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Do animal spirits rely on somatic markers? Keynes in light of neuroscience

Abstract: *Thanks to neuroscience, the brain is no longer a black box. It is possible to investigate its basic functioning and see whether its teachings may buttress Keynes's concept of animal spirits. Seven features constitute them: duality of reasoning; automatic analogical assessment; automatic decision; anchorage in emotions; intermediation between body and soul; beyond the rational/irrational dichotomy; and conventional basis. This article aims to compare these features comprising animal spirits with Damasio's "somatic marker hypothesis." It appears that both theories are very much in tune, in that they emphasize analogical induction, the intelligence of emotions, and the automaticity of cognition and action. It may prove useful, as a way to stimulate further research, to enrich and deepen animal spirits thanks to somatic markers.*

Key words: *Keynes, rationality, decision making, neuroscience, animal spirits.*

JEL classifications: *D01, D80, D81.*

For a long time, cognitive processes were seen as a black box (Boudon, 2007). Behaviorism and mainstream economics' views on rationality and decision making developed in part because it was impossible to delve inside such a black box to see what was actually going on. "The foundations of economic theory were constructed assuming that details about the functioning of the brain's black box would not be known" (Camerer et al., 2005, p. 9). As a result, highly abstract models relying heavily on mathematics took center stage in economic theories. Thanks to dramatic improvements of medical techniques and devices that occurred in the late 1980s and 1990s, this is no longer the case. The black box is being opened. The field of neuroscience is gaining considerable momentum, and cross-fertilization with economics has begun. A society for

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neuroeconomics was established in 2004, with Paul Glimcher as its first president. Numerous major papers have been published up to now, with a view to testing or refining mainstream or behavioral economists' theories on rationality or decision making. In this regard, three major trends in neuroeconomics research can be outlined: testing/refining subjective expected utility and its derivatives (e.g., Camerer, 2007; Camerer et al., 2005; Glimcher, 2009, 2011; Rustichini, 2009), Prospect theory (e.g., Camerer et al., 2004; Fox and Poldrack, 2009; Litt et al., 2008; Phelps, 2009; Sanfey et al., 2006; Trepel et al., 2005; Weber and Johnson, 2009) or devising a brand new "reward prediction error" model based on the role of dopamine (e.g., Caplin and Dean, 2009; Glimcher, 2009, 2011; Schultz, 2009). Nevertheless, scant to no attention has so far been paid to Keynes's views on rationality and decision making.

The aim of this article is to compare one of the most popular theories in the field of neuroscience, that of the "somatic marker hypothesis," developed by Antonio Damasio, Antoine Bechara, and their colleagues (e.g., for a synthetic account, see Bechara and Damasio, 2005), with Keynes's concept of animal spirits. Why the somatic marker hypothesis and not another theory? Because it appears, at first glance, that animal spirits *may* rely on somatic markers. Put differently, both theories *seem* to be highly *compatible*; the latter may inform the former, since they both stress the role of emotions and emphasize features that might seem "irrational." Conversely, other neuroeconomic theories endorse probabilistic and utility calculus, whether altered by a "weighting function" (as in prospect theory) or not (the "classical" subjective expected utility theory). And yet, Keynes was very leery about probability and utility calculus. Likewise, the somatic marker hypothesis (SMH) does not seem to rely on such calculus. Roughly speaking (a proper definition will follow later), it rests on emotions, seen as an action program, triggered by an automatic analogy with previous events stored in memory, the body serving as some kind of reminder. The crucial role of the body, emotions, and automatic analogy appear also to be characteristics of Keynes's animal spirits. Hence, the SMH *may* serve as the neurological underpinning of animal spirits—and enrich them. This intuition is our starting point. It remains to be seen whether this is the case. Thus, a major issue raised by this article is: are Keynes's microeconomic views susceptible to being grounded in biology, even bearing in mind that neuroscience is a science in its infancy? We do not assert here, that the SMH is all that there is with regard to neuroscience, nor do we maintain that other approaches cannot be insightful. The reader is invited to bear in mind that the subject matter of this article is not decision making in general but a specific kind of

decision making, for which Keynes devised his concept of animal spirits. In particular, for rational decisions and expected utility, many theoretical frameworks seem to be more appropriate—notably those discussed in Glimcher (2009, 2011). But we do not deal with them here, since we have chosen to focus on animal spirits. If—and to the extent that—we succeed in showing that both theories have much in common, it would not mean that biology underpins Keynes’s views on the firmest ground; it would merely imply that animal spirits are substantiated inasmuch as somatic markers themselves are. Of course, the SMH still needs more empirical support. It is not the end of the story. In neuroscience as well as in economics, no consensus has been reached. Should the SMH prove to be doubtful or shattered by a great deal of conflicting evidence in the future, then the basis of our comparison will have grown thin.

Finally, let us try to dispel a possible misunderstanding. Philip Mirowski brilliantly pointed at the dangers of metaphorical reasoning and the importation of theoretical frameworks from other disciplines, namely physics (Mirowski, 1989). The aim of our comparison is not to introduce a dubious metaphor with biology. According to Mirowski, the founding fathers of neoclassical thinking equated energy with utility, failing to take heed of the principle of conservation of energy (*ibid.*). By so doing, they forgot that the subject matters of physics and economics were totally alien to each other. Therefore, such importation was very misleading. It should be noted that this is not the case here, since the SMH and animal spirits share the same subject matter: human decision making. The “sole” difference is one of methods. Thus, we believe that a joint theoretical effort might be fruitful. At the very least, it cannot be rejected on a priori grounds without careful examination.

What are animal spirits?

On the face of it, the concept of animal spirits traces back to Galen, the most famous physician of the ancient world after Hippocrates, who lived in the second century and whose tremendous influence would be felt up to the sixteenth and seventeenth centuries, and Descartes (Koppl, 1991). According to Galen, animal spirits, released by the brain, were responsible for sensation and movement. They were tantamount to nerve impulse—for Descartes as well, albeit in a more complicated fashion. “Brewed in the heart and filtered through the brain, animal spirits percolate down the hollow cavities of nerve fibers and cause muscles to move” (Koppl, 1991, p. 208). On their way to the nerve fibers, they had to pass through some kind of “switching station” (*ibid.*), namely, the pineal gland. Descartes

put forth that this gland was the meeting point of the body and the soul (Descombes, 1999; Gallina, 2011). It was said to be the very location where the soul gave its orders to the body, and where the body could equally send messages to the soul. Thus, animal spirits were a kind of “clock clapper” (Livet, 2002) for the pineal gland: although it is the clock that strikes (i.e., the soul that gives orders), it needs a clapper (i.e., animal spirits). They were involved in every kind of perception and action. While attending MacTaggart lectures on Descartes, the young Keynes noted: “unconscious mental action” (Moggridge, 1992, p. 208). Afterward, the concept reappeared in the famous twelfth chapter of the *General Theory*, which deals with the “State of Long-term Expectations” (Keynes, 1978, ch. 12). These first impressions notwithstanding, one should ask: is the concept of animal spirits in this magnum opus the same as Descartes’s or did Keynes give it a twist and a depth of his own? This section briefly but thoroughly presents this concept.

Keynes’s focus on psychology, and hence animal spirits, is due to fundamental uncertainty, which stems from the flimsiness of knowledge as well as the erratic changes in the economy. Thus, in deciding whether to invest or not, entrepreneurs rarely use probability calculus, since the basis of such calculus does not exist, and they are guided mostly by their animal spirits. In Keynes’s views, there is duality of reasoning, but animal spirits are the default mode of action, whether economic or not. Thanks to them, individuals form expectations—that is, they *assess* events and *decide* on a given course of action. Contrary to what many mainstream economists believe, they are neither rational nor irrational. They appear to be embodied and anchored in emotions. They use analogical reasoning, most of the time cloaked in conventions, which has to be supported by a general state of confidence.

Fundamental uncertainty and the need for animal spirits

Keynes endorsed the view that fundamental uncertainty takes center stage in economic life, through expectations, by which he did not mean that the future could be reduced “to the same calculable status as the present” (Keynes, 1987), thanks to probability calculus. Indeed, it is because he believed that the full consequences of our acts cannot be foreseen that he started his Ph.D. thesis on probability (Dostaler, 2007; Skidelsky, 2004). The book that resulted from his Ph.D. thesis, *A Treatise on Probability*, was intended to be a philosophical investigation as to the conditions of the validity of probability reasoning (Carabelli, 1988). As a result of his investigation, Keynes found that these conditions were so stringent that probability was of little use.

Probabilities were not facts of the world (Lawson, 1988), they were outcomes of the incompleteness and imperfection of the knowledge at hand, and, very often, they were purely qualitative and one could not even make an ordinal comparison between two courses of events/propositions on their basis. In the conclusion of his *Treatise*, Keynes compared the study of probability to astrology, which was not meant as a compliment. From that period on, he continued castigating the “mathematical charlatanry” of those “who conceal themselves in a maze of mathematics from the eyes of common sense” (Keynes, 1973, p. 401) by using “pseudo-rationalist notions” (Keynes, 1987, p. 124) such as expected utility theory, namely, “the weighted average benefits multiplied by quantitative probabilities” (Keynes, 1978, p. 162; O’Donnell, 1990b). With regard to this point, whether Keynes’s thoughts display continuity (Carabelli, 1988; O’Donnell, 1990a, 2003) or discontinuity (Bateman, 1991; Davis, 1994; Gerrard, 1992; Gillies, 2003) remains a controversial issue. Given the scope of this article, I will simply assume that there is “continuity of adherence to an existing conceptual framework” (O’Donnell, 2003, p. 91).

Provided that this assumption is correct, one can assert that Keynes’s fundamental uncertainty had two roots: the limitations of our intellectual capabilities (which could be termed “epistemological uncertainty”) as well as the erratic changes of economic phenomena (“ontological uncertainty”). The first kind of uncertainty was stressed throughout *A Treatise on Probability*—“There is no direct relation between the truth of a proposition and its probability. Probability begins and ends with probability”—and in the twelfth chapter of *The General Theory*, where he referred to “instability due to human nature,” as well as in subsequent papers—“we simply do not know” anything about the remote future (Keynes, 1987, p. 114). But Keynes also alluded to an ontological uncertainty, by stating, for example, that “the outstanding fact is the extreme precariousness of the *basis* of knowledge” (Keynes, 1978, pp. 149–150; emphasis added): not knowledge, but its basis, meaning nature or the world itself. “Although nature has her habits, due to the recurrence of causes, they are general, not invariable,” because “contingencies are too numerous” (Keynes, 1973, p. 402). By stressing this fact, Keynes also stressed how flimsy the bulk of our everyday arguments are bound to be. Indeed, not only were our attempts at grasping the truth fragile for Keynes, but the social reality itself was non-ergodic, that is unique and nonrepetitive (Davidson, 1987, 1991, 1994, 1996). Hence, the future is not a mere repetition of the past. “The future never resembles the past, as we well know” (Keynes, 1987, p. 124).

As a matter of fact, “human decisions cannot depend on strict mathematical expectation” (Keynes, 1978, p. 163) and people have to rely on another kind of reasoning, namely, animal spirits.

Duality of reasoning

It should be abundantly clear that there was duality of reasoning for Keynes, the default mode being animal spirits and the other mode being mathematical calculation. “A large proportion of our positive activities” depends on animal spirits. “Most, probably, of our decisions to do something positive . . . can only be taken as a result of animal spirits” (Keynes, 1978, p. 161). It is up to “our rational selves” to decide whether to use animal spirits or “reasonable calculation,” “our rational selves choosing between the alternatives as best we are able, calculating where we can, but *often* falling back” on animal spirits (ibid., p. 163; emphasis added). “Duality of reasoning” does not mean “conflicting reasoning,” for “individual initiative will only be adequate when reasonable calculation is supplemented and supported by animal spirits” (ibid., p. 162). Thus, even if *most* of our decisions “need not be the result of reasonable calculation,” *some* of them can be the result of some collaboration between animal spirits and reasonable calculation. Three kinds of reasoning are possible: reasonable/mathematical calculation alone, animal spirits alone, or reasonable calculation “supplemented and supported by animal spirits.”

That Keynes devised a general concept is also worth noticing. The fact that he termed the chapter in which he introduced animal spirits “the state of long-term expectation” should not confuse the reader. Indeed, it is asserted that the decisions “taken as a result of animal spirits” have “consequences which will be drawn over *many days* to come” (ibid., p. 161; emphasis added). Moreover, they include short-term actions as chapter twelve also deals with speculation. Furthermore, it appears that animal spirits span a wide spectrum of expectations, whether “personal or political or economic,” “moral, or hedonistic or economic” (ibid.). Consequently, it may not be too rash to contend that Keynes had in mind a general microeconomic theory (Sardoni, 2002).

Animal spirits as both assessment and decision rules

All of this begs the question: what are animal spirits? It is written that they are concerned with “estimating the prospect of investment” writ large, that is, also portfolio expectations and not only expectations as to productive investment. Furthermore, among many phrasings, Keynes defined animal spirits as “spontaneous optimism.” And yet, optimism

pertains to the assessment of the future—that is, once again the prospect of investment.

But it is not only a way of assessing future events, since on numerous occasions, Keynes wrote that the animal spirits result in “decisions” or in “spontaneous activity.” He even coined the phrase “spontaneous urge.” Thus they might as well be seen as motives or decision rules.

Beyond rationality and irrationality

Thus, animal spirits pertain to a “non-calculated motivation to act” (Gerard, 1994, p. 332), and “non-rational factors [that] are not completely irrational” (Marchionatti, 1999, p. 430). “We should not conclude from this that everything depends on waves of irrational psychology,” warned Keynes. Indeed, animal spirits could be said to be sensible rather than rational. In defining animal spirits, Keynes talked about “our *rational selves* choosing between the alternatives as *best we can*” (Keynes, 1978, p. 163; emphasis added). As a result, even if animal spirits are not steady and their decisions might seem erratic, leading to “slumps and depressions exaggerated in degree” (ibid.) they “make the wheels go round.” They do so in part because they rely on conventions (see below). Even apart from the “compensating effects” of conventions, it is worth noting that animal spirits are intrinsically necessary for sensible decisions since “individual initiative will *only be adequate* when reasonable calculation is supplemented and supported by animal spirits” (ibid., p. 162; emphasis added). As Carabelli aptly put it, they are “reasonable non-deliberative action” (Carabelli, 1988, p. 298).

Beyond body and soul, and the dichotomy between emotions and reason

As Carabelli also pointed out, they are “intermediate between body and soul” (ibid.). Indeed, Keynes also used the following phrases to define them: “nerves,” “digestions,” “reactions to the weather.” This entire lexical field pertains to the body, as if animal spirits acted according to an embodied reasoning. They stem from the body in that the decision is automatic and nondeliberative, and they stem from the soul in that perception is already theory-laden and in that each choice necessarily entails some kind of cognition, however fast and nonconscious.

In Descartes’s theory, from which Keynes’s concept originated, animal spirits were, so to speak, the interface between body and soul. Action could stem from three sources: the body itself (e.g., respiration, digestion, etc.), an external object (responsible for a “passion,” entailing a notion

of submissiveness), and reasonable free will. All of them implied the animal spirits. Thus, they were responsible for “passion” as well as the conveyance of rational thoughts. For Descartes, “passion” had a very broad meaning, encompassing all kinds of sentiments and emotions (Descartes, 1649). Emotions (e.g., fear) needed to activate an “image” in order to be efficient and predispose the body to flee. But the fact that emotions needed an image should not be taken to mean that they were purely mental phenomena. In fact, “There is such a union between body and soul that, once we have joined some bodily action with some thought, anyone of the two cannot be presented without the other” (Descartes, 1649, art. 136). Thus, some alteration of the body can give birth to specific thoughts.

It should be clear that animal spirits pertain to “a non-calculated motivation to act. . . . The propensity to act reflects nonoptimising aspects of human behavior but that does not necessarily imply that it cannot be the subject of systematic analysis” (Gerrard, 1994, pp. 332). Such “nonoptimising aspects” are also emotional since Keynes used the words “whim” and “sentiment” to characterize them, stressing the fact that they are susceptible to a “delicate balance.” So, despite their strong emotional component, they are not irrational as was previously put forth. In fact, one may contend that they stand beyond the classical emotion/reason dichotomy.

The wellspring of animal spirits: analogical reasoning

If the previous analysis is correct, animal spirits are an embodied form of reasoning anchored in emotions, which is sensible instead of being optimal or rational. Having said that, we have still said too little. Since it is not a calculation, what could it be? Although I am ready to venture into a territory that may seem rather speculative to some readers, I beg them to ponder carefully the following considerations in order to see the grains of truth they might contain.

The argument goes that Keynes substituted the expectations/state of confidence pair of the *General Theory* for the probability/weight of argument pair of *A Treatise on Probability* (e.g., Dequech, 1999; Ferrari and Conceição, 2005). In defining what he termed “confidence,” he stated that it is “the likelihood of our best forecast turning out quite wrong.” In a footnote, he referred to the “weight of arguments” defined in the *Treatise*. Given that Keynes considered probability as a form of knowledge/reasoning and not as an object of knowledge/reasoning (Lawson, 1988; see also Hacking, 1975, 2001 for the distinction), this claim seems to be substantiated. In spite of all the diverging ambiguous definitions he

gave of the concept of weight, the most likely one appears to amount to a second-order probability (Runde, 1990). The snag in this definition is that we enter an infinite regress, for any assessment of the quality of an assessment in turn rests on an assessment of the quality of that assessment, and so on. Besides, it is not even clear what Keynes meant about this “best forecast” or “most probable forecast” in chapter 12: is it only a question of *likelihood* of prospective yields, of the *amount* of these yields or *both* as with “mathematical expectation?” In the first section of chapter 12, to introduce the content of the chapter, Keynes wrote that what he termed “long-term expectation” included, among many factors, “the changes in the tastes of consumers, the strength of effective demand from time to time during the life of the investment under consideration” (Keynes, 1978, p. 147), and all factors directly influencing the marginal efficiency of capital or prospective yields of the investment under consideration. Thus, it seems that the “best forecast” is our best assessment of the future effective demand: the so-called confidence then appears to be some kind of subjective, vague probability that we get wrong in estimating such demand. As a result, it cannot be any kind of second-order probability. Furthermore, prior to chapter 12, in presenting the notion of the marginal efficiency of capital (i.e., the expectation that animal spirits perform), Keynes never referred to any kind of probability calculus, merely to the calculus of a yield given a discount rate. In the last paragraph of the second section of chapter 12, in talking about the state of confidence, Keynes referred to the sole “expectation of prospective yields,” that is, the estimated return on investment, as if confidence were tantamount to some qualitative or vague probability assessment of these yields. In chapter 17, he equated “liquidity premium” with “best probabilities estimates” and “risk premium” with “the confidence with which we make them,” referring to the discussion to be found in chapter 12 (Keynes, 1978, p. 240). Apart from the fact that this entails an infinite regress, probabilities already being for Keynes estimates and not objects about which to form expectations, it is not sure whether there is no inconsistency here. According to him, the “risk premium” was a question of *stability* of prospective *yields*, and the “liquidity premium” was a question of *pace* with which any kind of wealth could become liquid. Thus, the difference between the two cannot be solely a question of estimates about the same features, since liquidity has nothing to do with yields (it has none) but with an elasticity of substitution and one of production (Davidson, 1994). As a result, liquidity cannot be said to comprise any estimation of estimated yields.

We seem to have no choice but to consider “confidence” to be a mere substitute for what Keynes dubbed “probability” in the *Treatise*, and not, his claims notwithstanding, for “weight of arguments,” given the redundancy of this concept with that of probability. Whenever one views probability as a *form* of reasoning, there is no distinguishing a second-order probability, unless one enters an infinite regress, since probability then encapsulates *all* uncertainty—and Keynes made it clear that most of the time the term had no numerical bearing, even between upper and lower numerical bounds (Keynes, 1973). Consequently, the emotions of animal spirits depend on an interpretation of the situation at hand, called “probability,” which in turn has an inductive basis. Indeed, “the central theme of *A Treatise on Probability* is induction. Keynes sought to formalize the inductive method and to provide a justification for its use” (Gerrard, 1992, p. 83). There, induction is said to consist of automatic generalizations. It stems from analogical reasoning or pattern matching; it is an answer to the question, “Does the current situation resemble another one that happened in the past?” There is more to induction than the mere counting of instances in order to derive frequencies of events, for it depends on two different kinds of analogy, “positive analogy” (i.e., the resemblances between the objects being observed) and “pure induction” or “negative analogy” (i.e., the differences between the same objects). One has to gauge whether the current phenomenon or proposition resembles one that has been encountered before. If anything, one has a basis upon which to build a conclusion. “We say that one argument is more probable than another (i.e., nearer to certainty) in the same kind of way as we can describe one object as more like another to a standard object of comparison” (Keynes, 1973, p. 39).

To summarize this point: expectations derive from an automatic estimation of the similarities between two investments, one that will take place in the future about which we have to gauge its prospective yields and another that happened in the past. The more uncertain the assessed similarities, the less confident we feel. But this personal degree of confidence might in turn be influenced by another kind of confidence, of a general, conventional kind, to “which practical men pay the closest and most anxious attention” (Keynes, 1978, p. 133).

Conventions and confidence

“As living human beings, we are forced to act. Peace and comfort of mind require that we should hide from ourselves how little we foresee. Yet we must be guided by some hypothesis. We tend therefore to substitute for the knowledge which is unattainable certain conventions” (Keynes,

1987, p. 124). Therefore, animal spirits have to rely on conventions. Conventions are not “complementary” (Lawson, 2004) to animal spirits; rather, animal spirits shape their arguments in conventional terms. Conventions intervene at two levels: as a way of interpreting events and choosing between a given course of events, and as a basis of the *general* state of confidence, “economic prosperity [being] excessively dependent on a political and social atmosphere which is congenial to the average business man” (Keynes, 1978, p. 145). Keynes’s focus on conventions has been broadly analyzed (e.g., Bateman, 1991; Davis, 1994; Dostaler, 2007; Ferrari and Conceição, 2005; Hillard, 1992; Lawson, 2004). For instance, part of chapter 12 is dedicated to analyzing how psychological conventions lie at the root of the speculation motive; it is asserted that “it is better to fail conventionally than to succeed unconventionally”; and “other factors,” among which conventions, are said to “exert their compensating effects” as regard productive investment.

Summarizing Keynes’s views as to animal spirits: (1) there are two systems of reasoning; (2) most of the time, rational calculation in the form of quantitative probability is out of the question and expected utility is of no use; (3) animal spirits are sensible rather than rational; (4) they comprise a specific way of assessment and a decision rule at the same time; (5) they are an embodied, emotional automatic reasoning leading to automatic action; (6) they stem from an inductive analogical cognition (or pattern matching); and (7) they are underpinned by conventions.

Outlines of the brain’s grand circuitry

Claude Bernard, the nineteenth-century physicist who shaped the concept of homeostasis, warned that “one cannot ever reduce the expressions of our soul to the crude properties of nervous systems in the same sort of way that one should ever understand gentle melodies by the sole properties of the wood or the violin’s strings that are necessary to express them” (quoted in Vincent, 2002, p. 21). Indeed, some caveats and qualifications appear to be reasonable as to neuroscience’s claims. Once they are expounded, one could present the great outlines of our neuronal circuitry as well as some basic definitions.

Caveats and qualifications

Indeed, Bernard aptly pointed to a great danger: reductionism. One should not airily discount or rule out the following caveats or qualifications. Metaphorically speaking, a theoretical framework is like a bridge: it cannot be stronger than its weakest point (Gallistel, 2009). Neuroeconomics

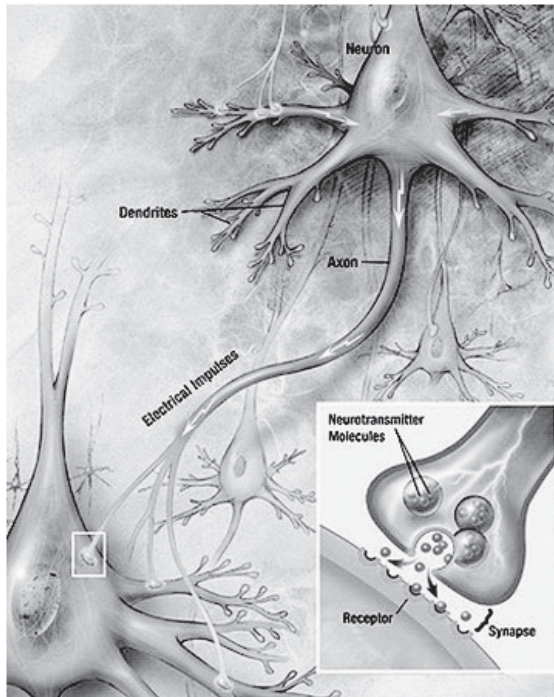
tends to rely on the huge assumption that the architecture of the brain accounts for feelings and thoughts (ibid.) as if it were solely a question of the location of brain areas. Thus, a prominent scholar has formulated: “What makes a sound different from a sight, a memory different from a perception, a fear different from a desire is not so much the chemistry involved but instead the specific circuits in which the chemicals act” (LeDoux, 2002, p. 61). Then, if one is not cautious enough, one might jump to conclusions on the basis of the neuronal circuits involved, inferring mental states from neural data, a process called “inverse inference” (Fox and Poldrack, 2009). And yet, as neuroscience is still in its blooming process, one cannot mistake its results for the ripe fruits of definite and definitive conclusions. This caveat is all the more serious, as it has been proved that the brain displays considerable plasticity, at every age (Doidge, 2007): brain areas are not fixed and immutable and do not necessarily correspond to brain functions.

Moreover, one should not discount the fact that most of neuroscience’s experiments are made on animals. Consequently, their results rely on the strong hypothesis that animals and humans share analogous cognitive processes (Glimcher, 2009, 2011; LeDoux, 1998, 2002).

Finally, one should always bear in mind the limits of the observation techniques themselves (Camerer et al., 2005). It is worth noting that these techniques cannot grant scientists direct access to the thoughts or the feelings per se, but rather to hints of such thoughts or feelings. Indeed, as far as humans are concerned, scientists face the following dilemma: either they ask respondents to self-gauge their inner state, which is very subjective, or they rely on an exterior observer, which is less subjective but much cruder. This should not be taken to mean that no conclusion can be arrived at. But one must always be very careful about manipulating neuroscientific results as if they were steadily and firmly grounded. For instance, in a survey of the extant literature, Lisa Barrett showed that even scientists themselves were only slightly above chance in estimating the emotions felt by their subjects; they were able to accurately gauge them on a valence/arousal axis, but apart from that, their assessment was rather poor and crude (Barrett, 2006).

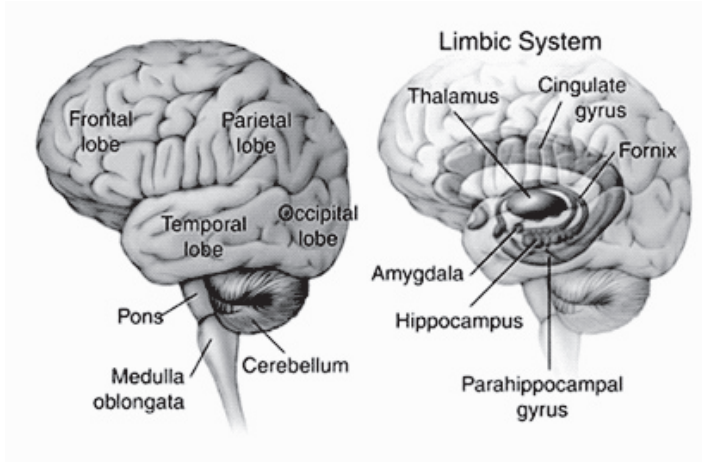
The basic working of the brain

Like any other area of our body, brain cells are composed of input channels (the dendrites), cell bodies (somas), output channels (axons), and connection spaces between axons and dendrites called synapses—although some of them are constituted of spaces between two axons or between an axon and a body cell. These connection spaces consist of

Figure 1 The neurons

extracellular fluids with many charged ions—see Figure 1. The default mode of our cells is idleness because of the constant firing of inhibitory neurons. Most of the time, the communication from the end of an axon (called an “axon terminal”) and the postsynaptic cell involves a chemical reaction via neurotransmitters, but sometimes it can occur by means of electrical stimulation, some cells entering a state of fusion. These neurotransmitters have excitatory or inhibitory effects. There is a balance between inhibitory and excitatory neurotransmitters. Once the latter outweigh the former, the balance changes and charged ions penetrate the postsynaptic cell. Then, they trigger an electrical response in the postsynaptic cell called an “action potential.” This action potential conveys the message to the next synapse. Our brain is in charge of converting “symbolic” conscious orders (e.g., to wake up or to talk) into “action potentials.” But, of course, it functions also largely on a nonconscious basis.

Since action potentials are very basic (they consist of electrical impulses), the meaning of the message they convey stems mainly from the brain areas they travel through—see Figure 2.

Figure 2 The brain's architecture

Neuromodulators are also involved. Although a neurotransmitter acts quickly and does not endure, a neuromodulator acts more slowly and its effects last longer. There are three types of neuromodulators: peptides (endorphins, primarily enkephalins), amines (dopamine, serotonin, epinephrine, norepinephrine), which enhance or inhibit the action of neurotransmitters, and hormones (which need specific receptors to act).

As a result, brain functions are not only a question of brain circuitry or brain locations but also of chemicals, and both play a vital role.

Now that we have raised sufficient qualifications and have presented the general outlines, it is time to turn to a comparison between animal spirits and *somatic markers* as regard analogical reasoning.

Analogical induction

First of all, we try to define some useful terms. Traditionally speaking, cognition is seen as an answer to “true/false” questions—for example, “Can I trust this person?” “What is the expected return on investment of this project? and so on—whereas emotion is an answer to “go/no go” questions—for example, “*Shall* I trust this person?” “*Shall* I invest in this particular project? and so on—(for a clear exposition, see Zajonc, 1998). According to Damasio, emotions are alterations of the body or changes in the levels of body chemicals, triggered by a precise object. Feelings are “nothing but” cognitive sequels of emotions (Damasio, 2009). Thus, emotions come first and feelings second. Moods (also called “background

emotions”) are similar to emotions but have no definite object (Phelps, 2009). In order to avoid possible confusion, it is worth distinguishing between somatic marker as a theoretical framework and somatic marker as a specific concept or entity *inside* that theory, which consists of a five-step sequence, one of which implies somatic markers as particular entities (see the next sections). The former will be designated by SMH; we retain “somatic marker” for the latter.

We now return to our comparison. The existence of two systems of reasoning is a widely held belief (Camerer et al., 2005; Loewenstein et al., 2008; Sanfey et al., 2006; Wargo et al., 2010). The first one is automatic. It can take the shape of reflexes, reactions (LeDoux et al., 2009), habits, routines, dispositions, and involves emotions most of the time. The SMH is said to pertain to it (Damasio, 1994, 2003). The second one is controlled and slower. It involves consciousness or the so-called working memory (LeDoux, 2002). Thus, the first point in our comparison, the existence of two systems of reasoning, animal spirits and *somatic markers* relying on automatic cognitive processes, unites them. Six points remain (cf. end of the first section). In this section, we broach three of them, namely, the way of assessment, based on analogical induction following a no probability rule. With regard to these three points, we will deal with long-term potentiation, aka LTP, a process that appears to be relatively uncontroversial and is not specifically linked to SMH, before turning to somatic markers per se and their inducers.

Long-term potentiation, or the grand, useful fallacy of the brain

Everyone processes 11 million bits per second (10 million are handled by the visual system alone) without being aware of it. Conscious or controlled processes involve 200 times less information (Blair, 2010). Thus, “automatic processes . . . are the default mode of brain operation. They whirl along all the time. . . . Controlled processes occur at special moments when a person encounters unexpected events, experiences strong visceral states, or is presented with some kind of explicit challenge” (Camerer et al., 2005, p. 18).

Survival is a question of quickness and efficiency. No wonder, then, that the brain is so structured that it can respond rapidly and accurately to what happens. It is a kind of learning machine that evolution bestowed on us to find the appropriate balance between adaptation to recurrent events and adaptation to novel situations (Damasio, 2010). Thus, the more novel a task, the more intensive the brain processes: “when subjects began playing, they were highly aroused and many parts of the brain

were active. However, as they got better at the game, overall blood flow to the brain decreased markedly, and activity became localized in only a few brain regions” (Camerer et al., 2005, p. 20).

Brain processes are inductive. One can summarize the way they work by twin basic principles: “neurons that fire together wire together” and “use it or lose it” (Doidge, 2007). In our adaptation to our surroundings, time is the master. When two stimuli occur during a very short period of time, an action potential is triggered in two sets of neurons. When the neurotransmitter is released from the presynaptic cell owing to the arrival of this action potential, it binds to specific receptors on the shores of the postsynaptic cell. If the molecules of neurotransmitters are numerous enough, charged ions enter these receptors. Then, they bring about the activation of protein kinases, which in turn give rise to new receptors that will take place alongside the others on the postsynaptic cell, thus strengthening the connection between neurons (Purves et al., 2008).

There is another way through which LTP occurs. The arrival of the action potential in the presynaptic terminal triggers also the release of chemical tags. So to speak, these tags will mark the path taken by the electric impulse. The entrance of calcium ions in the postsynaptic cell causes the release of neurotrophins in the extracellular fluid, which will then travel up to these tags. “When an action potential occurs in a postsynaptic cell, neurotrophins are released from the cell and diffuse backward across the synapse, where they are taken up by presynaptic terminals. Under the influence of neurotrophins, the terminals begin to branch and sprout new synaptic connections. . . . Activity thus induces growth” (LeDoux, 2002, p. 81). As a result, LTP reinforces connections between active neurons in a given period of time, a few seconds or less: the stimuli that caused the activity of these neurons are then automatically associated by the brain. This is the explanation of the first twin principle “neurons that fire together [i.e., they trigger action potentials during the same interval] wire together” [i.e., their connections are strengthened]. Experience impresses our brains in a Pavlovian way: automatic inductive inferences are constantly made, whether one is conscious of them or not. They allow for a fast manner of dealing with recurring events. Other implications come into play, which will be discussed later.

The balance between adaptation to recurrent events and to novel ones is provided by plasticity. The “use it or lose it” principle accounts for our “competitive plasticity”: “if we stop exercising our mental skills, we do not just forget them: the brain map space for those skills is turned over to the skills we practice instead” (Doidge, 2007, p. 59). Since our cognitive space is limited, brain areas have to evolve in order to adapt

to new situations. This gives rise to the “plastic paradox”: “the same neuroplastic properties that allow us to change our brains and produce more flexible behaviors can allow us to produce more rigid ones” (ibid., p. 242). The aim of flexible behaviors is to produce more rigid ones, because they respond more rapidly thanks to memory retrieval. “The memory is initially stored via synaptic changes that take place in the hippocampus. When *some aspect* of the stimulus situation *recurs*, the hippocampus participates in the reinstatement of the pattern of cortical activation that occurred during the original experience. Each reinstatement changes cortical synapses a little. . . . The slow rate of change of the cortex prevents the acquisition of new knowledge from interfering with old cortical memories” (LeDoux, 2002, p. 107; emphasis added).

Such inductive processes, which appeal to both memory and plasticity, and resort to analogy in order to compare the present situation to past ones (since the “same aspect” of the stimulation that gave rise to LTP has to “recur”), have been found to apply to all kinds of animals (Frith, 2007). Analogy activates four brain areas: medial frontal cortex, left prefrontal cortex, anterior insula, and the left inferior parietal cortex (Blair, 2010). Because an event is immediately followed by another, animals and humans alike tend to ascribe a causality relation between the two. *Post hoc ergo propter hoc*: it might be a fallacy, but it is how the brain works. This is what the “neurons that fire together wire together” principle is about. Pigeons have been found to follow the same arbitrary moves in order to bring about food release, because it was the random move they implemented *in the first place* just before the first food release, even though this release was implemented regularly by the experimenter (Frith, 2007). In another famous experiment, human respondents were asked to first spin a wheel of fortune before answering the following tricky question: “How many African countries are there in the UN?” Although it seems obvious that there is no link between the result of the wheel and the question asked, the former had a tremendous influence on the answer to the latter (Shiller, 2005). One sensible assumption is that the brain makes inductive inferences based on the quasi-simultaneity of events, whether we are conscious of this mechanism or not—hence, faulty thinking and superstition.

For Keynes, it was obvious that superstition and sound reasoning followed the same inductive logic: “The first introduction of iron ploughshares into Poland . . . having been followed by a succession of bad harvests, the farmers attributed the badness of the crops to the iron ploughshares, and discarded them for the old wooden ones. The method of reasoning of the farmer is not different from that of science” (Keynes,

1973, p. 273). Such a trick also comes into play in chess. Chess players store possible board setups in memory. It appears that thinking does not amount to calculation, but rather to analogical comparisons. Consequently, for randomly arranged chess pieces, novices are as good as experts. Thus, “decision making often takes the form of pattern matching rather than of explicit weighing of costs and benefits” (Camerer et al., 2005, p. 21)!

A vital distinction has to be made between the firing rates of neurons and LTP itself. For sure, neurons fire virtually “all the time” (they also need short rests), for any kind of activity (homeostasis, respiration, movement, and so on). For a certain action to proceed (e.g., eye movement), a particular group of neurons has to convey the relevant action potentials up to the appropriate muscles. The firing rate of neurons through time is a stochastic process (Glimcher, 2011), that is, not every neuron of a given group fires precisely at the same time. But the transmission of the action potential itself is not stochastic—it is binary: *the action potential is transmitted or not*. It is a question of threshold: once the balance between inhibitory neurons and excitatory ones has sufficiently changed, the action potential is conveyed, no matter how many neurons fire. Thus, LTP itself is not probabilistic. There is no Bayesian updating, for *LTP strengthens connections between neurons in a regular, linear fashion*, and not owing to some automatic estimation of ex ante and ex post probabilities. As far as LTP is concerned, it seems that Keynes’s views about automatic induction and the absence of calculation and Bayesian updating by animal spirits are somewhat underpinned. But it remains to be seen whether their reasoning has an analogical shape.

Analogical inducers

The SMH implies a five-step sequence: (1) the presence of an inducer is (2) automatically analyzed and (3) activates a somatic marker, which, in turn, (4) triggers a specific somatic state, (5) which then automatically fosters or causes some action.

Somatic markers need inducers to be triggered. Inducers are “emotionally competent stimuli” (Damasio, 1994, 2003), that is, specific stimuli. There are two kinds of inducers, primary and secondary (Bechara and Damasio, 2005; Martins, 2011). Primary inducers are innate or learned stimuli (e.g., a fear of snakes, news about winning a lottery) that automatically and compulsorily trigger some somatic state through the activation of somatic markers. They involve mostly the amygdala. But the ventromedial prefrontal cortex (VMPFC) can also play a role. Secondary inducers are “entities” initiated by memory or thoughts involving primary

inducers (Reimann and Bechara, 2010). The latter stem from the outside world, and the former from the inner world. Their magnitude is less than primary inducers, but there must be a preceding primary inducer in order to develop a secondary inducer. They rest extensively on the VMPFC. Indeed, “the VMPFC is a trigger structure for somatic states from secondary inducers” (Bechara and Damasio, 2005, p. 341).

How are these inducers analyzed? How do we recognize some stimulus as “emotionally competent?” Of course, this stimulus should be perceived. But the outstanding fact about perception is that it already contains some element of cognition; in other words, there is no perception devoid of any cognition that would passively render a loyal image of the surrounding stimuli. The boundary between perception and judgment is fuzzy (Koenigs and Adolphs, 2009; Reimann and Bechara, 2010). Indeed, perception is directly conceptual (Martin, 2009). But this still leaves open the fundamental question—how is perception analyzed or conceptualized?—by analogy or judgments of resemblance (Bechara et al., 2000; Bechara and Damasio, 2005; Damasio, 2003, 2010). By perceiving some given stimulus we automatically assess whether it is similar to another stimulus we perceived in the past. Consequently, the very nature of the inducer and the type of somatic marker it activates depends on an analogical judgment as to the similarity between the current stimulus and past ones. Our brain automatically does the pattern matching. In this regard, one might assert that the kind of reasoning implied by animal spirits and *somatic markers* is broadly aligned.

Three steps remain in the functioning sequence of the *somatic markers*: the activation of somatic markers, which elicit some specific somatic state and the action it prompts or helps to prompt. By examining them carefully, we may be able to further compare the two theories in terms of the points remaining in the shadows (namely, the sensibleness of expectations, their being anchored in emotions and embodied, their comprising a decision rule, and their reliance on conventions).

The end of dichotomies?

The SMH provides a theoretical framework for analyzing the role of emotions in decision making. According to this theory, emotions per se have two components: a *somatic marker* associated with a specific *somatic state*. Emotions are automatic action programs consisting of *alterations of the body*, or “somatic state” (Damasio, 1994, 2003, 2009, 2010), depending on a “process by which the brain determines or computes the *value of a stimulus*” (LeDoux, 2002, p. 206), called “somatic

marker.” They help value events, focus and retrieve relevant memories (Phelps, 2009). In the following subsections, we will determine whether they are embodied like animal spirits, and whether, if anything, somatic markers help decide sensibly on a par with animal spirits.

Beyond the body and soul dichotomy?

So far, we have seen two steps out of the five that make up the whole sequence: the inducer and the cognitive operations necessarily implied by its perception. Such operations activate somatic markers, which, in turn, trigger some particular somatic state leading to some action. When we talk about somatic states, we refer not only to the musculoskeletal system and visceral states but to the whole internal milieu (chemical activity inside the body, e.g., increased release of hormones). Crucial to our comparison is the fact that there are cognitive operations associated with a specific somatic state. All of these sequences happen so fast (often in less than half a second) that they escape control and shatter the body/soul dichotomy. In fact, in the actual processing, there is no severing of the cognitive operations from the somatic state, even if we can do it at an analytical level.

Damasio (e.g., 1994, 2003) regularly lavishes praise on William James for having underscored that action is implemented before we consciously perceive the associated emotion. We do not run because of fear, it is the other way round: we feel fear because we start to run. Alterations of the body happen first, at the end of the *somatic marker* sequence, and it is the awareness of such alterations by the brain that one calls “feeling.” Thus feelings and emotions are different, for the former are cognitive sequels of the latter (Damasio, 2009). Other implications come into play. In James’s phrasing, as well as in Damasio’s, the “somatic state” is specific to each kind of emotion. Put differently, an emotion entails a particular “somatic state.” This point of view was criticized early on by Cannon, who proposed that visceral states are too unspecific and diffuse to precisely define an emotion (thus, the cognitive appraisal is pivotal). This issue is still controversial. Even if Damasio’s theory is intended to go beyond the body/soul dichotomy in that inducers need cognitive operations, be they overt or covert, to play their role (Bechara and Damasio, 2005), “somatic states” take center stage. On the contrary, for the competing view, which could be called the “cognitive perspective,” it is the cognitive appraisal that takes center stage, since the somatic state is assumed to be too unspecific (e.g., the same increase in blood pressure and sweating for different emotions). “While James’s original theoretical proposal requires that emotions be associated with distinct

patterns of somato-visceral activity, the cognitive perspective implies that the peripheral activation associated with emotions can be reduced to a single dimension” (Rainville et al., 2006, p. 5).

Thus, Bechara, Damasio, and their colleagues tried to distinguish precise somatovisceral patterns for particular emotions so that a different somatic state may be ascribed to each emotion. Anger, fear, happiness, and sadness were assessed through changes in heart rate, respiratory activity, and sympathetic and parasympathetic regulation. Later, when the authors tried to test their findings by guessing the actual emotion felt merely by looking at these kinds of visceral alterations, their predictions were correct at a rate significantly greater than chance (Rainville et al., 2006).

From all of this, it follows that the body is not a mere vessel for the soul’s orders, or a passive conveyer of external stimuli, but that it can also affect the way we think about events. The most stimulating and disquieting experiments that illustrate this entanglement of body and soul follow the same pattern: the experimenter asks the respondents to move certain muscles or parts of the body and then examines the effect of this alteration on feelings and/or the performance of some intellectual tasks. For example, people were asked to slowly move the muscles of their faces in a specific order. Actually, they were instructed to smile step by step, although they were unaware of this. Puzzling as it may sound, people reported feeling happier thanks to such moves (Damasio, 2003). In another dazzling experiment, people were asked whether they approved of an editorial that was being aired on the radio while they were performing some simple moves. By shaking their heads “up–down” when listening to an editorial, respondents agreed more often than those who shook them “right–left”—supposedly, “what the brain seems to be doing is seeking a ‘global equilibrium’ that would reconcile the forced action with the response and the perceived attributes of the evaluated object” (Camerer et al., 2005, p. 17).

Thus, one may assert, as Keynes hinted, that even though body and soul can be separated at an analytical level, through the distinction between cognition and emotion, they cannot be in actuality, since an alteration of the body entails some kind of appraisal or cognition. One possible cause of misconception should be staved off. As we have seen, the very term “animal spirits” traces back to Descartes and Galen. And yet, since one work in Damasio’s magnum opus is titled *Descartes’s Error*, one may hastily conclude that *somatic markers* cannot have anything to do with animal spirits. First of all, the fact that Keynes used a Cartesian term does not qualify him as a fully fledged Cartesian. In fact, it has been

convincingly argued that the role of the amygdala and VMPFC in the SMH is tantamount to that of the pineal gland in Descartes's theory (Livet, 2002). What Damasio criticized in Descartes's theory was his views on the duality of substances, the *res extensa* (i.e., the body) and the *res cogitans* (i.e., the soul) (see Gallina, 2011). But it should be emphasized that no matter how dualistic they were on this point, they were not dualistic in regard to the way emotions work. Moreover, Keynes made it clear in chapter 12 of the *General Theory*, that animal spirits were, to quote once again Carabelli's apt phrase, "intermediate between body and soul." Of course, the SMH goes far beyond what Keynes only briefly alluded to. This is precisely why this theoretical comparison makes sense: provided that the two theories are compatible, the SMH may enrich and deepen animal spirits. So far, this seems to be the case.

The intelligence of our emotions

Emotions function thanks to somatic markers. Each event that triggers an emotion leaves a memory trace—it "marks" the body (*soma* meaning "body" in ancient Greek). It is vital for every learning process to be able to efficiently and rapidly assess the value of an event. Three kinds of memories are at play: one for factual knowledge, one for bioregulatory states (aka "somatic states"), and the last one, the somatic marker per se, linking the two. But these memories are not precisely stored as they are in computers. Instead, they are encrypted in the form of dispositions (Damasio, 2010), meaning that the brain needs to reexperience the emotion (i.e., reimplement the same somatic state that was triggered in the first place) in order to recall its content. "The VMPFC is a repository of dispositionally recorded linkages between factual knowledge and bioregulatory states" (Bechara et al., 2000, p. 296). Put differently, the VMPFC is the warehouse of the somatic markers. "For every life event, somatic consequences are marked and then reproduced when that event recurs" (Carter and Pasqualani, 2004, p. 901). Thanks to this reproduction, a value is ascribed to each inducer.

The concept of the somatic marker relates to a memory trace, automatically retrieved when the present situation resembles the one that designed the marker in the first place (Damasio, 2009). Somatic markers are efficient because they "have been connected, by learning, to predicted future outcomes of certain scenarios" (Damasio, 1994, p. 174). As a matter of fact, "the *somatic marker* hypothesis postulates that the way in which somatic signals bias our mental representation of competing options, by attaching differential feelings to them, im-

proves the efficiency of our decision-making process” (ibid.). Thus, they serve to reveal preferences and direct attention and cognitive resources to the relevant tasks. Their role is “to provide a metric for the decision maker in weighing various options for action or choice” (Phelps, 2009, p. 233).

In the now-famous Iowa gamble, individuals with impaired VMPFC performed poorly whereas their intellectual performances remained intact (Reimann and Bechara, 2010; Damasio, 1994, 2003). Moreover, 50 percent of the impaired patients could reach a conceptual stage, that is they were aware of which decks were good and which decks were bad. Still, they showed dramatic irrationality in completing the task (Bechara et al., 2000). *All* of the patients chose mostly the bad decks. This repeated failure was neither due to an impairment of the working memory (Bechara et al., 1998) nor to an incapacity to be emotionally conditioned (Bechara et al., 2000). Over time, there was no learning for the VMPFC patients, contrary to the control group. It was shown that although they could feel emotions after the result was announced, they could not feel any anticipatory emotion (ibid.). These patients were unable to use the emotional cues dispositionally stored in the VMPFC in order to predict the outcome of a given scenario and then choose an appropriate action. Somatic markers were mute. As a result, a VMPFC lesion seems to impair the ability to transform relevant knowledge into action (i.e., an incapacity to actually do what one says).

As a result, emotions appear to be more than a mere action program, for they are vital to sensible decisions. “Somatic marking enables individuals to make parsimonious decisions based on previous learned experience, without recourse to laborious and time-consuming calculation each time a decision has to be faced” (Carter and Pasqualani, 2004, p. 902).

As we have seen, animal spirits are “reasonable non-deliberative actions” (Carabelli, 1988, p. 298). This concept is very close to the SMH, in that it relies on analogy, is automatic (the occurrences of the words “spontaneous” and “urge” were numerous), and likewise it is the necessary keystone of rational decisions (“individual initiative will only be adequate when reasonable calculation is supplemented and supported by animal spirits” [Keynes, 1978, p. 162]). Like somatic markers, animal spirits are also emotional. Both focus on the intelligence of emotions, which shall not be taken to mean that emotions cannot distort judgment (e.g., Shiv et al., 2005), but rather that “extreme emotion distorts judgment, as does extreme cognition” (Mercer, 2010, p. 8).

Temporary conclusion

Animal spirits are sensible emotional spirits that rely on an embodied knowledge rather than probability calculus. Of the seven points defining them, at least six seem to be shared by the SMH. And I assume that even the seventh one, the importance of conventions, may be buttressed by Damasio's theory. Indeed, the famous neuroscientist extensively refers to mirror neurons (e.g., Damasio, 2003, 2010). Thanks to them, our brain directly simulates any action being performed by any individual within our sight, provided that this action belongs to our set of habitual actions, as if we were its actual subject (Rizzolatti et al., 2009; Rizzolatti and Sinigaglia, 2008)! It also implies that, owing to mirror neurons, one has a tendency to imitate an action made by another person, provided that such action is not alien to him/her. Of course, this tendency can be overridden, thanks to the work of the prefrontal cortex (Jeannerod, 2009). As Keynes analyzed with enormous gusto the herd behavior and the mimicry that takes place in financial markets, the aim of each investor being to guess in advance what the average opinion will be, it is somehow sensible for them to imitate the others. Thus, mirror neurons could provide a neurological underpinning for these erratic moves.

In any case, one must not hastily conclude that this is the end of the story. Neuroscience remains, so to speak, a science in its infancy. There are still many riddles to be unraveled and intrinsic limits to be removed or stretched and it may be unsure whether this can be done in the future. Nonetheless, as long as the SMH withstands criticism, it seems that it can stimulate research on animal spirits, thus substantiating Keynes's claims and catering to the needs of the further development of a psychological basis of economics.

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