Embodying rationality

Antonio Mastrogiorgio and Enrico Petracca

Department of Neurosciences, Imaging and Clinical Sciences, "G. d'Annunzio" University of Chieti-Pescara (Italy), Department of Economics, University of Bologna (Italy)

July 2016

Published as: Mastrogiorgio, A. & Petracca, E. (2016). 'Embodying rationality'. In L. Magnani & C. Casadio (Eds.), *Model-Based Reasoning in Science and Technology: Logical, Epistemological and Cognitive Issues*, Springer, pp. 219-237.

Embodying rationality

Antonio Mastrogiorgio[1]

Enrico Petracca[2]

The current notions of bounded rationality in economics share distinctive features with Simon's original notion of bounded rationality, which still influences the theoretical and experimental research in the fields of choice, judgment, decision making, problem solving, and social cognition. All these notions of bounded rationality are in fact equally rooted in the information-processing approach to human cognition, expressing the view that reasoning is disembodied and that it can be reduced to the processing of abstract symbolic representations of the environment. This is in contrast with the last three-decade advancements in cognitive psychology, where a new view on human cognition has emerged under the general label of 'embodied cognition', demonstrating that cognition and reasoning are grounded in the morphological traits of the human body and the sensory-motor system. In this paper we argue that embodied cognition might reform the current notions of bounded rationality and we propose a number of arguments devoted to outline a novel program of research under the label of 'embodied rationality': (1) reasoning is situated as it arises from the ongoing interaction between the subject and the environment; (2) reasoning, not being exclusively a mental phenomenon, constitutively relies on the physical resources provided by the environment; (3) the sensory-motor system provides the building blocks for abstract reasoning, (4) automatic thinking is rooted in the evolutionary coupling between the morphological traits of the human body and the environment.

[1] "G. d'Annunzio" University of Chieti-Pescara, Department of Neurosciences, Imaging and Clinical Sciences, Chieti (Italy). E-mail address: mastrogiorgio.antonio@gmail.com.

[2] University of Bologna, Department of Economics, Bologna (Italy). E-mail address: enrico.petracca2@unibo.it.

The world and reason are not problematical

M. Merleau-Ponty

1. Introduction[3]

In 1976, the still-to-become Nobel laureate in economics and cognitive psychologist Herbert A. Simon wrote these important words: "a person unfamiliar with the histories and contemporary research preoccupations of these two disciplines [economics and cognitive psychology] might imagine that there were close relations between them – a constant flow of theoretical and empirical findings from the one to the other and back. In actual fact communication has been quite infrequent [entailing a] state of mutual ignorance" (Simon 1976, p. 65). It is with a certain embarrassment that after 40 years, notwithstanding a remarkable lip service to the necessity of integrating psychology into economics, and some not negligible effort in that direction, these words have still a quantum of truth.

Scientific exchange between economics and psychology – or, better, between economic psychology[4] and cognitive psychology – still occurs today in a fragmentary, instrumental and fundamentally time-lagged way, mostly inattentive to the current foundational debates on how human cognition works (see, e.g., Rabin 1998). Among economic psychologists, there seems to be no real acknowledgment that in the last 30 years cognitive psychology has been undergoing a true paradigm shift, hinging upon the hypothesis of the constitutive dependence of human cognition from the morphological traits of the human body and its sensory-motor system. A huge amount of theoretical and empirical research has supported this new hypothesis (without any pretension to be exhaustive, among the major works are Varela et al. 1991; Clark 1997; Clancey 1997; Clark and Chalmers 1998; Rowlands 1999; Lakoff and Johnson 1999; Wilson 2002; Shapiro 2004; Noë 2004; Gallagher 2005; Pfeifer and Bongard 2006; Barrett 2011)[5]. This rich *corpus* of research is today identified through the label *embodied*

[3] This contribution is a modified version of an essay published in Italian in the journal *Sistemi Intelligenti* (Mastrogiorgio and Petracca 2015). We would like to thank Professor Lorenzo Magnani for the invaluable encouragement and support. A particularly grateful thought goes to the memory of Werner Callebaut, who first supported us on the way to embodied rationality.

[4] With the term 'economic psychology' we mean that domain of inquiry oriented to study phenomena such as *choice*, *judgment*, *decision making*, *problem solving* and *social cognition*. In this broad definition we include also the so-called *behavioral economics*. However, we remark that there is a significant disciplinary divide between 'psychological' and 'economic' approaches to the topics above, characterized for instance by different experimental practices (Hertwig and Ortmann 2001).

[5] Research in AI also supported this point of view on cognition (see, e.g., Brooks 1990).

cognition, which encompasses slightly different approaches such as *embodied* (strictly speaking) *cognition*, *distributed cognition*, *situated cognition*, *embedded cognition* and *enacted cognition*[6].

In this essay we argue that the theoretical and empirical relationship between economic psychology and cognitive psychology deserves to move beyond an instrumental and time-lagged approach. If this relationship has to be established, as we argue, at the foundational level, it has to unavoidably take into consideration the implications of embodied cognition for economic psychology. The notion that has historically constituted the privileged interface for exchanges between economics and psychology is the notion of economic *rationality*. Thus, rationality shall be our focus domain in order to inquire into a new foundational debate in economic psychology. In particular, within rationality studies in economics, our focus will be on the notion of *bounded rationality*. This choice is founded on specific and fundamental reasons. First, Herbert A. Simon, who first introduced the notion of bounded rationality in economics, was both an economist and a cognitive psychologist, founding father of the approach to cognitive psychology called *cognitivism*, object of serious critiques from embodied cognition. Furthermore, far from being a piece of archaeology, bounded rationality still constitutes the bulk of the most important developments in economic rationality. The recent notions of economic rationality stem from, as we shall see, Simon's original notion of bounded rationality, which still influences, both directly and indirectly, knowingly and more often than not unknowingly, all the theoretical and experimental productions in the fields of choice, judgment, decision making, problem solving, and social cognition in economics.

To the objective of setting the ground for a new foundational dialogue between economic psychology and cognitive psychology this essay is structured as follows. Section 2 offers a panorama of the main contemporary threads of inquiry into economic rationality, particularly emphasizing their Simonian roots. Section 3 is devoted to review the main (and various) conceptual points of embodied cognition, assessing their potential importance for economic rationality. In this essay, we use the label *embodied rationality* to convey the view of economic rationality as reformed in the light of embodied cognition.

2. State of art in economic rationality

The notion of rationality in economics has gone through a quite stylized historical development, originating from the concept of 'classical' rationality seen as the individual's ability to make optimizing choices (i.e., choices that maximize a function of interest, typically what is called 'utility',

[6] For a panorama on these different labels and their theoretical interconnections see Goldman and de Vignemont (2009), Kiverstein and Clark (2009), Fischer (2012).

given the satisfaction of consistency criteria in individual preferences) subject to exogenous constraints (see Blume and Easley 2008). Against this background, Simon introduced the notion of *bounded rationality* as a radical conceptual shift, meant to provide an altogether new framework for economic rationality (Callebaut 2007). By using the well-known metaphor of 'scissors' is probably the most suitable way to convey the nucleus of novelty of bounded rationality. As Allen Newell and Simon himself claimed (Newell and Simon 1972, p. 55): "[j]ust as a scissors cannot cut a paper without two blades a theory of thinking and problem solving [i.e., a theory of rationality] cannot predict behavior unless it encompasses both an analysis of the structure of task and an analysis of the limits of rational adaptation to task environment". According to this definition, the psychology of the individual on the one hand, and the environment in which the individual is embedded on the other hand, represent two necessary theoretical requirements – two blades of scissors – to develop a theory of rationality. In this way, continuing with the metaphor, the scissors "have cutting power […] only when both blades operate" (Bendor as quoted in Callebaut 2007, p. 78), that is to say, the two cores of rationality must be studied in conjunction. Alternatively, one can say that individuals and environments represent a single analytical unit.

This notion of bounded rationality has typically suffered from distorted, mostly diminutive and instrumental interpretations, forcing Simon himself, from time to time over the decades, to reaffirm the true revolutionary intentions behind the notion. In particular, the greatest misunderstanding over bounded rationality is related, as Gigerenzer and Goldstein (1996) point out, to a partial view of the scissors argument; indeed, many economists have equated, mistakenly, bounded rationality with the view of humans as 'limited' information processors. In this view, bounded rationality is reduced to just one blade of Simon's scissors. The lack of environment as key variable in the rationality framework has entirely expunged the adaptive dimension of rationality, which has been thus reduced to a static notion. Not by chance, it has been economists' reductionism to bring the revolutionary nucleus of bounded rationality into line with the framework of classical rationality, seen as optimization under constraints (see, e.g., Conslik 1996; Rubinstein 1998). But the environment is a necessary requirement for bounded rationality because, as Gigerenzer and Gaissmaier (2011, p. 457) point out, if one looks only at cognition, one is not able to understand when and why reasoning works or, alternatively, fails. In this regard, Callebaut (2007, p. 81) emphasizes that "[bounded rationality's] significance turns not on absolute cognitive levels, but on the difference between cognitive resources and task demands", that is, it turns on in terms of difference between cognitive abilities and environmental issues. This 'difference' engenders the adaptation process that is mostly visible when

individuals use 'satisficing'[7], rather than 'optimizing', criteria for making decisions. This focus on heuristic rules for judgment is probably the most significant and revolutionary aspect of Simon's new paradigm. In accordance with this revolutionary nucleus, the emphasis on heuristics has been the hallmark of the most recent notions of rationality, as we are going to discuss in what follows.

2.1 Heuristics and biases approach

The research program in *heuristics and biases*, founded by Daniel Kahneman and Amos Tversky in the 1970s, has today gained such wide consensus in economics[8], so as to earn Kahneman the Nobel Prize in 2002. This research program builds on the possibility of experimentally identifying a positive model of human behavior that violates some normative requirements of rationality; in particular, these normative requirements are based on the assumption that individuals are able to properly use formal logic and probability calculus (in particular Bayesian probability, see Oaksford and Chater 2007) in order to formulate correct judgments. In the *heuristics and biases* program, heuristics play a central role, in so far as people's reliance on them for judgment is at the root of systematic and factual violations of rationality canons. Heuristics are therefore the main source of systematic errors (*biases*) in judgment formulation (Kahneman et al. 1982; Gilovich et al. 2002). Over decades, a large number of heuristics and cognitive biases has been experimentally identified (Kahneman 2003). In order to explain the cognitive dynamics related to the use of heuristics, Kahneman identifies two types of cognitive process (*dual-system hypothesis*): on the one hand, the so-called System 1 is fast, automatic, emotional and involves unconscious aspects; on the other hand, System 2 is slower, deliberate, analytical and relies on conscious evaluations. System 1's imprinting over heuristics would explain in the end why humans make systematic errors in judgment (Evans and Frankish 2009; Kahneman 2011). The ability to use intentional reasoning (based on System 2) in order to formulate correct judgments would emerge only after the automatic responses (System 1-based) are suppressed. The Cognitive Reflection Test (CRT) (Frederick 2005) has been developed accordingly as a measure of humans' ability to suppress automatic responses in favor of intentional and conscious reasoning. In this perspective, the very nucleus of intelligence (conducive to rationality) would consist in the ability to control the dual-system dynamics.

[7] *Satisficing* is a neologism coined by Simon (1956), standing for the synthesis of the words *satisfying* and *sufficing.*

[8] This is mainly because the heuristic and biases approach is the theoretical foundation to *behavioral economics* (see Heukelom 2014).

2.2 Ecological rationality

An alternative research program in economic rationality, definitely critical of Kahneman and Tversky's *heuristics and biases*, is *ecological rationality*, developed by Gerd Gigerenzer and his research group. Gigerenzer explicitly claims that Kahneman's view stems from an incautious exegesis of Simon's work. In particular, Gigerenzer criticizes Kahneman for having embraced the wrong prevailing interpretation of bounded rationality as cognitive limitations in information processing (just one blade of the scissors), thus not paying any attention to the role of the environment. The *ecological rationality* research program is thus intended to restore Simon's original idea that cognitive resources and environmental demands represent an analytical unit.

Heuristics are, once again, the core of the analysis. Challenging the *heuristics and biases* approach, according to which heuristics are the source of judgment errors, *ecological rationality* looks at heuristics as *fast and frugal* rules able to reliably provide choice criteria in different situations. The main hypothesis of *ecological rationality* is in fact that each heuristic stems from an adaptive process to a specific environment (Gigerenzer and Gaissmaier 2011, p 456), and thus, accordingly, that heuristics allow comparatively better judgments (even with respect to the 'rational' rules of logic and probability calculus) when they are used in their own specific original environment (Gigerenzer and Brighton 2009). Heuristics under this point of view compose an *adaptive toolbox* (Gigerenzer and Selten 2002), which is the resultant of evolutionary processes (Barkow et al. 1992) and provides humans with adequate tools for accomplishing specific tasks.

Ecological rationality rejects the assumption that humans are 'Bayesian statisticians' – an assumption that would justify the use of normative standard of logic and probability for judgment assessment (as in Kahneman's view) – and posits that judgment's rationality can only be evaluated on the basis of which specific heuristics are chosen to accomplish specific tasks. Notice that *ecological rationality* does not reject the existence of errors in judgment: it simply posits that the source of errors does not lie in the cognitive limits of the subjects, but stems from the mismatch between heuristics and the environment in which they are used.

The panorama described in the two sections above is that of 'rationality wars' between Kahneman and Gigerenzer (Samuels et al. 2004), whose intensity shows no sign of abating. The research program in *embodied rationality* that we introduce in what follows, is sympathetic with ecological rationality regarding the necessity of following Simon's authentic view but, as we are going to discuss, it shall point out that *ecological rationality* is still decisively tied to a limit (if considered from today's standpoint) of Simon's framework: the 'cognitivist' view of cognition. Thus, *embodied*

cognition is meant to amend what is still unsatisfactory in the cognitive psychology foundations of *ecological rationality*[9].

3. Toward a theory of embodied rationality

3.1 Cognitivism and rationality

Technically, the 'cognitivist heaven' in which Simon placed bounded rationality is founded on the *physical symbol system hypothesis*, namely the idea that human cognition works through internal (i.e., mental) symbolic representations of the external environment processed by a centralized (i.e. in-line[10]) analytical system (Newell and Simon 1976). Residua of these cognitivist foundations are usually taken for granted – when acknowledged – by economic rationality threads of research; in this regard, we maintain that a significant shift in economic rationality can only pass through the explicit acknowledgment, questioning and overcoming of the residual cognitivist stances; in other words, this means following in rationality studies the same path followed by cognitive psychology in its progressive detachment from cognitivism (Haugeland 1978; Johnson 1997). Erkki Patokorpi (2008) has inaugurated this task, by acknowledging the so-called 'Simon's paradox', that is, the fact that the 'bounds' of human reason are represented through an 'unbounded' tool (i.e. the digital computer), and by identifying this heritage into contemporary rationality theories.

The residual cognitivist foundations of current theories of rationality are evident in both the *heuristics and biases* and the *ecological rationality* research programs. As already mentioned, in the *heuristics and biases* approach heuristics are just mental phenomena, lacking any coupling with the environment; using the computer metaphor, somewhat foundational to the cognitivist paradigm, heuristics would be like bugged computer programs[11]. On the other hand, despite *ecological rationality* puts a decisive emphasis on the cognition-environment coupling, heuristics, conceived as formal rules for information processing, are implemented through 'computer programs', explicitly in the footsteps of Simon's tradition (Gigerenzer et al. 1999).

[9] A further and recent thread of research in rationality is that of *grounded rationality* (Elqayam and Evans 2011). Grounded rationality conceives rationality as a set of rules embedded in specific epistemic communities. In this perspective, rationality is at first a relative and descriptive notion that, once institutionalized in a community, acquires a normative status.

[10] This assumption has later been relaxed, for instance by models of parallel processing.

[11] Fiori (2011) states that the 'dual-system' foundation of *heuristics and biases* (see Section 2.1) represents a break with respect to Simon's cognitivism. This interpretation is – according to us – not conclusive because Simon himself saw cognitivism as perfectly compatible with dual-system theories (see, e.g., Vera and Simon, 1993).

In the following sections, we shall discuss the ways in which the new point of view of embodied cognition can provide alternative foundations to the notion of bounded rationality. Two caveats are however in order here. Firstly, as we mentioned in the Introduction, *embodied cognition* is far from being a stable corpus of theories (see, e.g., Wilson 2002 that identifies 'six views' of embodied cognition). Due to this theoretical plurality, this essay does not focus on or embrace a specific view of embodied cognition, but rather brings out a number of new foundational possibilities. The second *caveat* is related to the fact that many topics that we discuss here may not sound so new to scholars accustomed to cognitive psychology. However, our assumption here is that there are good reasons to think that these topics might sound interesting to many scholars involved in economic psychology, making them worthy of being discussed here.

3.2 An enriched environment

In the next two subsections, we discuss two approaches within embodied cognition, respectively *situated cognition* and *distributed cognition*, important because they provide a new point of view on the role of environment in cognitive psychology. Our specific contribution here shall be to identify how these two points of view can help to rethink the notion of 'decision-making environment', so central in economic psychology.

3.2.1 The limits of syntactic representationalism and the first/third-person distinction

Distinctive evidence of the cognitivist heritage in contemporary investigations on rationality – as shown in particular by ecological rationality – lies in the notion of decision-making environment as expressed through the notion of *structure of the task environment* (see Simon 1956; Bullock and Todd 1999). In particular, ecological rationality categorizes environments according to syntactic 'structural' traits such as information redundancy, rarity, etc. (see Rieskamp and Dieckmann 2012; McKenzie and Chase 2012). This characterization tends to underestimate the role of the environments' semantics: a playground or a battlefield might result in the same syntactic representation. In this framework then, the adequacy of heuristics to a particular environment is measured by the *ecological correlations* of syntactic structures between heuristics and environments (e.g. McKenzie and Chase 2012)[12]. A perspective that goes beyond the syntactic view of

[12] We have to remark an important incongruence between the theoretical assumptions *of ecological rationality* and the actual framework through which these assumptions are implemented. A fundamental assumption of ecological rationality is that heuristics and environments are 'content-specific' and, as such, semantically characterized. But, this

environments replaces, at a first level of approximation, the structure of the task environment – in Simon's or Gigerenzer's understanding – with that of *context*, according to which the environment presents a markedly semantic dimension. This shift has already been accomplished by economists, especially behavioral economists, who claim the necessity of running experiments in semantic environments, very similar to real-life contexts (Loewenstein 1999).

However, recent cognitive psychology claims that this 'contextual turn' is not enough. *Situated cognition* denies that the notion of 'context' is adequate to account for the phenomena of human cognition, and claims that it should be replaced by the more radical notion of 'situation' (see e.g. Rohlfing et al. 2003). In particular, while contexts are founded on the conflation between 'first-person' and 'third-person' representations, that is, between subjective and objective descriptions of environments, situated cognition refuses this unwarranted conflation (Clancey 1993)[13]. The notion of situation builds on the centrality of action: action, and in particular inter-action between subjects and environments, makes first-person representations irreducible (basically because the outcome of a process of interaction is not pre-specifiable) (Greenberg 2001). The emphasis on the notion of interaction leads some researchers even to reject the ontological distinction between first and third person, and to propose a completely new ontological view in which the notion of interaction is autonomous[14] (Agre 1993).

The distinction between first and third person produces major implications for the conceptualization of the decision-making environment: there is no way to determine *a priori* which specific trait of the environment will be 'salient' for decisions. The attempt of amending the syntactic view of decision-making environments just by adding more semantic content is therefore inadequate because it would lack the essential interactionist perspective. Real-world interactions cannot even be substituted by surrogate interactions, as conceived for instance in game theory and experimental economics, where interactions lack any material and ostensive dimension. Consider, for instance, how the notion of 'learning' is framed in game theory (see, e.g., Fundenberg 1998).

A radical alternative to the poorly semanticized and non-interactive rationality frameworks has been proposed by the research program in *naturalistic decision making* (Klein 2008). Naturalistic decision

semantic dimension is practically lost when heuristics and environments are respectively characterized as rules and stylized structures.

[13] This point was at the center of a debate in 1993 between Simon (with his colleague Alonso Vera) and *situated cognition* scholars. Vera and Simon argued that situated cognition's arguments were not sufficient to legitimately claim for a re-foundation of cognitive psychology (see Petracca 2015).

[14] A perspective in which the ontology of relations outranks the one of subjects/environments can be found, for instance, in the 'dynamic systems' approach to cognition.

making rejects the idea that decision making can be 'simulated' at all: real-life decisions are therefore considered the only legitimate place to investigate into human rationality[15].

3.2.2 A 'distributed' and 'extended' reasoning

Cognitivism's footprint on current economic rationality is also visible in the persistent interpretation of the task environment as a set of constraints. In the ecological rationality interpretation, for instance, these constraints exert a selective pressure on heuristics, which in response adapt to them (Bullock and Todd, 1999). The cognitive psychology approach called *distributed cognition* rejects the idea of the environment as a mere set of constraints and proposes a radically different perspective, summarized by the words of Suchman that the "world's independence of [our] control is not an obstacle to be overcome but a resource to be made use of" (Suchman 1986, p. 13). In order to re-define the role of the environment in cognition, cognitive psychology has had to contend, even linguistically, with the theoretical limits imposed by the dualism cognition/environment. An attempt to amend such limits lies in the notion of 'extended mind' (Clark and Chalmers 1998), which represents an attempt to blur the boundaries between what is cognition and what is environment. Both 'distributed cognition' and 'extended mind', challenging the traditional understanding of environments, are meant to cast new light also on the reasoning process.

The central idea is that environments in which humans act systematically provide the resources that can be employed in reasoning processes. Consider the so-called *cognitive artifacts*, that is, physical objects such as a calendar, a shopping list, a computer or even fingers, which are used to support and improve reasoning (Hutchins 1999, p. 126). Cognitive artifacts are mainly used to *off-load* the cognitive load on the environment, thereby making cognitive resources available for other purposes. But the environment is also used for cognitive purposes less trivial than mere off-loading, which involve the very act of 'reasoning'. In this spirit, for instance, Kirsh and Maglio (1994) distinguish between *pragmatic action* and *epistemic action*: the former is devoted to a pragmatic purpose, i.e. to change an environment according to definite objectives, while the latter uses the environment for reasoning. Consider the game of Tetris, specifically studied by Kirsh and Maglio: to rotate figures is an action that players perform in order to facilitate the decision process of where to place figures. The rotation action – conceptually unnecessary for the purpose of the game – is an epistemic action that exploits the environment in order to make the decision process faster and more effective. Another

[15] *Ecological rationality* has tried to integrate *naturalistic decision making* within its own theoretical framework. In fact, Todd and Gigerenzer (2001, p. 382) state that their objective is that of providing a 'content-dependent' framework to *naturalistic decision making*. In spite of their attempt, it seems that they have not fully acknowledged the first- and third- person distinction, implicit in *naturalistic decision making*.

way in which the environment can support reasoning is when material interactions provide otherwise unattainable insights. The value of this kind of environmental interaction was suggested, for instance, by the mathematician Pólya (1957), who recommended the heuristic use of pen and paper to facilitate mathematical reasoning (see also Zhang 1997). With explicit reference to inferential processes, Lorenzo Magnani introduces the notion of *manipulative abduction* (Magnani 2001). A fundamental role in abductive reasoning (i.e. that reasoning process oriented to formulate explanatory hypotheses of observed facts) is played by the so-called *epistemic mediators* (such as diagrams on sheets of paper, etc.) used for hypotheses discovering. Magnani distinguishes between 'thinking about doing' and 'thinking through doing': in particular, the latter characterizes reasoning processes in which environmental interaction serves the purpose of providing information that would not be otherwise accessible to subjects.

These arguments can arguably have a direct impact on economic psychology. They do not only imply conceptualizing the task environment as 'resource' rather than as 'constraint', as it would be natural (and right) to do. Distributed cognition would also provide an altogether new point of view on the economic agent, which could be characterized more as a 'chance seeker' than as the usual 'information processor' (Bardone 2011). More concrete implications of distributed cognition and extended mind for economic psychology can be found at the methodological level. One, for instance, concerns the current practices of experimental economics. Excessive rigidity and standardization of experiments – claimed to be distinctive traits of experimental economics' investigations (see Hertwig and Ortmann 2001) – triggers a sort of 'illusion of control' with respect to actual human behavior[16]. Further, the pervasive mediation of computer screens in experimental economics laboratories, in particular when used to study human interactions, leads us to another consideration. As stressed by Oullier and Basso (2010), an essential component of the interaction among humans relies on the materiality of the interaction. Information conveyed through the body (i.e., through the so-called 'body language') is invaluable to the extent it could not emerge saliently otherwise.

Acknowledging that human-to-human is a specific form of human-to-environment interaction – in fact, as McDermott said, "we are environment to each other" (quoted in Suchman 1987, p. 47) – implies a wider understanding of 'distributedness' (Hutchins 2006). The pioneer of this wider 'distributed' perspective in economics is Hayek (1948). Clark and Chalmers (1998, chapter 9) introduced the concept of 'scaffold' to express how distributed and interactive mechanisms lead to establish supra-individual structures, such as routine and formal and informal rules, able to steer individuals' social action (see also Denzau and North 1994).

[16] It is interesting to recall, on this point, the anecdote reported by Daniel Dennett concerning a child who, not allowed to use fingers for calculations, used tongue and teeth as substitutes (Dennett 1995).

3.3 Rationality and body correlates

3.3.1 Reasoning as simulation and the role of embodied metaphors

The notion of 'procedural rationality' – one of Simon's main intellectual achievements[17] – is fundamentally linked to a 'pragmatic' interpretation of rationality (Harman 1993). In his early work on administrative behavior, Simon (1947) in fact understood rationality as means-ends chains, where the core of rationality consisted in evaluating means' adequacy to reach pre-specified ends[18]. The human cognitive faculties of imagining, planning, predicting things or events that are alien to the current situation (i.e. outside the strict phenomenological dimension of 'here and now') are thus necessary cognitive requirements for the notion of procedural/pragmatic rationality. Beyond emphasizing the importance of contingent cognition (*on-line cognition*), the foundational perspective of embodied cognition is able to shed new light also on non-contingent cognition (*off-line cognition*) (Wilson 2008)[19]. In what follows, we shall consider what embodied cognition is able to say on off-line reasoning in economic rationality.

The cognitive phenomenon of *simulation*, which concerns the exploitation of the sensory-motor system for understanding and reasoning (Jeannerod 2001; Hesslow 2002; Gallese and Lakoff 2005), has been identified as the main mechanism at the root of off-line reasoning (Barsalou 2008; Goldman and de Vignemont 2009). Simulation assumes a central role in contemporary embodied theories because it constitutes the fundamental mechanism through which 'mental representations' and their 'manipulations' (indeed very controversial notions in cognitive psychology) work[20]. Among the different types of emphasis on the role of *modal*[21] dimension in simulation (see Meteyard and Vigliocco 2008), the most radical embodied cognition approach – also known as 'strong embodiment'

[17] Simon (1976) distinguished between 'substantive' rationality, where rationality concerns the outcome of choice, and 'procedural' rationality, where rationality concerns the process of choice. Procedural rationality, in the case for instance of consumers' choice, focuses on how consumers choose and not on what they choose.

[18] Russell and Norvig (1994) import this definition of rationality in the AI framework.

[19] While opponents of embodied cognition typically reduce it to a theory of on-line cognition, Wilson claims that offline cognition is embodied cognition's true testbed (Wilson 2008, p. 330).

[20] Whether the supporters of *situated cognition* underestimate the role of mental representations (in fact representations are almost unessential in their framework), the supporters of the 'simulation' view try to explain the very nature of those representations. This distinction is revealing of the theoretical plurality underlying embodied cognition.

[21] Modal is a representation codified using the sensory-motor system. Conversely, a-modality pertains to representations' independence from the sensory-motor system.

– claims that anything necessary to create and manipulate representations is embodied in the sensory-motor system, and thus it can be identified in terms of *body correlates*. An example of simulative approach to reasoning is Lakoff and Johnson (1999)'s attempt to explain inferential processes through the mechanism of *inference-preserving-cross-domains mappings*, according to which one projects the inferential structure of an original domain to a target domain, usually more abstract. For example, if we say "she is a cold person", the concept of 'cold' (source domain) will be mapped into 'lack of affection' (target domain) (Núñez 2008, p. 337). Therefore the notion of 'cold', which evokes a body dimension, provides the foundations for creating the notion of 'lack of affection', instantiated through a metaphorical process[22]. In this perspective, the morphological traits of the human body play the role of non-arbitrary constraints to the human capability of making abstractions and inferences.

The importance of the framework of embodied cognition to economics can in particular be appreciated when there is an overlapping of topics between disciplines, as is the case with the topic of 'ownership'. Beyond the many 'economic' explanations, ownership has been explained in the embodied cognition framework by emphasizing the determinants of contact and proximity to the owned object (see, for example, Tummolini et al. 2013). By juxtaposing the studies on embodied ownership on the one hand, and ownership-related economic phenomena – such as the *endowment effect* (Kahneman et al. 1991) – on the other hand, answers to many puzzles (Plott and Zeiler 2005) might easily be found. Further on ownership, embodied metaphors play a crucial role. In a recent study, Florack et al. (2014) shows that the physical act of hand washing – one of the most popular embodied metaphors – decreases the endowment effect.

3.3.2 Body correlates and dual-system dynamics

The human body as the ultimate new foundation of cognitive processes and, in turn, of reasoning processes, can also be central in understanding dual-system dynamics in economic judgment (see, e.g., Kahneman 2011). In a recent article, Mastrogiorgio and Petracca (2014)[23] investigate the body determinants of automatic/deliberative reasoning in numerical tasks. They argue that the activation of automatic responses (System 1) is closely dependent on the use of specific numerals (and not 'numbers' as magnitudes). The idea is that, within a given numeral system, such as the common 10-based Arabic system, some numerals (e.g., 1, 2, 5, 10, 100,…) are handled in a faster and more

[22] Notice that the metaphor of 'scissors' itself, used to define *bounded rationality*, is based on this logic.
[23] See also Mastrogiorgio (2015) for further remarks.

automatic way if compared with other numerals of the same system[24]. The literature on mathematical cognition (see Cohen Kadosh and Walsh 2009) shows that the automatic use of specific numerals in numeral systems is dependent by the underlying counting systems. For instance, the 10-based Arabic system relies on the computation method based on the fingers of both hands (see Gibbs 2006). This example suggests that the identification of body correlates underlying automatic behavior in different decision domains can be of fundamental importance to a theory of economic reasoning.

3.4 The body as pivot of the scissors

If the goal that inspires modern rationality studies in economics is the identification of "invariants of human behavior" (as suggested by Simon 1990), then one should suddenly acknowledge that a true invariant in human behavior is the human body. However, Simon's scissors metaphor constitutively rules out the human body, considered as a sort of cumbersome presence. It is somehow ironic that the human body is however right there, both in Kahneman's and Gigerenzer's theories, just because they place so great emphasis on heuristics: a synonym for 'heuristic' is in fact – and of course not by chance – 'rule of *thumb*'. The metaphor of the scissors is, once more somehow ironically, perfectly suited for considering the role of body as theoretical *locus* of connection between cognition and environment: as we discussed above, the two blades have cutting power only in combination, that is to say, the two blades can cut only if there is a pivot that holds them together. This pivot is the human body, which constitutes a material interface between cognition and environment.

It is important to emphasize that in this new perspective the body is a necessary theoretical *locus* for a theory of rationality, and so that it needs to be more than simply 'taken into account'. Many experimental studies already take into account body variables (e.g. temperature, blood pressure, etc.) that affect choices, decisions and judgments. What those experiments lack is however the attribution of a deeper theoretical status to the human body for a theory of human rationality. This is, however, a situation that is goingto be amended (Spellman and Schnall 2009; Reimann et al. 2012; Mastrogiorgio and Petracca 2015).

3.4.1 Policy implications

[24] Wulf Albers (2001), within the *ecological rationality* framework, models heuristic calculation by means of the so-called 'prominent numbers' (i.e., numerals 1, 2, 5, 10 …) in the decimal system. Albers does not however explain why some numerals are processed faster and easier than others.

Some brief consideration, as economists who want to speak mainly to economists, has to be proposed concerning the implications of embodied cognition for policy making. In recent years, research has focused primarily on *nudging*, that is, the idea of designing environments so as to drive individuals' choice toward socially desired outcomes, without modifying the structure of economic incentives and maintaining the freedom of choice (Thaler and Sunstein 2008). The notion of *architecture of choice* refers in particular to the way in which options are presented, in order to encourage socially-desired choices. Experiments on nudging are typically run in real-world contexts, and place a decisive emphasis on the embodied substratum of the architecture of choice. An example of typical nudging advice would be to place healthy foods at 'eye level' in a self-service restaurant, so as to make them comparatively more chosen (Thorndike et al. 2012). In this regard, in a domain that is already implicitly 'embodied', explicitly considering the point of view of embodied cognition can be important in at least two directions: i) theoretically, so as to identify the body as a conceptual *locus* for nudging; ii) operatively, shaping environments in order to enhance their *ergonomics*. Ergonomics is the keyword here: all the environments of choice are ostensive at the human-body scale. Thus, an important objective of embodied rationality is to foster a programmatic link between the disciplines of ergonomics and economics (see also Hendricks 1996).

4. Conclusions

This essay has focused, on the one hand, on the identification of those traits, distinctly cognitivist, characterizing Simon's legacy in current studies on economic rationality; on the other hand, it has proposed new hypotheses to reform those traits in the light of the more recent advancements in cognitive psychology. The starting point of our analysis has been the crucial notion of bounded rationality. As one of the most influential cognitive psychologists, Andy Clark, put it: "we should however distinguish the conception of reason as embodied and embedded from the important but still insufficiently radical notion of 'bounded rationality" (Clark 1997, p. 243, n. 4). This essay has accordingly attempted the 'radicalization' of bounded rationality in the light of the multiple directions suggested by the fertile and varied field of study of embodied cognition. There is much work to do but, for the moment, it has just been important to remark the existence of a plurality of roads.

It is useful to provide a brief summary of the specific ways embodied cognition might reform the notion of bounded rationality, as they have been discussed in this paper. They can be condensed in a few stylized programmatic points:

- reasoning is situated, that is, interaction is the fundamental way in which reasoning takes place: thus, it is necessary to distinguish between first-person and third-person representations of decision environments.
- reasoning is not exclusively a mental phenomenon as humans constitutively use the resources provided by the environment in order to reason; this also means that the environment should be conceptualized as a resource rather than as a constraint;
- off-line reasoning works through simulations that exploit the resources provided by the sensory-motor system, so that sensory-motor experience provides the building blocks of abstraction;
- automatic thinking stems often from the (evolutionary) coupling between some morphological traits of the human body and the environment they were originally fitted to.

We hope these programmatic points to be at the center of future research under the label of *embodied rationality* (see Spellman and Schnall 2009; Mastrogiorgio and Petracca 2015).

5. References

Agre, P. E. (1993). The symbolic worldview: Reply to Vera and Simon. *Cognitive Science*, 17(1), 61-69.

Albers, W. (2001). Prominence theory as a tool to model boundedly rational decisions. In Gigerenzer, G. & Selten, R. (Eds.), *Bounded rationality: The adaptive toolbox* (pp. 297-317). Cambridege: MIT Press.

Bardone, E. (2011). *Seeking chances: From biased rationality to distributed cognition*. Berlin and Heidelberg: Springer.

Barkow, J., Cosmides, L., Tooby, J. (Eds) (1992). *The adapted mind: Evolutionary psychology and the generation of culture*. New York: Oxford University Press.

Barrett, L. (2011). *Beyond the brain: How body and environment shape animal and human minds*. Princeton: Princeton University Press.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, 59(1), 617–645.

Blume, L.E., & Easley, D. (2008). Rationality. In Durlauf, V. S. N. & Blume, L. E. (Eds), *The new Palgrave dictionary of economics*. Basingstoke: Palgrave Macmillan.

Brooks, R. A. (1990). Elephants don't play chess. *Robotics and Autonomous Systems*, 6 (1-2), 3-15.

Bullock, S., & Todd, P.M. (1999). Made to measure: Ecological rationality in structured environments. *Mind and Machines*, 9(4), 497-541.

Callebaut, W. (2007). Simon's silent revolution. *Biological Theory*, 2(1), 76-86.

Clancey, W.J. (1993). Situated action: A neuropsychological interpretation (Response to Vera and Simon). *Cognitive Science*, 17(1), 117-133.

Clancey, W.J. (1997). *Situated cognition: On human knowledge and computer representations*. Cambridge, MA: Cambridge University Press.

Clark, A. (1997). *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT Press.

Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis*, 58(1), 10-23.

Cohen Kadosh, R., & Walsh, V. (2009). Numerical representation in the parietal lobes: Abstract or not abstract? *Behavioral and Brain Sciences*, 32(3-4), 313-373.

Conlisk, J. (1996).Why bounded rationality. *Journal of Economic Literature*, 348(2), 669-700.

Dennett, D. C. (1995). *Darwin's dangerous idea: evolution and the meanings of life*, New York: Simon and Schuster.

Denzau, A.T., & North, D.C. (1994). Shared mental models: Ideologies and institutions. *Kyklos*, 47(1), 3-31.

Evans, J., & Frankish, K. (Eds.) (2009). *In two minds: Dual processes and beyond*. Oxford: Oxford University Press.

Elqayam, S., & Evans, St.B.T. (2011). Subtracting 'ought' from 'is': Descriptivism versus normativism in the study of the human thinking. *Behavioral and Brain Sciences,* 34(5), 233-248.

Fiori, S. (2011). Forms of bounded rationality: The reception and redefinition of Herbert A. Simon's Perspective. *Review of Political Economy*, 23(4), 587-612.

Fischer, M.H. (2012). A hierarchical view of grounded, embodied, and situated numerical cognition. *Cognitive Processing*, 13(1), 161-164.

Florack, A., Kleber, J., Busch, R., Stöhr, D. (2014). Detaching the ties of ownership: the effects of hand washing on the exchange of endowed products. *Journal of Consumer Psychology*, 24(2), 284-289.

Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives*, 19(4), 25-42.

Fudenberg, D. (1998). *The theory of learning in games*. Vol. 2. Cambridge, MA: MIT Press.

Gallagher, S. (2005). *How the body shapes the mind*. New York: Oxford University Press.

Gallese, V., & Lakoff, G. (2005). The brain's concepts: The role of the sensorimotor system in reason and language. *Cognitive Neuropsychology,* 22(3), 455-479.

Gibbs, R.W. (2006) *Embodiment and cognitive science*. New York: Cambridge University Press.

Gigerenzer, G., & Brighton, H. (2009). Homo heuristicus: Why biased minds make better inferences. *Topics in Cognitive Science,* 1(1), pp. 107-143.

Gigerenzer, G., & Gaissmaier, W. (2011). Heuristic decision making. *Annual Review of Psychology*, 62(1), 451-482.

Gigerenzer, G., & Goldstein, D.G. (1996). Reasoning the fast and frugal way: Models of bounded rationality. *Psychological Review*, 103(4), 650-669.

Gigerenzer, G., & Selten, R. (Eds.) (2001). *Bounded rationality: The adaptive toolbox*. Cambridge, MA: MIT Press.

Gigerenzer, G., Todd, P.M., the ABC Group (1999). *Simple heuristics that make us smart*. New York: Oxford University Press.

Gilovich, T., Griffin, D., Kahneman, D. (2002). *Heuristics and biases: The psychology of intuitive judgment*. Cambridge, UK: Cambridge University Press.

Goldman A., & de Vignemont F. (2009). Is social cognition embodied?. *Trends in Cognitive Sciences*, 13(4), 154-159.

Greenberg, S. (2001). Context as a dynamic construct. *Human-Computer Interaction*, 16(2), 256-268

Harman, G. (1993). Rationality. In Smith, E.E., & Osherson, D.N. (Eds.), *Thinking: An invitation to cognitive science*. *Vol. 3.* Cambridge, MA: MIT Press.

Hayek, F.A. (1948). *Individualism and Economic Order*. Chicago: University of Chicago Press.

Haugeland, J. (1978). The nature and plausibility of cognitivism. *Behavioral and Brain Sciences*, 1(2), pp. 215-226.

Hendricks, H.W. (1996). The ergonomics of economics is the economics of ergonomics. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 40(1), 1-10.

Hertwig, R., & Ortmann, A. (2001). Experimental practices in economics: A methodological challenge for psychologists? *Behavioral and Brain Sciences*, 24(3), 383-403.

Hesslow, G. (2002). Conscious thought as simulation of behaviour and perception. *Trends in Cognitive Sciences* , 6(6), 242-247.

Heukelom, F. (2014). *Behavioral economics: A history*. New York: Cambridge University Press.

Hutchins, E. (1999). Cognitive artifacts. In Wilson, R.A., & Keil, F.C. (Eds.), *MIT Encyclopedia of cognitive science* (pp. 126-128). Cambridge, MA: MIT Press.

Hutchins, E. (2006) The distributed cognition perspective on human interaction, In Enfield, N., & Levinson, S. (Eds.), *Roots of Human Sociality* (pp. 375-398). New York: Berg.

Jeannerod, M. (2001). Neural simulation of action: A unifying mechanism for motor cognition. *NeuroImage,* 14(1)*,* 103-109 .

Johnson, D.M. (1997). Good old-fashioned cognitive science: Does it have a future? In D.M. Johnson, D.M., & Erneling, C.E. (Eds.), *The Future of the Cognitive Revolution* (pp. 13-31). New York: Oxford University Press.

Kahneman, D. (2003). Maps of Bounded Rationality: Psychology for Behavioral Economics. *American Economic Review,* 93, 1449-1475.

Kahneman, D. (2011). *Thinking fast and slow*. New York: Farrar, Straus and Giroux.

Kahneman, D., Slovic, P., Tversky, A. (1982). *Judgment under uncertainty: Heuristics & biases.* Cambridge, UK: Cambridge University Press.

Kahneman, D., Knetsch, J.L., Thaler, R.H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *Journal of Economic Perspectives,* 5(1), 193-206.

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science,* 18(4), 513-549.

Kiverstein, J., & Clark, A. (2009). Introduction: Mind embodied, embedded, enacted: One church or many? *Topoi*, 28(1), 1-7.

Klein, G. (2008). Naturalistic decision making. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *50(3)*, 456-460.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. New York: Basic Books.

Loewenstein, G. (1999). Experimental economics from the vantage-point of behavioural economics. *The Economic Journal*, 109(453), 25-34.

Magnani, L. (2001). *Abduction, reason, and science: Processes of discovery and explanation*. New York: Kluwer Academic/Plenum Publishers.

Mastrogiorgio, A. (2015). Commentary: Cognitive Reflection Versus Calculation in Decision Making. *Frontiers in Psychology*, 6, 936. doi: 10.3389/fpsyg.2015.00936.

Mastrogiorgio, A., & Petracca, E. (2015). Razionalità incarnata, *Sistemi Intelligenti*, forthcoming.

Mastrogiorgio, A., & Petracca, E. (2014). Numerals as triggers of System 1 and System 2 in the 'bat and ball' problem. *Mind & Society*, 13(1), 135-148.

McKenzie, C.R.M., & Chase, V.M. (2012). Why rare things are precious: How rarity benefits inference. In Todd, P., Gigerenzer, G., the ABC Research Group (Eds.), *Ecological rationality: Intelligence in the real world* (pp. 309-334). New York: Oxford University Press.

Meteyard, L., & Vigliocco, G. (2008). *The role of sensory and motor information in semantic representation: A review*. In Calvo, P., & Gomila, A. (Eds.), *Handbook of cognitive science: An embodied approach* (pp.293-312). San Diego, US: Elsevier Publishers Limited.

Newell, A., & Simon, H.A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Newell, A., & Simon, H.A. (1976). Computer science as empirical inquiry: Symbols and search. *Communications of the ACM,* 19(3), 113-126.

Noë, A. (2004). *Action in perception*. Cambridge, MA: MIT Press.

Núñez, R. (2008). *Mathematics, the ultimate challenge to embodiment: Truth and the grounding of axiomatic systems.* In Calvo, P., & Gomila, A. (Eds.), *Handbook of cognitive science: An embodied approach* (pp. 333-353). San Diego, US: Elsevier Publishers Limited.

Oaksford, M., & Chater, N. (2007). *Bayesian rationality: The probabilistic approach to human reasoning*. Oxford: Oxford University Press.

Oullier, O., & Basso, F. (2010). Embodied economics: How bodily information shapes the social coordination dynamics of decision-making. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1538), 291-301.

Patokorpi, E. (2008). Simon's paradox: Bounded rationality and the computer metaphor of the mind. *Human systems management,* 27(4), 285-294.

Petracca, E. (2015). A tale of paradigm clash: Simon, situated cognition and the interpretation of bounded rationality. MPRA Paper 64517, University Library of Munich. https://mpra.ub.uni-muenchen.de/64517/

Plott, C.R, & Zeiler, K. (2005). The willingness to pay-willingness to accept gap, the 'endowment effect', subject misconceptions, and experimental procedures for eliciting valuations. *American Economic Review*, 95(3), 530–545

Pólya, G., (1957). *How to solve it: A new aspect of mathematical method.* London: Penguin.

Pfeifer, R., & Bongard, J. (2006). *How the body shapes the way we think: A new view of intelligence*. Cambridge, MA: MIT Press.

Rabin, M. (1998). Psychology and economics. *Journal of Economic Literature*, 36(1), 11-46.

Reimann, M., Feye, W., Malter, A. J., Ackerman, J. M., Castaño, R., Garg, N., Kreuzbauer, R., Labroo, A. A., Lee, A. Y., Morrin, M., Nenkov, G. Y., Nielsen, J. H., Perez, M., Pol, G., Rosa, J. A., Yoon, C. & Zhong, C. B. (2012). Embodiment in judgment and choice. *Journal of Neuroscience, Psychology, and Economics*, 5(2), 104-123.

Rieskamp, J., & Dieckmann, A. (2012). Redundancy: Environment structure that simple heuristics can exploit. In Todd, P., Gigerenzer, G., the ABC Research Group (Eds.), *Ecological rationality: Intelligence in the real world* (187-215). New York: Oxford University Press.

Rohlfing, K. J., Rehm, M., Goecke, K.U. (2003). Situatedness: The interplay between context(s) and situation. *Journal of Cognition and Culture*, 3(2), 132-157.

Rowlands, M. (1999). *The body in mind: Understanding cognitive processes.* Cambridge, UK: Cambridge University Press.

Rubinstein, A. (1998). *Modeling bounded rationality*. Cambridge, MA: MIT Press.

Russell, S.J., & Norvig, P. (1994). *Artificial intelligence: A modern approach*. Englewood Cliffs, NJ: Prentice-Hall.

Samuels, R., Stich, S., Bishop, M. (2004). Ending the rationality wars: How to make disputes about human rationality disappear. In Renee E. (Ed.), *Common sense, reasoning, and rationality* (pp.236-268). New York: Oxford University Press.

Shapiro, L. (2004). *The mind incarnate*. Cambridge, MA: MIT Press.

Simon, H.A. (1947). *Administrative behaviour*: *A study of decision-making processes in administrative organization*. New York: MacMillan.

Simon, H.A. (1956). Rational choice and the structure of environments. *Psychological Review*, 63(2), 129-138.

Simon, H.A. (1976). From substantive to procedural rationality. In Kastelein, T.J., Kuipers, S.K., Nijenhuis, W.A., Wagenaar, G.R. (Eds.) (pp.65-86). *25 Years of Economic Theory: Retrospect and prospect*, Boston: Springer.

Simon. H.A. (1990). Invariants of human behavior. *Annual Review of Psychology*, 41(1), 1-19.

Spellman, B.A., & Schnall, S. (2009). Embodied rationality. *Queen's Law Journal,* 35(1), 117-164.

Suchman, L. (1986). What is a plan? *ISL Technical Note,* Xerox Palo Alto Research Center.

Suchman, L.A. (1987). *Plans and situated actions: The problem of human-machine communication*. New York: Cambridge University Press.

Thaler, R., & Sunstein, C. (2008). *Nudge: Improving decisions about health, wealth, and happiness*. New Haven, CT: Yale University Press.

Thorndike A.N., Sonnenberg, L., Riis J., Barraclough S., Levy D.E. (2012). A 2-phase labeling and choice architecture intervention to improve healthy food and beverage choices. *American Journal of Public Health*, 102(3), 527-533

Todd, P. M., & Gigerenzer, G. (2001). Putting naturalistic decision making into the adaptive toolbox. *Journal of Behavioral Decision Making*, 14(5), pp. 381-383.

Tummolini, L. Scorolli, C., Borghi, A.M. (2013). Disentangling the sense of ownership from the sense of fairness. *Behavioral and Brain Sciences*, 36(1), pp. 101-102.

Varela, F., Thompson, E., Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge, MA: MIT Press.

Vera, A.H., & Simon, H.A. (1993). Situated action: A symbolic interpretation. *Cognitive Science*, 17(1), 7-48.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review*, 9(4), 625-636.

Wilson, M. (2008). How did we get from there to here? An evolutionary perspective on embodied cognition. In Calvo, P., & Gomila, T. (Eds.), *Handbook of cognitive science: An embodied approach* (pp. 375-395). San Diego, US: Elsevier Publishers Limited.

Zhang, J. (1997). The nature of external representations in problem-solving. *Cognitive Science,* 21, 179-217.