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ECONOMIC AGENCY THROUGH MODULARITY THEORY

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ECONOMIC AGENCY THROUGH MODULARITY THEORY*

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ABSTRACT: Economic agency as a matter of rational decision-making and as a problem of bounded rationality has never gone too far from its earlier formalization in the 1950s. Not that the advancement on this topic is so slow, but the same problem concerning higher level cognition as another general program of cognitive science is not as easy as behavioral studies. This paper will show a parallelism between economic agency and folk-psychological perspective, and in turn will give a short description on how folk psychology is unseparable from modularity theory. In short, then there must be a way to cope with cognition as the black box of economics if we can identify the appropriate level of description of cognitive structure, i.e.: modularity theory.

Keywords: bounded rationality, folk psychology, modularity theory

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> "But the distance is so great between our present psychological knowledge of the learning and choice processes and the kinds of knowledge needed for economic and administrative theory..."(Simon, 1955).

1. INTRODUCTION

Cognition, devoted as the black box of economics (Arthur, 2000) recently has earned more spaces to make more 'realistic' economic agent and agency. Rabin (2002) indicates an agitation from psychological perspective to make mainstream economics psychologically more realistic. He mentioned several names; inter alia, Kahneman, Tversky, Thaler, and more recently Camerer and Loewenstein as the main critics against the mainstream economics that is a legacy of von Neumannesque formalization. Thus, a specific label attached to the new approach to economics is established, known as 'behavioral economics'.

This paper in turn will not move further to sink itself into the debate. Rather, given a more comprehensive review on contemporary economics and contemporary cognitive science, we will neither encourage a search of unified psychological theory of economic behavior nor a complete disbandment of previously established rationality assumption implemented well in many simulational approaches towards economic behavior.

Firstly, we will examine the nature of contemporary rational assumptions of economic theory. This form of higher level cognition is very much complex to deal with in casual terms of more empirically-based methodologies standard in eliminativist programs such as psychophysical procedures, heuristic search, or vision detection, although such work has been initiated through the so-called neuroeconomic programs (Camerer, 2003). At its main core, rational formalization of economic agency will still hold at least for these two reasons:

1. It is mathematically representable with the help of its traditional formalization through game theory, decision theory, and other rule-based traditions (McFadden, 1997).
2. It is open for bottom-up or cross-level[1] explanations so its whereabouts can be more accessible, either domain-specifically or domain-generally.

Secondly, we will give a report on how mainstream economics is deeply involved with folk-theoretical assumptions. This report will be subsequently parallel with domain specificity that is apt to receive wider insights from general programs of cognitive science, and in many parts, detached from domain-general stance that is found to be more difficult to reconcile with the multi-level complexities of cognition itself.

Finally, we will propose some insights we borrowed from modularity theory to which economic agency should be assigned, hence it gains the proper level of explanations and eventually, more explanatory power concerning the multidimensionality and uncertainty of human behavior.

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[1] This term is in accordance to second-order cyberneticians' standpoint that does not tend to describe complex systems in mere hierarchical levels to allow fractal-like similarity emerge out of scale measurement, but instead, emphasize much on the role of rather arbitrary (or bottstrapping) interpretive systems of thought to observe emergent and self-organizing phenomena without explicit reference to scale measurement (Heylyghen, 1997; Rocha; 1997).

2. BOUNDED RATIONALITY

Herb Simon indicates a significant distance between psychological knowledge and economic theory in his preliminary criticism on rational choice theory (Simon, 1955). The distance seems to remain still.

Being rational, according to early rational choice theory, is to maximize the values of pay-off V of specific strategies S that is causally brought by perceived particular behaviors A. Simplest strategy to attain such maximization is maximin rule as follows:

$$\hat{V}(a) = \max_{a \in A} \min_{s \in S} V(s)$$

that is easily representable in strategic formalization such as game-theoretic models.

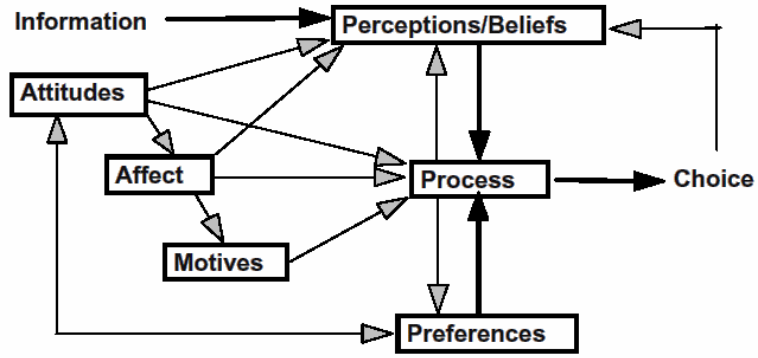

Figure 1. Basic structure of a human economic agent (McFadden, 1999).

This formalization leads to easier-to-measure empirical bases, if the theory only intend to explain the behaviors of agents in a well-defined market with very restricted alternatives. But how well-defined a market or an economic transaction depends on how complete and effective the information about the environment, how powerful the agent is able to reason or compute her strategy, and how she learns from abstract reasoning and experience from time to time. In general, the traditional concept of rationality should be bounded.

Elaboration will eventually come up with these viewpoints:

- through what channel the information is gathered.
- through what mechanism or process the information is capable to generate particular perceived and executed behaviors; and
- how this mechanism or process improves by learning or declines by fatigue and aging.

In short, reckoning the complexity of environment, sensation and perception, central nervous system, proprioception and kinesthesia then back to the environment, as depicted in figure 1, we can depart from questions of how a specific perception can lead to recognized $A^* \subset A$, how the reason comes up with every possible $s \in S$, how corresponding values of $V(s)$ are calculated, and how a recognized or perceived $a \in A^*$ is executed.

2.1. KT-man

Based on previous formalization of rationality, seminal work of Kahneman and Tversky (1979) captures the empirical facts on many economic phenomena into the so called 'prospect theory'.

Instead of relying the strategies of each agent on maximin or probabilistic solution, KT-man inherently has a unique deviation called marginal sensitivity. Traditionally, pay-off value is considered to be expected value for assumed continuous probability distribution $P_a(s)$ that in turns will give mixed strategies as follows $\hat{V}(a) = \max_{a \in A} V(s_a) P_a(s)$.

But this is not always the case.

In prospect theory the expected pay-offs are valued by $P^*_a V(s_a\text{-}r)$, where P^* is a function which weights probabilities nonlinearly, overweighting probabilities below some value or so and underweighting larger one. The value function $V(s_a\text{-}r)$ exhibits diminishing marginal sensitivity to deviations from the reference point r, and an effect of reflection appears. The expected pay-off value can now be convex for losses [$V(s_a - r) > 0$ for $s < r$] and concave for gains [$V(s_a - r) < 0$ for $s > r$].

In finance, prospect theoretical phenomenon appears in the problem called 'the equity premium' (Camerer, 1998), as a result of comparison of returns of stocks and bonds. In 'normal' stock markets, average return of stock is much higher than bond, giving a way to measure risk for investors. According to mainstream economics, investors must be extremely risk-averse in order to gain such high premium of stock market, but they usually do not. Instead of taking a certain return from bonds, investors tend to engage in riskier choice, expecting higher return from stocks regardless the fact that people are easier to lose money in stocks. The assumptions from expected utility theory do not hold.

This *risk-seeking* behavior is not necessarily irrational but it is important for analysts to recognize the asymmetry of human choices (Bernstein, 1996). There is perfect channel of information, but in turn it will lead to completely complex procedures to determine perceived and executed behaviors. As a result, KT-man is not a general framework compared to rational choice formulation. Instead, it performs some *ad hoc* models to capture many peculiarities in people's economic behavior. Therefore we argue that there must be a lower level explanation of economic rationality instead of merely behavioral analysis.

2.2. GP-man

Genetic programming (GP) has been an influential paradigm in modeling decision-making mechanism since the birth of bioinformatics. Its application to decision theory is an inspiration from its great success in explaining many biological phenomena.

A proponent of this approach is Edmonds (1998) who evolutionary characterizes an economic agent according to these following main principles:

- Represent the agent by a whole evolving population of genes corresponding to one of its alternative models
- Populations of agents are thus modelled as populations of evolving populations
- Base the fitness function on either its error in modeling known past data or the utility the agent would have gained in the past if she has used this model but also with other factors such as the size of model and its predictivity
- Restrict the variation operators so towards an exploitative learning process (generalization, specialization, averaging, combining, and mutating)

- Give the agent limited inferential ability to use its best model to choose its action.

In short, too many background assumptions (evolutionary change of human cognition, inferential ability, calculation of fitness function) involved in this general and macro model as shown in Figure 2.

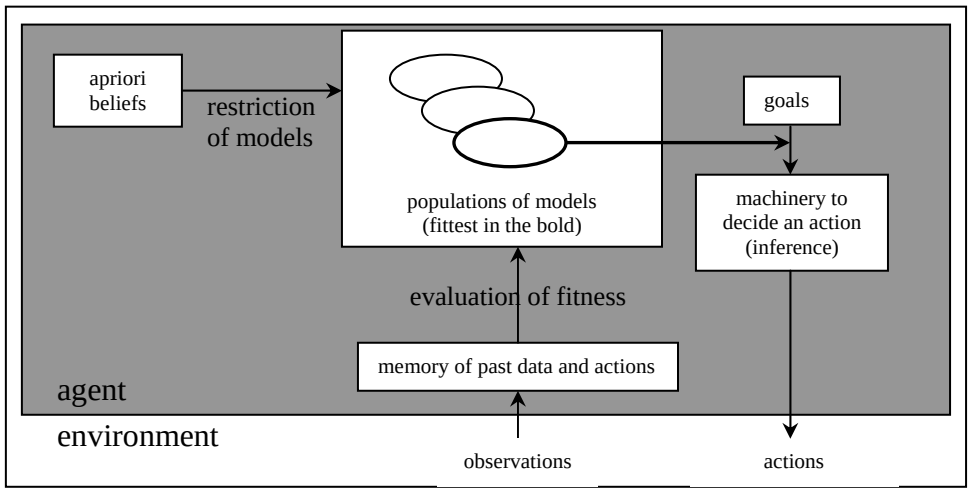

Figure 2. Basic Structure of a Simplified Economic Agent (Edmonds, 1998).

The criticisms soon appear concerning those background assumptions. In our opinion, Darwinian evolution really has a possibility in neurological development, e.g.: neural darwinism (Edelman, Tononi, 2000). But once a specific abstract reasoning contained in cognition, viz. economic rationality, even if it involves many agents in entire population, the mechanism, at least in higher level cognition does not follow simple random mutation and environmental selection. As Dennett (1995) puts it in his attack on meme (a.k.a. evolutionary entity of cognition), what is preserved and transmitted in cultural, hence including economic evolution is *information* – in a media-neutral, language-neutral sense.

Subsequently Dennett adds that such mutation Edmonds tries to apply in his rational model may be directed by purposeful human decision-making among competing cultural alternatives, rather than being simply random choices as expected by Darwinian theory. This is one of the interpretations of what Lamarkianism means, with all of its negative connotations that in turn, will not perform a biological evolutionary mechanism at all.

Hereby a notion of GP-man as an *homo economicus* seems to lose the appropriate meaning of metaphor between biological and rational change.

No matter how far the background assumptions are taken to, the general formalization of economic agency does not leave von Neumann's basic model. And in more general form – that is, not restricted on economic rationality but in every aspect of human reasoning or human's theory of mind in anticipating each other – this includes another field of cognitive science researches and disputes known as folk psychology.

3. FOLK PSYCHOLOGY

Many behavioral analyses give much concern on simple stimulus-response mechanism along with its modifications. In addition, parallel with the basic idea of domain specificity, early formalization

of rationality gains its cognitive background assumption from the so-called 'folk psychology' or the common understanding of mental states (Goldman, 1993), usually deals much with desires, beliefs, preferences, and many other terms that are very closely related to formalization of rationality.

There is some proposition from eliminativist (Churchland, 1980) that the term is just like phlogiston or caloric fluid, that it will eventually disappear along with lower level advancement in cognitive science. This is just the case when we observe through the looking glass of neuroeconomic programs.

Regardless the facts that such eliminativism can lead to wrong framework – since there is no exact way to relate economic behavior to action potentials of neurons studied by psychophysics (Edelman, Tononi, 2000) – to be honest, the idea of folk psychology was derived from philosophical assumptions, or very higher level explanation of cognition that sometimes loses its connection with biological realism. For example, von Erckhardt (1994) considers folk psychology to consist, at a minimum, of (a) a set of attributive, explanatory and predictive practices, and (b) a set of notions or concepts used in those practices; very much close to the primitive terms required by rationality formalization.

In turn, folk psychological states can be a way of trying to make sense of what is going on in the black box of other people's minds (Bermúdez, 2003). Analog to what has been going on in particle physics, beliefs and desires are explanatory constituents very much similar to observable behavior in, say, subatomic particles that are postulated to make sense of observable effects.

Further, looking at folk psychology is dealing with two dominant approaches: theory-theory, as opposed to simulation-theory.

3.1. Theory-Theory

In theory-theory paradigm, some sort of 'knowledge structure' – typically a body of rules or principles or propositions – serves to guide the execution of the capacity to be explained. These rules or principles or propositions are often described as the agent's 'theory' of the domain in question (Stich, Nichols, 1992).

In some cases, the theory may be partially accessible to consciousness; the agent can tell us some of the rules or principles he is using. More often, however, the agent has no conscious access to the knowledge guiding his behavior. In short, she does not know that she knows. The theory is 'tacit', following the earlier findings of Chomsky, Fodor, and many others who attach themselves in modularity programs (see section 4).

In details, a body of knowledge is theory-like if it has (1) an interconnected ('coherent') set of concepts, (2) a distinctive set of ontological commitments, and (3) a causal-explanatory network.

In many ways, such paradigm can explain many things – we ourselves are in such theory if such theory exists at all. As children get older – folk psychology deals much with language acquisition of infants along with its pathologies such autism – they master more and more of the principles of folk psychology, gain more theories. What is so unsatisfactory of this stance is how those knowledge structures can be assembled from tinier pieces because taking beliefs and desires as atomic constituents will lead to infinite possibilities, and again, *ad hoc* solutions as Stich and Nichols (1992) themselves puts it:

"By itself, of course, the theory-theory would not enable us to predict the data, since the theory-theory does not tell us anything about the order in which the principles of folk psychology are acquired."

3.2. Simulation-Theory

In this paradigm, using some pretense mechanism, knowledge structure of folk psychology is acquired through some off-line simulation.

The notions are clear, especially against the theory-theory paradigm: that there is no such tacit theory, no evidence to support the suggestion that we have such knowledge and some evidence to suppose that we do not. It is more likely, say simulationists, that these abilities are simply encouraged by the 'innate capacity to simulate others'.

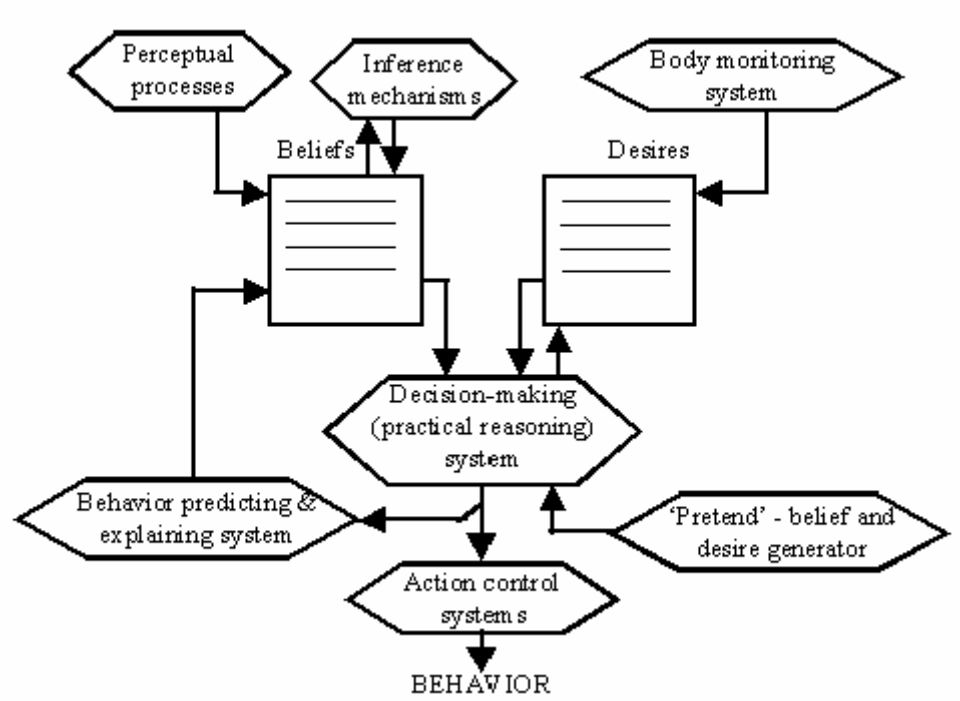

Figure 3. Folk-theoretical diagrams in which both simulational and tacit theory are represented. See Figure 1 and 2 to see parallelism between formalization of economic rationality and folk-psychology (Stich, Nichols, 1992).

All versions of the simulation theory have something in common, that is when we predict the behavior of another person, or of ourselves far in the future, the mechanism which governs the daily interaction of our beliefs and desires, the practical-reasoning mechanism, is disengaged from its actual inputs, or to put it bluntly, from external stimuli and from our own salient beliefs and desires. At the same time, this mechanism is disconnected from the action controllers, the mental mechanisms responsible for a decision-to-behave being translated into actual behavior (Arkway, 2003).

Operating 'off-line' in this term, is that the decision-making mechanism is fed pretend-input in the form of those beliefs and desires we 'imagine' we would experience ourselves if we were in the same situation of the person whose behavior we are about to predict. The practical reasoning mechanism then processes these pretend inputs and a pretend decision-to-behave is generated. This pretend decision-to-behave is transformed into the prediction of behavior.

Simulationists are not explicit about the kind of explanations produced by simulation. Since the simulation theory is founded on the premise that there is no body of internally represented commonsense psychological knowledge, and consequently no laws in which it is represented, appealing to the covering law model the same way tacit theorists do is not a gateway into explanation.

What simulation needs to do is a causal account of folk psychological explanation whose satisfaction conditions either involve simulation essentially or, if not, at least compatible with simulation as an heuristic device for picking out what is the most likely to be the correct explanation.

4. MODULARITY

What seems to disappear from folk-psychological assumptions is the absence of the clarity of the so-called postulated subatomic particles of folk psychology, i.e.: beliefs and desires.

Either tacit or simulational, both departed from the same source, the notion of modularity, that the mind is made up of genetically specified, independently functioning 'modules' (Fodor, 1983).

Unlike beliefs or desires, the modules are considered to be hardwired (not assembled from more primitive processes), of fixed neural architecture (genetically specified), domain-specific (a module computes a constrained class of specific inputs bottom-up, focusing on entities relevant only to its particular processing capacities), fast, autonomous, mandatory (a module's processing is set in motion whenever relevant data present themselves), automatic, stimulus-driven, and insensitive to central cognitive goals.

A further characteristic of modules is that they are informationally encapsulated. In other words, other parts of the mind can neither influence nor have access to the internal workings of a module, only to its outputs. Modules only have access to information from stages of processing at lower levels, not from top-down processes (Karmiloff-Smith, 1992).

The bottom-up processes here can give us a possibility to build more elementary viewpoints differed from beliefs and desires.

4.1. Modules

Speaking of modules practically means referring to mental structures or components of the mind that can be invoked in order to explain various cognitive capacities.

Very roughly, this means that modules are dedicated to solving restricted classes of problems in unique domains (Samuels, Stich, Tremoulet, 1998), highly related to two fundamentally different sorts of mental structure: (i) sometimes it is used to refer to systems of mental representations following those works of Chomsky on generative grammar; (ii) on other side the term is used in order to talk about computational mechanisms that is deemed to be classical architecture of cognition as those of Newell and Simon.

For instance, the claim that there is a vision module implies that there are mental structures which are brought into play in the domain of visual processing and are not recruited in dealing with other cognitive tasks (Pylyshyn, 1999).

But soon, such specific modules are found to be dilemmatic, for instance, Pylyshyn's impenetrability of visual processing in terms of the so-called 'early vision' (Marr, 1982) is so vague whenever one wants to determine its limitation. This seems to be the same case of Fodor's peripheral modularity. Input systems (those responsible for perception and language processing) and output systems (those responsible for action) are plausible candidates for modularity, but not 'central systems' (those systems responsible for reasoning and belief fixation).

Steven Pinker, has suggested that not only are there modules for perception, language and action, but there may also be modules for many tasks traditionally classified as central processes.

Apparently, instead of seeing it as peripheral modules, based on biological evidences, Pinker certainly sees many modules appear in central system – or central nervous system shaped by evolution – including intuitive mechanics: knowledge of the motions, forces, and deformations that objects undergo; intuitive biology: understanding how plants and animals work; intuitive psychology: predicting other people's behavior from their beliefs and desires; and the self-concept: gathering and organizing information about one's value to other people, and packaging it for others (Pinker, 1994). We can see clearly that Pinker's such modules are found to be ubiquitously implemented in folk psychology, albeit the difficulties to find more elementary conditions. At least through this stance, bottom-up processes are more plausible.

It is not yet decidable, if at all, which paradigm is going to take the lead, or we should wait for another turn of Kuhnian scientific revolution that allows one of those two sides dead. But implementatively, the notion of modules can give us way to construct plausible cognitive computational architecture, especially for the purpose of explaining economic rationality.

4.2. Cognitive Architecture

Finding an implementative way according to the modularity theories is dealing with another bigger battle, which is between domain specificity that has been the entire background assumption of this paper, and domain generality that does not allow cognition to be separated into many seemingly independent constituents.

But as Fodor and Pylyshyn (1988) brightly noted – despite their difficulties to find appropriate ways to 'separate' modules – that we can assemble two major stream of cognitive architecture into one single paradigm.

Since the development of the first artificial neural network, the idea of distributed processing enjoyed a victory in the battle against its symbolic and serial counterpart. In defense of connectionism or distributed processing, Elman and Bates say that no one really understands the limits and capabilities of non-linear dynamical systems that are allowed to happen by connectionist architecture; but perhaps, someday it will be established, and therefore parallel distributed processing is no complete scientific humdrums or even wrong scientific enterprise (Elman, Bates, 1993).

Probably, the best way to resolve the unknown limitation of connectionist architecture is to accept Fodor and Pylyshyn's suggestion to put some restraints to connectionist architecture, to put it as an implementative method for 'classical' or symbolic requirements. From neuroscientific and psychological viewpoints concerning the nature of consciousness, this 'classical' argument finds its

very strong supports (Edelman, Tononi, 2000; James, 1890; Searle, 1980; Simon, 1955), although for some reason, such arguments cannot cover the computational model it encourages such as how really the brain works.

4.3. Early Efforts

Neural networks that learn only one task can have simple architectures and may not need modularity. However, real organisms generally have not one task but many different tasks to accomplish in order to survive and reproduce. Hence, their nervous systems tend to be organized with anatomically and functionally distinct modules.

In biological reality it is the nature that creates network architectures. Hence, it might be interesting to study how modular network architectures may spontaneously arise as part of a process of development in individual networks or evolution in a population of networks.

Unfortunately, such attempts has been developed for very limited purposes: identity and spatial locations (Di Ferdinando, Calabretta, Parisi, 2000), syntactic acquisition (Smolensky, Legendre, Miyata, 1992); although in turn, there is much hope to construct architecture with wider range of purposes. Apart from traditional connectionism, modularity theory is merely serial computing. But if the computing is embedded in a cognitive architecture (partially built, consisting of modules; entirely built, artificial intelligence), then it must adopt serial computing mechanism of any kinds.

Apt to the problem of rationality in economics, what becomes a necessity is an attempt to construct partial building, i.e.: Pinker's intuitive (or commonsense or folk) psychology, and self-concept, based on his descriptive and elaborated work on language acquisition. Rationality thus is not merely a problem of syntax, but it requires much advancement on semantic acquisition and operation, especially in those fields implicitly involved with decision making, e.g.: effects of the media to financial market vaguely indicated by Schuster (2003) as follows:

> "In principle, however, there is the possibility that the media, due to their function of generating selective awareness and selective behavior, induce and reinforce specific market reactions which develop into dynamic interactions afterwards."

In many ways, there is no way to explain this dynamic interaction other than using a modular approach in which human linguistic and perceptional capacities can be grasped proportionally.

This is not an easy – if not speculative at all – thing to do. But some 'evidences from the field' of Camerer and some implicit processes of economic decision-making, may give a direct implication a border between economics and psychology seems clearer, if only there were such well-defined border in this highly complex and adaptive economic system.

> Economic agents bring to their actions not just their preferences and endowments, but also their understanding…. In many of the small, standard problems of economics, we can ignore this. In the larger issues of development and reconstruction, and in constructing an economics for problems of complication and ill-definition, we cannot. We need to take cognition seriously (Arthur, 2000).

5. CONCLUSION

This paper gives a touchstone to which the next research on cognitive mechanism underlying decision making of *Homo sapiens* should be directed.

We give a short description showing that both contemporary theory of economic agency and folk-psychological perspective on cognitive science are on the same side, in terms that they speak in the same language, same terms, hence, same level of description where only generality that differs.

Further, we do not attempt to take the debate between tacit theory and off-line simulation very seriously in this paper, unless, as we expect in the future, the difference between both paradigms can generate a unique consequence from each of them. We only emphasize that folk psychology is an emergent properties of bottom-up processes that occur in the level of modules.

Albeit the complications and debates, modularity theory as a theory of meso-level cognition – based on biological evidences, it is assumedly related to the development of neuron throughout nervous system in infant; based on the contemporary folk psychology, modularity implemented through connectionist architecture can capture human linguistic capabilities – is not only a theory bridging the gap. Instead, we believe, it is a way to move deeper into the black box, untangle it in such a way so there is no reason for economists to be an outsider looking in at the cognitive mechanism as behaviorists do it.

This standpoint gives us a chance to explore this possibility further in more technical way, including the hypothesis of modular time and appropriate perceptual coding that is part of our future works.

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