SOMATIC MARKERS: THEATER IN THE BODY OR THEATER IN THE BRAIN?

Given my previous discussion on the physiology of emotions, you should expect not just one mechanism for the somatic-marker process but two. By virtue of the basic mechanism, the body is engaged by the prefrontal cortices and amygdala to assume a particular state profile, whose result is subsequently signaled to the somatosensory cortex, attended, and made conscious. In the alternative mechanism the body is bypassed and the prefrontal cortices and amygdala merely tell the somatosensory cortex to organize itself in the explicit activity pattern that it would have assumed had the body been placed in the desired state and signaled upward accordingly. The somatosensory cortex works as if it were receiving signals about a particular body state, and although the "as if" activity pattern cannot be precisely the same as the activity pattern generated by a real body state, it may still influence decision making.

"As if" mechanisms are a result of development. It is likely that as we were being socially "tuned" in infancy and childhood, most of our decision making was shaped by somatic states related to punishment and reward. But as we matured and repeated situations were categorized, the need to rely on somatic states for every instance of decision making decreased, and yet another level of economic automation developed. Decision-making strategies began depending in part on "symbols" of somatic states. To what extent we depend on such "as if" symbols rather than on the real thing is an important empirical question. I believe this dependence varies widely, from person to person, and from topic to topic. Symbolic processing may be advantageous or pernicious, depending on the topic and the circumstances.

OVERT AND COVERT SOMATIC MARKERS

The somatic marker itself has more than one avenue of action; it has one through consciousness and another outside consciousness.

Whether body states are real or vicarious ("as if"), the corresponding neural pattern can be made conscious and constitute a feeling. However, although many important choices involve feelings, a good number of our daily decisions apparently proceed without feelings. That does not mean that the evaluation that normally leads to a body state has not taken place; or that the body state or its vicarious surrogate has not been engaged; or that the regulatory dispositional machinery underlying the process has not been activated. Quite simply, a signal body state or its surrogate may have been activated but not been made the focus of attention. Without attention, neither will be part of consciousness, although either can be part of a covert action on the mechanisms that govern, without willful control, our appetitive (approach) or aversive (withdrawal) attitudes toward the world. While the hidden machinery underneath has been activated, our consciousness will never know it. Moreover, triggering of activity from neurotransmitter nuclei, which I described as one part of the emotional response, can bias cognitive processes in a covert manner and thus influence the reasoning and decision-making mode.

With due respect for humans and with all the caution that should be associated with comparisons across species, it is apparent that in organisms whose brains do not provide for consciousness and reasoning, covert mechanisms are the core of the decision-making apparatus. They are a means to build "predictions" of outcome and bias the organism's action devices for behaving in a particular way, which may appear to the external observer as a choice. This is, in all likelihood, how worker bumblebees "decide" on which flowers they should land in order to obtain the nectar they need to bring back to the hive. I am not proposing that deep inside each of our brains there is a bee brain deciding for us. Evolution is not the Great Chain of Being, and it has obviously taken many separate roads, one of which led to us. But I believe much can be gained by studying how simpler organisms perform such seemingly complicated tasks with modest neural means. Some mechanisms of the same type may operate in us too. That is all.

Honeysuckle Rose!

"You're confection, goodness knows, honeysuckle rose," so go the naughty lyrics of the Fats Waller jazz standard, and so goes the fate of the busy bee. The reproductive success and ultimate survival of a bee colony depend on how successful the foraging behavior of bumblebees turns out to be. If they do not work enough at collecting nectar, there will be no honey, and as energy resources dwindle, so will the colony.

Worker bees are equipped with a visual apparatus that allows them to distinguish colors of flowers. They are equipped also with a motor apparatus that allows them to fly and to land. As recent investigations have demonstrated, worker bees learn, after a few visits to flowers of different colors, which are more likely to contain the nectar that they must obtain. It is apparent that, out in a field, they do not land on every possible flower to discover whether there is or not nectar available in each one. They clearly behave as if they predict which flowers are more likely to have nectar, and they land on those flowers more frequently. In the words of Leslie Real, who has experimentally investigated the behavior of worker bumblebees, (*Bombus pennsylvanicus*), "Bees appear to form probabilities on the basis of frequency of encounter of different types of reward states, and begin with no prior estimation of likelihoods."[10] How can bees, with their modest nervous systems, produce behavior that is so suggestive of high reason, so seemingly indicative of the use of knowledge, probability theory, and goal-oriented reasoning strategy?

The answer is that the deliberation is apparently achieved by having a simple but powerful system capable of the following: First, detecting stimuli which are innately set as valuable and thus constitute a reward; and second, responding to the presence of reward (or lack thereof) with a bias, which can influence the motor system toward a particular behavior (e.g., landing or not), when the situation which delivered (or not) the reward (say, a flower of a given color) appears in the visual field. A recent model has been proposed by Montague, Dayan, and Sejnowski for such a system using both behavioral and neurobiological data.[11]

The bee does have a nonspecific neurotransmitter system, which probably uses octopamine, and which is not unlike the dopamine system in mammals. When the reward (nectar) is detected, the nonspecific system can signal to both visual and motor systems and thereby alter their basic behavior. As a result, on the next occasion in which the color that was associated with reward (say, yellow) appears in view, the motor system is prone to land on the flower so colored, and the bee is more likely to find nectar than not. The bee is in fact making a choice, not consciously, not deliberately, but rather using an automated device which incorporates specific natural values, a preference. According to Real, two fundamental aspects of preference must be present: "High expected gain will be preferred to low expected gain; low risk will be preferred to high risk." Incidentally, on the bee's manifestly small memory capacity (it has only short-memory and not an especially large one), the sampling on the basis of which the preference system operates must be extremely small. As few as three visits will apparently do. Again, I am not suggesting at all that our decisions come from a hidden bee brain, but I believe it is important to know that a device as simple as the one outlined above can perform as complicated a task as described here.

INTUITION

Acting at a conscious level, somatic states (or their surrogates) would mark outcomes of responses as positive or negative and thus lead to deliberate avoidance or pursuit of a given response option. But they may also operate covertly, that is, outside consciousness. The explicit imagery related to a negative outcome would be generated, but instead of producing a perceptible body-state change, it would inhibit the regulatory neural circuits located in the brain core, which mediate appetitive, or approach, behaviors. With the inhibition of the tendency to act, or actual enhancement of the tendency to withdraw, the chances of a potentially negative decision would be reduced. In the very least, there would be a gain of time, during which conscious deliberation might increase the probability of making an appropriate (if not the most appropriate) decision. Moreover, a negative option might be voided altogether, or a highly positive one made more likely by enhancement of the impulse to act. This covert mechanism would be the source of what we call intuition, the mysterious mechanism by which we arrive at the solution of a problem *without* reasoning toward it.

The role of intuition in the overall process of making decisions is illuminated in a passage by the mathematician Henri Poincaré, whose insight fits the picture I have in mind:

> In fact, what is mathematical creation? It does not consist in making new combinations with mathematical entities already known. Anyone could do that, but the combinations so made would be infinite in number and most of them absolutely without interest. To create consists precisely in not making useless combinations and in making those which are useful and which are only a small minority. Invention is discernment, choice.
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> How to make this choice, I have before explained; the mathematical facts worthy of being studied are those which, by their analogy with other facts, are capable of leading us to the knowledge of a mathematical law, just as experimental facts lead us to the knowledge of a physical law. They are those which reveal to us unsuspected kinship between other facts, long known, but wrongly believed to be strangers to one another.
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> Among chosen combinations the most fertile will often be those formed of elements drawn from domains which are far apart. Not that I mean as sufficing for invention the bringing together of objects as disparate as possible; most combinations so formed would be entirely sterile. But certain among them, very rare, are the most fruitful of all.
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> To invent, I have said, is to choose; but the word is perhaps not wholly exact. It makes one think of a purchaser before whom are displayed a large number of samples, and who examines them, one after the other, to make a choice. Here the samples would be so numerous that a whole lifetime would not suffice to examine them. This is not the actual state of things. The sterile combinations do not even present themselves to the mind of the inventor. Never in the field of his consciousness do combinations appear that are not really useful, except some that he rejects but which have to some extent the characteristics of useful combinations. All goes on as if the inventor were an examiner for the second degree who would only have to question the candidates who had passed a previous examination.[12]

Poincaré's view is similar to the one I am proposing. You do not have to apply reasoning to the entire field of possible options. A preselection is carried out for you, sometimes covertly, sometimes not. A biological mechanism makes the preselection, examines candidates, and allows only a few to present themselves for a final exam. This proposal, it should be noted, is intended cautiously for the personal and social domain for which I have supporting evidence, although Poincaré's insight suggests that the proposal might be extended to other domains.

The physicist and biologist Leo Szilard made a similar point: "The creative scientist has much in common with the artist and the poet. Logical thinking and an analytical ability are necessary attributes to a scientist, but they are far from sufficient for creative work. Those insights in science that have led to a breakthrough were not logically derived from preexisting knowledge: The creative processes on which the progress of science is based operate on the level of the subconscious."[13] Jonas Salk has forcefully articulated the same insight and proposed that creativity rests on a "merging of intuition and reason."[14] It is thus appropriate at this point to say a word about reasoning outside the personal and social realm.

REASONING OUTSIDE THE PERSONAL AND SOCIAL DOMAINS

The squirrel in my backyard that runs up a tree to take cover from the neighbor's adventurous black cat has not reasoned much to decide on his action. He did not really think about his various options and calculate the costs and benefits of each. He saw the cat, was jolted by a body state, and he ran. I am looking at him now, in the solid branch of my pin oak, his heart pounding so strongly that I can see the ribcage flail, his tail beating to the nervous rhythm of squirrel fear. He had a powerful emotion and now he is just upset.

Evolution is thrifty and tinkering. It has had available, in the brains of numerous species, decision-making mechanisms that are body-based and survival-oriented, and those mechanisms have proven successful in a variety of ecological niches. As the environmental contingencies increased and as new decision strategies evolved, it would have made economical sense if the brain structures required to support such new strategies would retain a functional link to their forerunners. Their purpose is the same, survival, and the parameters that control their operation and measure their success are also the same: well-being, absence of pain. Examples abound to demonstrate that natural selection tends to work precisely this way, by conserving something that works, by selecting other devices which can cope with greater complexity, rarely evolving entirely new mechanisms from scratch.

It is plausible that a system geared to produce markers and signposts to guide "personal" and "social" responses would have been co-opted to assist with "other" decision making. The machinery that helps you decide whom to befriend would also help you design a house in which the basement will not flood. Naturally, somatic markers would not need to be perceived as "feelings." But they would still act covertly to highlight, in the form of an attentional mechanism, certain components over others, and to control, in effect, the go, stop, and turn signals necessary for some aspects of decision making and planning in nonpersonal, nonsocial domains. This seems the kind of general marker device that Tim Shallice has proposed for decision making, although he has not specified a neurophysiological mechanism for his markers; in a recent article, Shallice comments on a possible similarity.[15] The underlying physiology

might be the same: body-based signaling, conscious or not, on the basis of which attention can be focused.

From an evolutionary perspective, the oldest decision-making device pertains to basic biological regulation; the next, to the personal and social realm; and the most recent, to a collection of abstract-symbolic operations under which we can find artistic and scientific reasoning, utilitarian-engineering reasoning, and the developments of language and mathematics. But although ages of evolution and dedicated neural systems may confer some independence to each of these reasoning/decision-making "modules," I suspect they are all interdependent. When we witness signs of creativity in contemporary humans, we are probably witnessing the integrated operation of sundry combinations of these devices.

THE HELP OF EMOTION, FOR BETTER AND FOR WORSE

The work of Amos Tversky and Daniel Kahneman demonstrates that the objective reasoning we employ in day-to-day decisions is far less effective than it seems and than it ought to be.[16] To put it simply, our reasoning strategies are defective and Stuart Sutherland strikes an important chord when he talks about irrationality as an "enemy within."[17] But even if our reasoning strategies were perfectly tuned, it appears, they would not cope well with the uncertainty and complexity of personal and social problems. The fragile instruments of rationality need special assistance.

The picture is, however, even more complicated than I have suggested so far. Although I believe a body-based mechanism is needed to assist "cool" reason, it is also true that some of those body-based signals can impair the quality of reasoning. Reflecting on the investigations of Kahneman and Tversky, I see some failures of rationality as not just due to a primary calculation weakness, but also due to the influence of biological drives such as obedience, conformity, the desire to preserve self-esteem, which are often manifest as emotions and feelings. For instance, most people fear flying more than they do driving, in spite of the fact that a rational calculation of risk unequivocally demonstrates that we are far more likely to survive a flight between two given cities than a car ride between those two same cities. The difference, by several orders of magnitude, favors flying over driving. And yet most people feel more safe driving than flying. The defective reasoning comes from the so-called "availability error," which, in my perspective, consists of allowing the image of a plane crash, with its emotional drama, to dominate the landscape of our reasoning and to generate a negative bias against the correct choice. The example may appear to be at odds with my main argument but it is not. It shows that biological drives and emotions *can* demonstrably influence decision making, and it suggests that the body-based "negative" influence, although out of step with actual statistics, is nonetheless survival-oriented: planes do crash now and then, and fewer people survive plane crashes than survive car crashes.

But while biological drives and emotion may give rise to irrationality in some circumstances, they are indispensable in others. Biological drives and the automated somatic-marker mechanism that relies on them are essential for some rational behaviors, especially in the personal and social domains, although they can be pernicious to rational decision-making in certain circumstances by creating an overriding bias against objective facts or even by interfering with support mechanisms of decision making such as working memory.

An example from my experience will help clarify the ideas discussed above. Not too long ago, one of our patients with ventromedial prefrontal damage was visiting the laboratory on a cold winter day. Freezing rain had fallen, the roads were icy, and the driving had been hazardous. I had been concerned with the situation and I asked the patient, who had been driving himself, about the ride, about how difficult it had been. His answer was prompt and dispassionate: It had been fine, no different from the usual, except that it had called for some attention to the proper procedures for driving on ice. The patient then went on to outline some of the procedures and to describe how he had seen cars and trucks skidding off the roadway because they were not following these proper, rational procedures. He even had a particular case in point, that of a woman driving ahead of him who had entered a patch of ice, skidded, and rather than gently pulling away from the tailspin, had panicked, hit the brakes, and gone zooming into a ditch. One instant later, apparently unperturbed by this hair-raising scene, my patient crossed the ice patch and drove calmly and surely ahead. He told me all this with the same tranquillity with which he obviously had experienced the incident.

There is not much question that in this instance not having a normal somatic-marker mechanism was enormously advantageous. Most of us would have had to use a deliberate overriding decision to stop us from hitting the brakes, out of panic or out of sheer feeling for the unfortunate driver in front of us. This exemplifies how automated somatic-marker mechanisms can be pernicious to our behavior, and how, under some circumstances, their absence can be an advantage.

The scene now changes to the following day. I was discussing with the same patient when his next visit to the laboratory should take place. I suggested two alternative dates, both in the coming month and just a few days apart from each other. The patient pulled out his appointment book and began consulting the calendar. The behavior that ensued, which was witnessed by several investigators, was remarkable. For the better part of a half-hour, the patient enumerated reasons for and against each of the two dates: previous engagements, proximity to other engagements, possible meteorological conditions, virtually anything that one could reasonably think about concerning a simple date. Just as calmly as he had driven over the ice, and recounted that episode, he was now walking us through a tiresome cost-benefit analysis, an endless outlining and fruitless comparison of options and possible consequences. It took enormous discipline to listen to all of this without pounding on the table and telling him to stop, but we finally did tell him, quietly, that he should come on the second of the alternative dates. His response was equally calm and prompt. He simply said: "That's fine." Back the appointment book went into his pocket, and then he was off.

This behavior is a good example of the limits of pure reason. It is also a good example of the calamitous consequence of not having automated mechanisms of decision making. An automated somatic-marker mechanism would have helped the patient in more ways than one. To begin with, it would have improved the overall framing of the problem. None of us would have spent the amount of time the patient took with this issue, because an automated somatic-marker device would have helped us detect the useless and indulgent nature of the exercise. If nothing else, we would have realized how ridiculous the effort was. At another level, sensing the potentially wasteful approach, we would have opted for one of the alternative dates with the equivalent of tossing a coin or relying on some kind of gut feeling for one or the other date. Or we might simply have turned the decision over to the person asking the question and replied that it really did not matter, that he should choose.

In short, we would picture the waste of time and have it marked as negative; and we would picture the minds of others looking at us, and have that marked as embarrassing. There is reason to believe that the patient did form some of those internal "pictures" but that the absence of a marker prevented those pictures from being properly attended and considered.

If you are wondering how bizarre it is that biological drives and emotion may be *both* beneficial and pernicious, let me say that this would not be the only instance in biology in which a given factor or mechanism may be negative or positive according to the circumstances. We all know that nitric oxide is toxic. It can pollute the air and poison the blood. Yet this same gas functions as a neurotransmitter, sending signals between nerve cells. An even subtler example is glutamate, another neurotransmitter. Glutamate is ubiquitous in the brain, where it is used by one nerve cell to excite another. Yet when nerve cells are damaged, as in a stroke, they release excessive glutamate into the surrounding spaces, and thus cause overexcitation and

eventually death of the innocent and healthy nerve cells in the vicinity.

Ultimately, the question raised here concerns the type and amount of somatic marking applied to different frames of the problem being solved. The airline pilot in charge of landing his aircraft in bad weather at a busy airport must not allow feelings to perturb attention to the details on which his decisions depend. And yet he must have feelings to hold in place the larger goals of his behavior in that particular situation, feelings connected with the sense of responsibility for the life of his passengers and crew, and for his own life and that of his family. Too much feeling at the smaller frames or too little at the larger frame can have disastrous consequences. Floor traders at a stock exchange are in a similar predicament.

A fascinating illustration of these points can be found in a study involving Herbert von Karajan.[18] The Austrian psychologists G. and H. Harrer were allowed to observe the pattern of von Karajan's autonomic responses in several circumstances: while he landed his private jet at the Salzburg airport, while he conducted in the recording studio, and while he listened to the playback of the recorded piece (the piece was Beethoven's *Leonora* Overture No. 3).

Von Karajan's musical performance was punctuated by large response changes. His pulse rate went up more dramatically during passages of emotional impact than during passages of actual physical exertion. The profile of his pulse rate when he listened to the playback was parallel to that obtained during the recording. The good news is that Mr. Karajan landed his plane like a dream and even when he was told, after touchdown, to make an emergency takeoff in a steep ascent angle, his pulse increased a bit but far less so than during his musical exercises. His heart was in the music, as well it should have been, and as I once discovered personally at a concert: Just before he lowered the baton to begin a performance of Beethoven's Sixth, I whispered something to my wife, who was sitting next to me. Von Karajan froze the movement of his arm, turned around, and fulminated at me with his eyes. Too bad nobody measured our respective pulses.

BESIDE AND BEYOND SOMATIC MARKERS

Necessary as something like the somatic-marker mechanism may be to construct a neurobiology of rationality, it is apparent that necessity does not make for sufficiency. As I indicated in my account, logical competence does come into play beyond somatic markers. Moreover, several processes must precede, co-occur with, or immediately follow somatic markers, to permit their operation. What are those processes, and can anything be ventured about their neural substrate?

What else happens when somatic markers, overtly or covertly, do their biasing job? What happens in your brain so that the images over which you reason are sustained over the necessary time intervals? To address these questions, let us return to a problem outlined at the beginning of the chapter. What dominates the mind landscape once you are faced with a decision is the rich, broad display of knowledge about the situation that is being generated by its consideration. Images corresponding to myriad options for action and myriad possible outcomes are activated and keep being brought into focus. The language counterpart of those entities and scenes, the words and sentences that narrate what your mind sees and hears, is there too, vying for the spotlight. This process is based on a continuous creation of combinations of entities and events, resulting in a richly diverse juxtaposition of images which accords with previously categorized knowledge. Jean-Pierre Changeux has proposed the descriptor "generator of diversity" for the prefrontal structures which presumably carry out this function and lead to the formation of a large repertoire of images elsewhere in the brain. This is an especially apt descriptor since it conjures up its immunological forerunner, and generates itself a curious acronym.[19]

This generator of diversity requires a vast store of factual knowledge, about the situations we may face, about the actors in those

situations, about what they can do and how their varied actions produce varied outcomes. Factual knowledge is categorized (the facts that constitute it being organized by classes, according to constituent criteria), and categorization contributes to decision making by classifying types of options, types of outcomes, and connections of options to outcomes. Categorization also ranks options and outcomes relative to some particular value. When we face a situation, prior categorization allows us to discover rapidly whether a given option or outcome is likely to be advantageous, or how diverse contingencies can modify the degree of advantage.

The process of knowledge display is possible only if two conditions are met. First, one must be able to draw on mechanisms of *basic attention,* which permit the maintenance of a mental image in consciousness to the relative exclusion of others. In neural terms, this probably depends on enhancement of the neural activity pattern that sustains a given image, while other neural activity around it is depressed.[20] Second, one must have a mechanism of *basic working memory,* which holds separate images for a relatively "extended" period of hundreds to thousands of milliseconds (from tenths of a second to a number of consecutive seconds).[21] This means that the brain reiterates over time the topographically organized representations supporting those separate images. There is, of course, an important question to be asked at this point: what drives basic attention and working memory? The answer can only be *basic value,* the collection of basic preferences inherent in biological regulation.

Without basic attention and working memory there is no prospect of coherent mental activity, and, to be sure, somatic markers cannot operate at all, because there is no stable playing field for somatic markers to do their job. However, attention and working memory probably continue to be required even after the somatic-marker mechanism operates. They are necessary for the process of reasoning, during which possible outcomes are compared, rankings of results are established, and inferences are made. In the full somatic-marker hypothesis, I propose that a somatic state, negative or positive, caused by the appearance of a given representation, operates not only as a *marker for the value of what is represented, but also as a booster for continued working memory and attention.* The proceedings are "energized" by signs that the process is actually being evaluated, positively or negatively, in terms of the individual's preferences and goals. The allocation and maintenance of attention and working memory do not happen by miracle. They are first motivated by preferences inherent in the organism, and then by preferences and goals acquired on the basis of the inherent ones.

In terms of the prefrontal cortices, I am suggesting that somatic markers, which operate on the bioregulatory and social domain aligned with the ventromedial sector, influence the operation of attention and working memory within the dorsolateral sector, the sector on which operations on other domains of knowledge depend. This leaves open the possibility that somatic markers also influence attention and working memory within the bioregulatory and social domain itself. In other words, in normal individuals, somatic markers which arise out of activating a particular contingency boost attention and working memory throughout the cognitive system. In patients with damage in the ventromedial region, all of these actions would be compromised to a smaller or greater degree.

BIASES AND THE CREATION OF ORDER

There are thus three supporting players in the process of reasoning over a vast landscape of scenarios generated from factual knowledge: *automated somatic states,* with their biasing mechanisms; *working memory;* and *attention.* All three supporting players interact and all three seem concerned with the critical problem of creating order out of parallel spatial displays, a problem first recognized by Karl Lashley, which arises because the brain's design only permits, at any one time, a limited amount of conscious mental output and movement output.[22] The images which constitute our thoughts must be structured in "phrases," which in turn must be "sententially" ordered in time, just as the frames of movement which constitute our external responses must be "phrased" in a particular way and those

phrases placed in a particular "sentential" order for a motion to have its desired effect. The selection of the frames that end up composing the "phrases" and "sentences" of our mind and movement is made from a parallel display of possibilities. And because both thought and movement require concurrent processing, the organization of several ordered sequences must go on continuously.

Whether we conceive of reason as based on automated selection, or on a logical deduction mediated by a symbolic system, or—preferably—both, we cannot ignore the problem of order. I propose the following solution: (1) If order is to be created among available possibilities, then they must be ranked. (2) If they are to be ranked, then criteria are needed (values or preferences are equivalent terms). (3) Criteria are provided by somatic markers, which express, at any given time, the cumulative preferences we have both received and acquired.

But how do somatic markers function as criteria? One possibility is that when different somatic markers are juxtaposed to different combinations of images, they modify the way the brain handles them, and thus operate as a bias. The bias might allocate attentional enhancement differently to each component, the consequence being the automated assigning of *varied degrees* of attention to *varied contents,* which translates into an uneven landscape. The focus of conscious processing could be driven then from component to component, for instance, according to their rank in a progression. For all this to happen, the components must remain displayed for an interval of time of hundreds to a few thousand milliseconds, in relatively stable fashion, and that is what working memory achieves. (I found some support for this general idea in recent studies on the neurophysiology of perceptual decision by William T. Newsome and his colleagues. A change in the balance of signals applied to a particular neuron population representing a particular content resulted in a "decision" in favor of that content by what appeared to be a "winner-take-all" mechanism.[23])

Normal cognition and movement require organization of concurrent and interactive sequences. Where there is a need for order there is a need for decision, and where there is a need for decision there must be a criterion to make that decision. Since many decisions have an impact on an organism's future, it is plausible that some criteria are rooted, directly or indirectly, in the organism's biological drives (its reasons, so to speak). Biological drives can be expressed overtly and covertly, and used as a marker bias enacted by attention in a field of representations held active by working memory.

The automated somatic-marker device of most of us lucky enough to have been reared in a relatively healthy culture has been accommodated by education to the standards of rationality of that culture. In spite of its roots in biological regulation, the device has been tuned to cultural prescriptions designed to ensure survival in a particular society. If we assume that the brain is normal and the culture in which it develops is healthy, the device has been made rational relative to social conventions and ethics.

The action of biological drives, body states, and emotions may be an indispensable foundation for rationality. The lower levels in the neural edifice of reason are the same that regulate the processing of emotions and feelings, along with global functions of the body proper such that the organism can survive. These lower levels maintain direct and mutual relationships with the body proper, thus placing the body within the chain of operations that permit the highest reaches of reason and creativity. Rationality is probably shaped and modulated by body signals, even as it performs the most sublime distinctions and acts accordingly.

David Hume, who was keenly aware of the value of the emotions, might not disagree with the statements above, and Pascal, who said that "the heart has reasons that reason does not know at all," might have found the preceding account plausible.[24] If I might be permitted to modify his statement: *The organism has some reasons that reason must utilize*. That the process continues beyond the reasons of the heart is not in doubt. For one thing, using the instruments of logic, we can check on the validity of the selections

our preferences have helped make. For another, we can go beyond them using the strategies of deduction and induction in readily available language propositions. (After completing this manuscript, I came across several compatible voices. J. St. B.T. Evans has recently proposed that there are two types of rationality, largely concerned with the two domains I have outlined here [personal/social and not]; the philosopher Ronald De Sousa has argued that emotions are inherently rational; and P.N. Johnson-Laird and Keith Oatley have suggested that basic emotions help manage actions in a rational way.[25])