, from a variety of disciplines, including psychology, economics, cognitive and behavioral neuroscience, as well as computer science and artificial intelligence" (p. v).[3]

What is borrowed and from which disciplines differs between the two styles of neuroeconomics, however. BES tends to borrow constructs from psychology and experimental methods from cognitive and behavioral neuroscience to transform economics, whereas NE mainly borrows theories and constructs from standard economics to transform neuroscience. Both styles bring together psychology, economics and neuroscience, but in very different ways. What is a source on which to draw for one style is the target of improvement for the other (neuroscience for BES and economics for NE, respectively).

In addition, the ideal of interdisciplinarity is often associated with some form of *integration*: in other words, successful interdisciplinarity involves more than the mere borrowing of theories, constructs and methods from different disciplines (see e.g. Klein 2010). The extent to which psychology, economics, and neuroscience are integrated into neuroeconomics is unclear, however. Part of the problem lies in the vagueness of the very notion of integration, and why integration would be epistemically superior to "mere borrowing" in the first place (see e.g. Grüne-Yanoff 2016). Even leaving these conceptual and epistemic issues aside, interdisciplinary integration would seem to require at least a shared understanding of key concepts (see, e.g. Burnham et al., 2016, p. 114). In the case of neuroeconomics, "value"

[3] That this interdisciplinary endeavor also raises terminological difficulties (in terms of how to connect the different vocabularies of the various disciplines) is nicely illustrated in the Dialogue in Padoa-Schioppa and Schoenbaum 2015. See also O'Doherty (2014).

could be such a concept (see Section 2.1 of this *Handbook*). Indeed, to date the identification of particular brain areas (roughly, the ventromedial prefrontal cortex (vmPFC) and the ventral striatum) as encoding "subjective values" is regarded as one of the biggest successes of neuroeconomics. In broad terms, the brain computes a single decision variable (the subjective value, sometimes also called the expected value, which is seen as the physical instantiation of economic utility) for every option considered, subsequently compares them, and finally selects the one with the highest value. Subjective values turn out to predict fairly well the decisions that agents make (Levy and Glimcher 2012; Bartra et al. 2013).

Nevertheless, it is suggested in an illuminating dialogue between Camillo Padoa-Schioppa and Geoffrey Schoenbaum (Padoa-Schioppa and Schoenbaum 2015) in *Current Opinion in Behavioral Sciences* that an understanding of "value" common to sciences with an interest in decision-making has not yet been achieved (see also O'Doherty 2014). Padoa-Schioppa, one of the leading figures in neuroeconomic research on subjective value, and Schoenbaum, a psychologist working in the area of learning theory, discuss the difficulties they have in understanding each other's notion of value. Even though the dialogue hints at potential correspondence between concepts in economics and psychology, Padoa-Schioppa's remark, "In principle, values defined in economic choice and values defined in learning theory have nothing to do with each other" (p. 20) is both telling and sobering.

These conceptual difficulties seem to reflect the different backgrounds, training and interests among practitioners of neuroeconomics. As a psychologist working in the area of learning theory, for example, Schoenbaum is "naturally" interested in how people learn the values they assign to different options, pointing out that there are multiple types of learning processes in humans. Model-free reinforcement learning is distinguished from model-based reinforcement learning, for example. Related to this is the distinction between habitual and goal-directed control systems of behavior. Psychologists tend to be interested in how these

mechanisms and systems work in human learning, how they interact, and how they are implemented in neurocomputational substrates (see also O'Doherty, Cockburn and Pauli 2017). Among the breakthroughs in this regard, which could be considered another major success story in neuroeconomics, is the work of Schultz and associates showing that in reinforcement learning dopamine neurons encode a *reward prediction error* (RPE) (see Section 1.1 of this *Handbook*). As is typical of many economists, Padoa-Schioppa prefers to remain agnostic about how subjective values are learned, as well as about how decisions are made – either habitually or in a goal-directed manner ("… value is what I can measure from choices", p. 20). Note that the dialogue between Schoenbaum and Padoa-Schioppa is reminiscent of the contrasting attitudes towards dual-system theory mentioned above: what is of the greatest interest to psychologists and to at least some behavioral economists, namely, showing that there are two systems operating and that there is neurobiological evidence for this, is deemed irrelevant by other economists *even within the field of neuroeconomics*.

Thus, neuroeconomics encompasses a variety of approaches. To the extent that interdisciplinary integration requires a common understanding of key concepts, this variety calls into question the success of neuroeconomics as an interdisciplinary field. At the same time, progress has been made on various fronts. In addition to the two success stories already mentioned, we now know much more about the neurobiological substrates of intertemporal choice (Section 2.2 of this *Handbook*) and social preferences (Section 2.3 of this *Handbook*), for example. Knowledge about which brain areas supply input to the vmPFC and the ventral striatum, and how these inputs are aggregated in the vmPFC and the ventral striatum, is also advancing rapidly.

5. *Signs of Convergence*

Convergence between BES and NE seems to have been taking shape in recent decades. Signs of it can be witnessed on three fronts pertaining to aspirations, methodology, and views about the content of economic theory.

First, there seems to be more agreement concerning both the immediate and the ultimate goals of neuroeconomics. In their survey, Fehr and Rangel define neuroeconomics as follows:

> "Neuroeconomics combines methods and theories from neuroscience, psychology, economics, and computer science to investigate three basic questions: 1) What are the variables computed by the brain to make different types of decisions, and how do they relate to behavioral outcomes? 2) How does the underlying neurobiology implement and constrain these computations? 3) What are the implications of this knowledge for understanding behavior and well-being in various contexts: economic, policy, clinical, legal, business, and others? The ultimate goal is to produce detailed computational and neurobiological accounts of the decision making process that can serve as a common foundation for understanding human behavior across the natural and social sciences (Wilson, 1999)." (Fehr and Rangel 2011, pp. 3-4)

One could say that the immediate goal of neuroeconomics is to answer Fehr and Rangel's first and second questions. Before possible implications for economic theorizing can be considered, however it is imperative to understand, first, the computations made by the brain when making decisions and the key variables involved in them, and second, how these computations are implemented in the hardware of the brain and are constrained by its properties. In short, the first concern of neuroeconomics is to advance the aspect of

neuroscience that deals with decision-making in the brain, which often goes under the name of *decision neuroscience*.[4]

The ultimate goal of neuroeconomics is to use what has been learned in decision neuroscience to improve economic theorizing, or even more ambitiously as Fehr and Rangel argue, to develop a common foundation for understanding human behavior that can unify the natural and social sciences. As noted, improving economic theorizing has always been the goal of BES, but as Glimcher makes clear, this is also the ultimate goal of NE. The ultimate goal of neuroeconomics, he argues, is eventually to produce what he calls calls "hard" or "because" theories. These are theories of human decision-making that not only better predict behavior, but also more closely approximate the underlying physical and mental processes giving rise to human behavior than traditional neoclassical theory (Glimcher 2011, p. 393). Therefore, what Glimcher (2003) initially presented as the ultimate goal of neuroeconomics, namely to improve neuroscience, now appears to be an intermediate goal in the development of a unified foundation for understanding behavior.

The second point of convergence between BES and NE is the recognition that the brain should be studied on the level of both computation and physical implementation. Following on from Marr (1982), Glimcher (2003) has always stressed this. However, it took a while for proponents of BES to realize that understanding decision-making in the brain is much more

[4]The relation between neuroeconomics and decision neuroscience is cast in different ways in the literature. Instead of portraying decision neuroscience as an indispensable first stage of neuroeconomics, as we do, "neuroeconomics" and "decision neuroscience" are sometimes used interchangeably (Smith and Huettel 2010; O'Doherty and Camerer 2015). At yet other times, neuroeconomics is presented as a first transient step to decision neuroscience (cf. Bossaerts and Murawski 2015).

complicated than merely reading off brain activity from fMRI scans. What brain scans deliver is always a description or, more generally, a rendering, which like all renderings could be effected on different levels and in different ways.

Appearances notwithstanding, neuroscience does not necessarily study brain activity directly on the level of physical implementation, namely the level at which mental constructs are (allegedly) instantiated. BES neuroeconomists, in fact, have come to realize, as cognitive neuroscientists also did, that the algorithms and computations carried out in the brain need to be uncovered before sense can be made of its electrochemical and physical activity. This is why something like a "computational turn" has been occurring in neuroeconomics, which as Konovalov and Krajbich (2016) see it is a detour that has mitigated the impact of neuroeconomics on mainstream economics, but is necessary for its development.

These first two points of convergence between BES and NE concern their aspirations and methodologies. The third point, on the other hand, concerns their respective views on the content of neuroeconomic theory. We showed above how BES proponents interpreted many neuroeconomics findings as being in direct contrast to what they took to be the main lesson economists should learn from neuroscience, namely that standard economic theory needs wholesale revision. For example, Platt and Glimcher's (1999) finding that expected utility theory predicts quite well how neural activity in the parietal cortex of monkeys varies with changes in rewards and probabilities was regarded as vindicating rather than refuting standard economic theory. Subsequent developments in NE indicate, however, that Glimcher and NE proponents more generally were looking for evidence that there were brain areas (such as the lateral intraparietal cortex) in which something like expected utilities of choice options are computed and compared. This was just a step towards "brain-based" improvement in standard economic theory: once the relevant brain areas are identified, knowledge about the properties of neural activity in these areas could be used to figure out the constraints they

impose on computations. More recently, however, Glimcher expressed a rather different view. Far from supporting standard economic theory, he now argues that these constraints vindicate aspects of prospect theory (e.g., that variable reference points do indeed play a large role in human decision-making; cf. Glimcher 2016).[5] He initially criticized BES for proposing an obsolete view on how emotions and cognition figure in human decision-making, however (cf. Glimcher et al. 2005). Glimcher, arguing that there was no neurobiological evidence to assume that there are two distinct systems or processes operating in the brain, one affect-driven and the other "cognitive", each computing distinct values. He further stated that the brain represents and computes a single decision variable. This latter argument has gained strong support (as reported above). As Glimcher acknowledges, however, the fact that there is a *single* common currency at the final aggregation stage of decision-making is compatible with the presence, further upstream in the decision-making process, of multiple systems providing competing inputs. In fact, there is evidence that in the case of intertemporal choice, for example, the orbitofrontal cortex processes immediate rewards, whereas the dorsolateral prefrontal cortex advocates patience and self-control. Thus, even though dual-system theorists might be wrong in suggesting that there are two dissociable valuation systems in the brain, they might be right in thinking that there are several "systems" providing input to a final unitary valuation system.

[5] Prospect theory has been developed by behavioral economists as a more realistic economic theory than that of expected utility. Hence, BES and Glimcher seem to converge here. Ironically, however, it seems that neurobiologist Glimcher is keener on preserving as much standard economic theory as possible than behavioral economists, who are more open to radical deviations from the theory.

A shared picture of how different brain areas collaborate and sometimes conflict with each other in producing behavior seems to be emerging. Perhaps more importantly, however, proponents of both BES and of NE agree that there is still a lot that is not known. As Glimcher (2016) reports, almost nothing is known thus far about how the brain operates when decision-making is guided by *symbolic* computation. Symbolic computation is involved when an investor uses mathematical tools to predict the value of a stock in a stock market, for example. It seems that a lot of what we take to be economically significant behavior involves such symbolic computation. This only strengthens the impression that current knowledge about decision-making in the brain is just the proverbial tip of the iceberg. This does not justify any grave doubts about the prospects for a full understanding of such decision-making, but we cannot help but notice that this professed humility is a far cry from the overconfidence that characterized the early years of neuroeconomics.

6. *A Roadmap for the Handbook*

We hope that the above observations have stimulated the readers' interest in reading on, and that we have succeeded to highlight some of the aspects that make neuroeconomics such a fascinating field of inquiry. Many different issues are at stake, some of which have been and still are objects of intense debate, even within neuroeconomics. Moreover, all these issues have a wider significance in disciplines and fields other than neuroeconomics.

This *Handbook* comprises three volumes. The contributions to Volume I comprise a collection of pioneering manifestos and works of early neuroeconomics enthusiasts, including the staunch statements of some influential critics denying the relevance of neuroscience to economics. Volume II highlights and reports path-breaking work done in neuroeconomics in various domains ranging from social preferences to marketing. Volume III is devoted to the methodological and philosophical issues involved in, and raised by, neuroeconomics.

Devoting an entire volume to methodological and philosophical issues is admittedly unusual, but as philosophers of economics we, the editors, have a natural predilection for foundational issues. In addition, given the fact that neuroeconomics is riddled with foundational issues (as we hope to have shown above), this bringing together of works with more methodological and philosophical reflections should be of interest to all our readers. The articles in Volume III are meant to bring clarity to the controversies that have surrounded neuroeconomics; to systematically evaluate its prospects and limitations; and to identify current and potential future implications for neighboring sciences concerned with understanding human behavior. Together they provide a unique perspective from which to appreciate the more substantive issues presented in the previous two volumes. Hence, bringing these bodies of literature together should be of significance to scientists interested in neuroeconomics as well as methodologists and philosophers of economics and of science more generally. Both audiences should find ample food for thought.

The set of articles that comprise this *Handbook* are intended to reflect their relative influence within the field. To that end, we combined our sense of what was important in the field with the results of a citation analysis in *Scopus* and *Web of Science*.[6] We are aware that this is a risky endeavor given that both quantitative and qualitative assessments are bound to be inaccurate, and that the inaccuracies, although different, do not necessarily compensate each other. Moreover, due to the publishers' financial constraints, not all of the papers we initially selected are included in the final version of this *Handbook*. Finally, even though we tried to include the most influential articles, we also sought to paint a comprehensive picture of the

[6] The citation analyses were carried out in Scopus and Web of Science: one based on the number of citations and the other one based on the cited references within the sets of articles retrieved from Scopus and Web of Science. (October 2016).

field, including some of the most recent developments (which have not yet had the chance to accumulate a large number of citations). We hope that, in spite of its limitations, the final product offers readers a vivid sense of what neuroeconomics is and how it relates to its parent and neighboring sciences.

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