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2008

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by

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March 10, 2009

Prepared for a special edition of the French Economic Review (Revue Française d'Economie)

Abstract

Some economists believe that neuroeconomists threatens the theory of economics. Glenn Harrison's paper "Neuroeconomics: A Critical Reconsideration" (2008) provides some support for this view, though some of the points he makes are somewhat disguised. The field of neuroeconomics is barely into its teenage years; and it is trying to do what? Criticize and redesign the field of economics developed over hundreds of years? But that is not what neuroeconomics is trying to do, in spite of all the efforts of some economists trying to place it into that shoebox (see the argument in great detail in Andrew Caplin, Andrew Schotter 2008). Neuroeconomics is a Mendelian-Economics of sort; it is a science that is able to generate data by fixing the environment to some degree, varying a single independent variable for its affects, and is able to see each individual's choices from initiation of the decision-making process to its outcome. Mainstream (standard) economics, on the other hand, looks at the average of the outcomes of many individuals and proposes how people chose those outcomes, retroactively. The two fields, neuroeconomics and standard economics, are evaluating two sides of the same coin: one with and the other without *ceteris paribus*; they are not in conflict with one another.

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Introduction

It has been suggested that economics is a very narrow field whose theories define the variables and the conditions within which these theories apply. Gul and Pesendorfer suggest that in mainstream economics, the one most referred to as standard economics, “the testable implications of a theory are its content” (page 8 in Faruk Gul, Wolfgang Pesendorfer 2008). This is a paradox, because this implies that standard economic theory chooses to use only those testable implications that it can, even if they don't actually function in the economics of practice. If this is the case, then Gul and Pesendorfer’s statement should really say that standard economics uses “those testable implications that it wishes to be part of a theory, which then become its content void of applicability.”

Understandably, some economists believe that neuroeconomics threatens standard economics. By “standard economics” I mean the type of economics that has been taught in universities as “economic theory” since Adam Smith provided its basic tenets; hereafter I call “standard economics." Standard economics is based on the foundation of many great thinkers, including von Neumann and Morgenstern, who established the axiomatic definitions of the expected utility theory and which came under so much scrutiny of late. Standard Economics is based on many assumptions of human behavior. These assumptions, however, do not fit standard economics because the foundation of standard economics does not consider basic human decision-making processes that, in fact, formulate the decision outcomes. SE assumes that data collected about outcomes represent human decision-making via "revealed preferences" and since SE only concerns itself with outcomes, what is revealed is sufficient to predict such future decisions, ceteris paribus.

Contrary to popular belief in some economic circles, neuroeconomics is neither psychology nor the study of functional magnetic resonance imaging (fMRI). Neuroeconomics is a scientific process by which researchers from many disciplines, including economics, cooperate and share methods in order to design various experiments that *specifically prompt* certain types of human decision-making. In most neuroeconomic experiments a particular type of decision-making process is stimulated specifically to modify human preferences for reaching a particular outcome. In this way, neuroeconomists are able to control the economic process in order to evaluate the outcome in a controlled environment. Neuroeconomists have used various hormonal stimulations of particular emotions to see how much emotional components affect preference changes and in what direction. Other experiments use emotional stimulus in a less invasive way, such as while lying in the fMRI scanner subjects may be shown images of sad, angry, happy, or fearful faces, or perhaps sexy looking females may walk past the computer room, barely noticeably, to see how purchase decisions change by the mere presence of the other sex nearby. There are also experiments in which one gets a better feeling for how prices affect purchase decisions, some with the surprising find that often times higher prices imply better quality even if the higher prices are just decorations on cheap stuff, such as standard cheap wine.

Neuroeconomics contains methods that were developed by psychologists, neurologists, anthropologists, biologists, geneticists, mathematicians, physicists, and experts many other fields, including experimental and behavioral economists. Neuroeconomists use various stimulus to trigger a specific desired choice-behavior to understand the causal relationship between the environment and economic outcomes. Hence neuroeconomics is not in competition with standard

economics, since the two have different methods and they attempt to achieve different goals. It is true that initially some neuroeconomists believed that the standard economic theory was wrong. Soon it became clear that neuroeconomics is a different field, albeit using some economic models as its foundation.

The War

Some of the statements found in the literature Harrison refers to undoubtedly give reason to his opinion about neuroeconomics, but those statements he critiques are not representative of the work of neuroeconomists at large; they merely provide a critique of *some* of the methods used and *some* of the ways data have been analyzed. One may critique the theory of the expected utility and the way its axioms are so rigidly drawn—and many researchers are doing just that. I believe those who critic standard economic foundations are wrong. I do not share the opinion of those researchers who attack the expected utility theory even though I am a neuroeconomist. Standard economic theories stand on a narrow frame, and one must accept that the expected utility theory fits that narrowness perfectly. As standard economics makes unrealistic assumption about the environment in which its agents make their decisions, whenever real agents make their decisions in experiments, their decision outcomes need not follow the predicted outcomes of the standard economic theory.

However, I do fight against the understanding that agents who do not decide according to the predicted outcomes of the standard economic theories make anomalous decisions or make mistaken or non-optimal choices. Agents make choices based on an evolutionary process involving interactive chemical and physiological set of steps yielding a decision that is optimal and completely rational for the person at that moment of his life. Since the human body's

functions are not based on the clock or mathematical processes of economic theories, it would be a mistake to criticize the outcome of a biological process by a theory that is built on automatons whose goal is distinct from the goal of their body parts—e.g. brain. Furthermore, standard economic theories assume that agents reveal their true preferences by their choice outcomes, but since preferences are created, enforced, and directed by the chain of chemical events in the brain that are not visible, it is clear that revealed preferences have little to do with, let alone be equal to, actual choice outcomes.

It seems that the tug of war is not over the merits of the two fields--or at least it should not be over that. The questions we must ask are as follows. Can we say that standard economics, whose values are derived from a very narrowly, and rather unrealistically defined theory, is important to the world as an applied science? I suggest that the answer to this is clearly "no." Can we say that neuroeconomics, whose values are derived from experiments in which some aspects of the experiments are in controlled lab environment, is important to the world as an applied science? I suggest that the answer here is clearly a "yes." Thus here we are facing a tug of war of political importance rather than a scientific one. I recommend the merging of the two fields in order to gain a better concept of what "useful" economics should be. Useful economics is one that may be applied to the very creatures that have economic exchanges in real life. Standard economics is a theory without live participants while neuroeconomics works with live participants with little theory for the time being. The two fields combined would provide a comprehensive picture of the agent, whose decisions (both outcome and the process by which those outcomes were reached) drive our economy.

Ceteris Paribus

A key issue leading to the different findings in neuroeconomics is that real agents appear to have inconsistent preferences whereas standard economics requires a rational agent to have consistent preferences. One reason why we may find such inconsistencies stems from the forever present *ceteris paribus* allowance (rule, actually) in standard economics. For example, a person's preferences must not change *ceteris paribus* when presented with identical bundles of choice sets repeatedly. Note that being shown identical bundles more than once implies that something has changed: time passed. Although in theory we may evoke two or more time periods that are completely identical to one another, i.e. a bundle consisting of goods α and β with probability p and $(1-p)$ respectively may remain the same bundle over time, no matter how much time has elapsed between the showings. Thus a rational agent in the ceteris paribus frame of standard economics will indeed be consistent, since there is no reason to choose α in one moment and β in the next moment if nothing else has changed.

The problem with the assumption of ceteris paribus is that in real life such is not possible to evoke. Thus, by definition, experimental economics, which is conducted in real life enduring the passing of time, is not able to ever replicate the economic theories empirically. Looking at it this way, standard economic theories must stand in a vacuum, quite distant from all types of empirical examination, since the basic tenet of ceteris paribus cannot exist in anything empirical. Not only is it extremely important to observe changes during the passing of time in terms of changing preferences and the factors actually responsible for those preference changes, but any passing of time invalidates a theory that assumes time standing still. To see why the tiniest passage of time is so critical in terms of preferences, assume a unit of time to be $t_i \in T$ where T implies all the time available. Time t_0 is the initial time at which the economic choice is made

the first time between the above bundles α and β with probability p and $(1-p)$ respectively. Time is always positive and is one-directionally increasing: $t_1 > t_0$. The changing of time from $t_0 \to t_1$ is substantial, regardless how small it is. During the time in which we move from $t_0 \to t_1$, the earth has turned a tiny bit, the sun has rotated a bit, and all other atoms within the universe have moved a tiny bit, however small that distance may be. Thus in real life it is not possible to duplicate exactly any moment of life, ever! Thus α and β of one moment with probability p and $(1-p)$ respectively is actually α_{t_0} and β_{t_0} in one moment and α_{t_1} and β_{t_1} in the next moment, although their respective probabilities may remain the same.

The difference between α_{t_0} and β_{t_0}, and α_{t_1} and β_{t_1} is thus not capturable in standard economics because the t is irrelevant (expect in terms of discounting where t is a set unit of time with all else remaining ceteris paribus). However, in experimental economics where people experience this time passage, for example, by having a heart beat or taking a breath, the two bundles shown in the two different times are not perceived as identical. In particular, hormonal fluctuations from moment to moment in the human brain affect emotions and the cognitive base (frames and biases) upon which agents make their decisions. Endogenous variables within the decision-making apparatus (i.e. the human brain) change as $t_0 \to t_1$ influencing the expected value of utility to be gained from each option of choice from bundles α and β such that while one, say α, is the rational maximized choice at time zero, β might become the rational maximized choice at time one. This implies that experimentally found inconsistencies—relative to standard economic theories—are not inconsistencies at all but are measurement errors, stemming from the

passage of time, from the perspective of the researchers and not from the perspective of the experimental subjects.

It is important to deliberate on the chemical changes in the brain because the essence of human consumption is based on the chemical state of the human brain at the moment a choice is being made. It is not possible to look at the outcome of these decisions and pretend that a *ceteris paribus* will provide enough stability for the same individual to make the same decision twice in moments passing, even if to the observer the bundles appear to be identical in the two decision-choice tasks. This illuminates the conflict between those economic theorists who equate decision-output with preference and those who do not.

The narrow formulation of economic theories whose models rely upon constraints that are not possible to achieve in human terms might not provide the quality of forecasts and reports that are useful for policy making. Perhaps the recent global financial crisis is a good example of a failure of being able to apply standard economic theories to real life human decisions where emotions are involved.

Revealed Preferences and Exogenous Modifiers

Standard economic theories assume that individual decision-making is based on *calculated effort* and *calculated utility* at all times (Andrew Mas-Colell *et al.* 1995; Oliver E. Williamson 1993; John Quiggin 1993), which we now know from various research results is not the case. Let me quote Camerer, Loewstein and Prelec (2004, 2005) "…there is considerable evidence from neuroscience and other areas of psychology that the motivation to take an action is not always

closely tied to hedonic consequences" (Colin Camerer *et al.* 2004; Colin Camerer *et al.* 2005). Harrison responds by "…this is not what economics assumes at all. We say that choices reveal preferences, on a good inferential day…" (Glenn W. Harrison 2008, page 8). I have discussed the problems with the assumption that "choices reveal preferences" in the previous sections so let me visit what "a good inferential day" may mean in terms of revealed preferences.

It is raining where I am today—may this be "a good inferential day"? Yesterday the sun was out for about an hour; was that a better "inferential day"? More importantly, are the two days equal in terms of what decision I will make and how these decisions will reveal my preferences? If on the rainy day one chooses bundle α and on the sunny day bundle β, will that inform economics in any useful way? If we look at a city's of population on a particular day when half of the city was in rain and the other half in sunshine, and the choices made were 50/50 in terms of the two bundles, can we say anything about the preferences of the residents of this city? Now, if on Sunday I travel on the freeway without any traffic to a store to purchase α of the two bundles, and on Monday I make the same trip but with heavy traffic on the same freeway and this time I chose β, how informative are these two outcomes in terms of my preference? Can we say anything about consistency or inconsistency of one's preferences?

The meaning of "a good inferential day" is much grander than it appears in terms of human decision-making and human preferences. Indeed, whether a day is good or bad may make a huge difference in what the outcome of a particular decision will be and in neither case will the economist be able to say with certainty that she captured the revealed preference of any agent by the agent's choice-outcome. The problem is not resolvable because a choice cannot reveal the

general preference of an agent given the enormous number of variables affecting the agent's preference continuously, many of which are unknown to both the agent and the economist. A particular choice can provide only the agent's momentary preference for the particular good under the specific exogenous (rain, sunshine) and endogenous (relaxed, nervous) conditions for those particular variables (specific hormones that make her enjoy the sunshine, dislike the rain, relax on the freeway with no traffic, and make her edgy after a traffic-laden freeway drive) that partook in that specific decision-making task (choose between α and β).

So what is the policy-maker to conclude using the theory of consumer choice under uncertainty? When it comes to decision-making by a firm whether to manufacture more of α or β, what is standard economic theory going to recommend in the small city above? Harrison suggests that when a subject perceives a good differently from other times, then "one can argue that it is a different task" (Glenn W. Harrison 2008, page 9). Thus Harrison would conclude that the choice between α and β on a rainy day represents a different task from choosing among the same goods on a sunny day. I beg to differ on this point. It is not the task that changed, after all, the choice is still between α and β; nor did the objective value of the goods changed, after all α is still α and β is still β. What changed is the *perceived* value of α relative to β because *ceteris paribus* did not and cannot hold!

What's Your Hormone Got to Do with It?

It is hard to accept that people make decisions in a laboratory setting similarly to how they would make those same decisions in the real world. Harrison points out that the representation of a task in an artificial lab environment is different from a real one. Yet research shows that the

representation of something fake is very real in the mind of an individual. Numerous studies show that both in humans and in monkeys, images or sounds of the real thing trigger the activation of the brain similarly to when the individual is actually doing the real thing. Images of a hand (even if clearly a rubber hand) activate the exact same region of the brain as if the participant's hand itself was really poked (Philip L. Jackson *et al.* 2006; Philip L. Jackson *et al.* 2005; India Morrison *et al.* 2004; Philip L. Jackson *et al.* 2005; H. Henrik Ehrsson *et al.* 2007). Hand to mouth actions in monkeys activate the exact same brain areas as when they simply listen to sounds that are associated with similar actions (Valeria Gazzola *et al.* 2006).

Experiments of the kind used in the laboratory have been taken out to real societies and the results show that not only do people behave similarly in lab environment and real life experiments, but that there is a cultural influence over how an economic choice is made (Joseph Patrick Henrich 2004; Joseph Patrick Henrich *et al.* 2005; Joseph Patrick Henrich *et al.* 2001). The most important aspect of these findings is that "rationality" is dependent on the culture of the beholder and while all humans are rational (by definition this is so because of the forces of the evolutionary process), human rationality is different from the rational agent defined in economic theories.

If economic theory holds, there is only one way to solve a particular problem. The meaning of "rational" has changed over the years but it remains controversial whether it is a term that should be used at all. At one point "rational" meant to be a *Homo economicus*, implying self-maximizing choices in a consistent fashion with continuity such that unrelated alternatives will not change one's preferences. Today we find that humans maximize elements in decision-making

that are not visible if we only look at outcomes—hence looking only at outcomes provides faulty image of incentives and preferences. It is now clear that when humans make a choice between two bundles, the utility they receive first is in a form of a hormonal reward, which allows them to make the choice. Thus the process of the choice itself provides a utility that is not captured by standard economic theories. If this agent receives a greater reward from choosing the option that seems to be non-optimal from the perspective of standard economics, the agent is maximizing her utility from the process and not the bundle to be received. In this case the economist might label this choice "anomalous," even though it is a fully rational and maximized choice from the agent's point of view.

The point of highest importance in decision-outcomes is the hormones of the human brain that fluctuate in the body in response to environmental stimuli. The same exact task will have a different outcome if a particular hormone is in high or low levels in the body—and these hormones change naturally given external environmental and internal changes in the human body. Variations of these hormones are beyond observational possibilities for a theoretical economist. Returning to my hypothetical city discussed earlier, a person will make choices differently based on whether he had heavy traffic or could sail through the freeway on his way to work, if his team won or lost the game, or if he had sex recently or not (Coren L. Apicella et al., 2008; P. C. Bernhardt et al., 1998; J. M. Coates and J. Herbert, 2008; J. Klinesmith et al., 2006; P. H. Mehta et al., 2008; P. H. Mehta and R. A. Josephs, 2006; J. R. Roney et al., 2007; J. R. Roney and Z. L. Simmons, 2008; G. Saad and J. Vongas, under review--the sample here is not comprehensive). Women will have completely different chemical structures continuously, as part of their menstrual cycle (Jean-Claude Dreher et al., 2007; K. M. Durante et al., 2008; M.A.

Farage and T.W. Osborn, 2008; G.F. Miller et al., 2007; M. Pearson and B.C. Schipper, 2008; I. S. Penton-Voak et al., 1999; I.S. Penton-Voak and D.I. Perrett, 2000). Given any choice task will lead to different economic outcomes given her monthly cycle, his luck on the freeways or the success of his teams with their games (Paul J. Zak *et al.* 2005).

Most recent neuroeconomic research, using hormonal studies, show that the human reward system in the brain prefers to maximize its utility in the currency of dopamine rather than money. It is also clear that most activities translate into chemical processes in the brain, which activate the reward center, evoking an economic system that is completely invisible to economists looking at outcomes. It was a great surprise, and at first often under attack, when it was found (in labs and in field experiments) that humans are willing to punish at a cost to themselves. Why would a rational human chose less money over more money, *ceteris paribus*? Attacks came from all sides, but then as experiments captured the utility of punishing: hormonal reward in the brain, the attacks slowed (Tania Singer *et al.* 2006; James H. Fowler 2005; D. J-F. DeQuervain *et al.* 2004).

Hormonal research shows that indeed, many economic decision-making can be stimulated one way or another by the natural variations of hormonal levels (Paul J. Zak *et al.* 2005; Paul J. Zak *et al.* 2004), or the use of administered hormones that are set to stimulate a particular part of the brain. For example, landmark studies showed that the hormone Oxytocin makes people more trusting (Michael Kosfeld *et al.* 2005) and more generous (Paul J. Zak *et al.* 2007; Angela A Stanton 2007). Oxytocin is manufactured in the human brain in various amounts throughout the day. Environmental stimuli as simple as a salesman tapping a shopper's shoulder to say "how are

you?" may make the shopper release more oxytocin, which then makes the shopper more trusting toward the sales rep. Hormonal variations in the brain have been there throughout human evolution, each with specific roles. Oxytocin, for example, has the role to support communication with strangers as well as to create bond between mother and child at the moment of birth—among many other functions.

Some other hormones of importance are better known from the news or from individual experiences even by laymen. The rush of adrenaline in dangerous situations is well known to assist the person to get out of danger. The same hormone may help the market trader make quick decisions in a quick-action market day, be it a bull or a bear situation. We can find parallels to this and other activities in non-human primates, showing us the evolutionary necessary connection of our hormones to our development and to everyday decision-making.

If a researcher can change the decision-making outcome of a person by the administration of hormones that all people otherwise already have (in other words hormones are not drugs), can we say that decision-making can be modeled without the understanding of the chemical structure of the brain?

Molecular Rationality

Yet interestingly, part of the debate over the separation of standard economics and neuroeconomics is possibly misplaced. Neuroeconomics shows that humans' neurological decision-making systems behave consistent and the tenets of the expected utility theory's four axioms may well stand the times--with the exception of the ceteris paribus requirement. In experimental games with hormonal stimuli, studies find that humans are stimulated similarly and

in the same direction, and the outcome of their decision-making is similarly modified by the hormonal stimuli. Some clever animal experiments show why.

We know that the Orbitofrontal cortex (over the eyes under the orbit of the eyebrows) has neurons that encode actual utility values. Monkeys, for example, with single-neuron experiments in the Orbitofrontal cortex make their decision-choice based on certain numbers of drops of juices they receive. Amazingly, experiments like these lead to the setting up of each monkey's specific utility function based on the clearly identifiable indifference curves it possesses for the juices (Camillo Padoa-Schioppa 2007). A most fascinating study with monkeys showed that they have personal and social values similarly to humans. Images were shown to monkeys and they could choose to look at them for some quantity of juice (the price). The monkeys were willing to exchange juice as pay to see some images, while for other images they were willing to pay with juice to go away. In particular, male monkeys were found to want to pay with juice currency to see the photographed faces of dominant males and the amount they paid for this was more than what they were willing to pay to see female rumps in estrus, while they demanded to be paid a higher juice-amount to be willing to look at photographed faces of less dominant males than they perceived themselves to be (Robert O. Deaner *et al.* 2005). Notice that not only are we able to capture an economic utility function by measuring neuron activity directly in the brain, we are doing so in monkeys; humans are not uniquely beholden to rational choices.

Since it is possible to decipher the exact utility function of an individual given the measure of the currency exchange for goods and services by a single neuron, and since a particular brain cell remains consistent in its choices so long as it is not tricked by varying probability of juice

payments (M. L. Platt, P. W. Glimcher 1999), it is possible to address whether economic theory is capable of predicting a particular decision-outcome. If, for example, we find that the brain sometimes chooses apples and other times oranges in a *ceteris paribus* environment with single-neuron experimenting, then we know that an economic theory requiring consistency will not be applicable. On the other hand, if cells choose consistently under *ceteris paribus* conditions of the environment in a single-neuron experiment, we then know that neuroeconomics has provided support rather than critique of the standard economic theory.

Conclusion

As research is not yet complete even with monkeys, and it has not actually yet begun with humans due to of the obvious logistical nightmare of single-cell experimenting, all we can say for now is that molecularly speaking, every single human is made of the same chemical elements and bonds. It is not going to take hundreds of years for neuroeconomics to find a model that will fulfill the need of economists but we must give this nascent science some room to grow. Wonderful discoveries lie ahead. The science of economics will certainly be more in tune with the versatilities of everyday economics. Economics stands only to gain from the tools of neuroeconomics. Of course, similarly to the standard supply and demand model taught in every introductory economics class, the benefits of this new science accrue to the average and not to each individual. It is likely that while some standard economic theories will be proven wrong, many others will be proven to stand taller than ever.

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