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Emotions as a mechanism for boundedly rational agents: The fast and frugal way

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Abstract

Herbert Simon has warned us that an explanatory account of human rationality must identify the significance of emotions for choice behavior. Customarily emphasizing the cognitive dimensions of decision making, relatively few researchers have paid close attention to specifying the complex ways in which emotion may shape human thinking and decisions. Accordingly, this paper is an attempt to follow Simon's suggestion and specify how emotions can enter into the theory of bounded rationality. To accomplish our task, we capitalize on Rom Harré's work on causal powers, from which we propose a strategy to study the significance of emotion in decision-making processes. In an attempt to elaborate on an explanation of behavior by mechanism, we discuss a version of bounded rationality recently put forward by Gigerenzer, Todd, and the ABC Research Group [Simple Heuristics that Make us Smart, Oxford University Press, New York, 1999] and Gigerenzer and Selten [Bounded Rationality: The Adaptive Toolbox, MIT Press, Cambridge, MA, 2001, pp. 1–12], the so-called adaptive toolbox of fast and frugal heuristics. Coupled with insights from evolutionary psychology and neuroscience, this version of bounded rationality gives us a better grasp of the functional role of emotions within the human decision machinery.

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> Hence, in order to have anything like a complete theory of human rationality, we have to understand what role emotion plays in it.
>
> (Herbert Simon, *Reason in Human Affairs*, p. 29)

1. Introduction

In his book *Reason in Human Affairs*, Herbert Simon (1983) warns us that an explanatory account of human rationality must identify the significance of emotions for choice behavior. Customarily emphasizing the cognitive dimensions of decision making, relatively few researchers have paid close attention to specifying the complex ways in which emotions influence human thinking and decisions (including Simon himself; but see Simon, 1967, 1983). Accordingly, we aim to follow Simon's advice and propose to specify how emotions can be accommodated into the theory of bounded rationality (BR). Integrating emotions into the BR framework could illuminate the underlying mental processes that govern human decision making.

Emotions, we argue, play a central role in guiding and regulating choice behavior, by virtue of their capacity to modulate numerous cognitive and physiological activities. By coordinating specific instances of cognitive processing and physiological functioning, emotions are one of the tools that allow agents to make (often) adaptive inferences and choices (Levenson, 1999). Since we view emotions as constituting part of the adaptive toolbox of specialized heuristic processes, we entertain the notion that they can be studied as content and domain specific. With this in mind, an account of decision making – in terms of a mechanism composed of specialized cognitive processes that are governed by emotions – will be provided. It is worthwhile to stress that our paper calls into question the view that emotions are but sand in the decision machinery. Instead, we offer a framework that can assist in evaluating the cases in which emotions lead to fast and adaptive behavior responses.

The paper is structured as follows. In Section 2 we discuss the philosophical guidelines necessary for studying the causal relevance of emotions, maintaining that emotions can be studied as a network of interacting cognitive and physiological processes (with neural underpinnings) that produce stable and predictable behavior patterns. To do so, we spell out certain enabling and triggering conditions that emotions may satisfy in order to have the causal power of guiding individual judgments and decisions. In the third section, we clarify the confusion surrounding the notion of BR. Our interpretation of BR closely follows Gigerenzer, Todd, and the ABC Research Group's (1999) notion of the adaptive toolbox of heuristics. This vision of BR implies that emotions, seen as a constellation of domain-specific heuristics, are among the building blocks of the configuration of our mental architecture. Sections

4 and 5 will, respectively, discuss the theoretical and methodological implications emerging from our discussion with a focus on ongoing research in behavioral economics. Section 6 will wrap up the argument and concluding remarks will follow.

2. Philosophical guidelines: Emotions as causally powerful processes

A growing number of students of epistemology and economic methodology have labored hard to show that an explanatory account of behavior is meant to uncover the mechanisms or processes that produce the phenomenon under study (Elster, 1983; Machamer, Darden, & Craver, 2000; Muramatsu, 2004). According to this view, an "explanation by mechanism" is the most promising way to elucidate how the *explanandum* comes about and what it is that makes the phenomenon occur in the way that it does. Our argument is built upon the idea that an explanatory account of choice behavior requires us to uncover mental processes or mechanisms productive of judgment and decision making in the real world.

It is important to acknowledge that many philosophers disagree on a precise account of what a mechanism is. We suggest an interpretation of mechanism that is applicable to the explanatory purposes of behavioral scientists (including economists and psychologists). A mechanism for a behavior can be understood as a system made up of processes (with specific inner properties) that interact in a systematic fashion to generate a non-random behavioral output (Glennan, 2002; Machamer et al., 2000). In our opinion, the merit of an explanation that captures a mechanism (also known as explanation by mechanism) lies in its ability to offer scientists firmer ground for distinguishing genuinely causal relations from spurious correlations; law-like generalizations from accidental ones; real effects from artifacts, and so forth.

To work out an explanation of decision making that describes a mechanism significant for rational behavior, and why (and how) specific emotional processes are causally productive of choice behavior, we will capitalize on Harré's (1970) work on causal powers. He argues that ascribing to a thing or a person a causal power requires that we specify whether such a thing or a person satisfies certain enabling and triggering conditions.

2.1. Enabling conditions and emotions

According to Harré, enabling conditions are those requirements that, when satisfied, allow one to hypothesize that a thing (or a person) has a causal power; it is in a state of readiness or has a certain inner disposition to act (Harré, 1970; Harré & Madden, 1975). To illustrate, take the case of dynamite. Dynamite has the power to explode [4] because of its inner chemical components that have certain properties, such as nitroglycerin. Quite analogously, it can be suggested that emotions equip

[4] It is common to describe emotional reaction and expression as 'an explosion.' Being able to invoke such emotional reactions might provide an advantage, as they can allow agents to create the necessary conditions to cause others to 'explode'.

individuals with the capacity to make quick inferences and decisions by virtue of their properties that give rise to changes in cognitive and physiological functioning.

Ample research has shown that emotions affect various cognitive processes. For the purposes of this paper, it is sufficient to touch briefly on three of them: (i) attention, (ii) learning, and (iii) memory.

There is empirical evidence that emotions play an important role in focusing agents' attention on the most urgent and important pieces of information within a particular environmental structure, while overlooking more peripheral ones (Faucher & Tappolet, 2002). To paraphrase Simon, emotions play a central role in directing our attention – they distract us from our current thoughts and actions and call our attention to tasks that require our immediate attention (1983, p. 21; for a discussion on the need to treat attention as a scarce resource and the difficulties of explaining attention allocation by standard choice framework, see Berger, 1989). [5] For example, the elicitation of fear prompts agents to focus their attention on the importance of the incoming stimulus (while ignoring all other pieces of information), with the aim of properly allocating efforts to search for fast and effective solutions (Öhman & Mineka, 2001). Holland and Gallagher (1999, p. 68) tell us that via attention-directing processes emotions also deploy needed resources for learning. [6] Taken together, "these functions increase the likelihood that the most appropriate cues will control behavior" (Holland & Gallagher, 1999). Cognitive neuroscientists have also found that the amygdala – a key brain structure of emotional processing – is involved is assessing the significance of an incoming stimulus that subsequently influences attention and reaction.

A growing corpus of evidence shows how emotions exert a substantive influence on learning (LeDoux, 1996; Mineka & Cook, 1988). The conscious affective component of an emotion process and the bodily expression associated with it enable individuals to learn from their own experiences and from others' interactions within the environment. This quality of emotions facilitates individuals' inferences about the consequences associated with an alternative course of action. Consider these illustrations. Soldiers respond quickly and automatically to the sound of bullets because previous experiences taught them to appraise this as a cue for danger. Young children who see their parents and friends fearful of swimming in a particular lake might

[5] Koestler's (1967) example of driving under different conditions can be illustrative, especially when we consider the need to switch from unconscious to conscious operations. Experienced drivers do not need to pay much attention to driving; they perform the act effortlessly, as if it were second nature, and thus can devote their entire attention to the traffic around them. On the other hand, when faced with an emergency or difficult driving conditions, drivers suddenly have to pay close attention to their own actions, reducing in the process the level of attention that can be allocated to the traffic.

[6] Among economists, it is worth noting Shackle's (1961) earlier attempt to incorporate attention into his theory of choice under uncertainty. Shackle's intuition, though he made no reference to emotions, was based on the idea that to catch our attention the various options or outcomes before us need to offer both plausible and substantial gains (or losses) from our present reference point. More recently, DellaVigna and Pollet (2003) have offered an interesting discussion regarding whether investors pay enough attention to long-term fundamentals.

infer that this is a dangerous thing to do without having to examine it on their own. According to Damasio, "emotions of all shades eventually help connect homeostatic regulation and survival 'values' to numerous events and objects in our autobiographical experience" (Damasio, 1999, pp. 54–55). The influence of emotions in this version of cognitive processing highlights the plausibility of Damasio's (1994) somatic marker hypothesis, where the feeling component of emotions serves as a source of inference about the expected hedonic consequences of various options.

Memory processes are intimately related to learning and they are also influenced by emotion. This is partially due to their role in activating and regulating activities involved in encoding, storing, and retrieving information about important events. Research on emotion and memory shows that the activation of emotions affects the ways in which individuals reconstruct previously experienced situations. Experimental psychologists have stressed that individuals tend to remember more easily events that triggered strong emotions in comparison to incidents that were emotionally neutral (Bower, 1981). Based on a series of experiments, Bower (1981; Bower & Cohen, 1982) suggests that individuals in whom happy feelings are induced tend to remember pleasant events more easily and more precisely than unpleasant ones, whereas individuals experiencing unhappy feelings tend to recall sad incidents in a more accurate manner – a phenomenon known as mood recall congruency. In essence, the idea is that "people's feeling affects what records they can retrieve from memory. People can best retrieve events originally learned in a particular mood by somehow reinstating or returning to that same mood" (Bower & Cohen, 1982, p. 214). That is, emotional events are typically better recalled in comparison to non-emotional events (Christianson, 1992). One explanation of this phenomenon has been the idea that emotional information has privileged access to processing resources, which could possibly lead to better memory formation (Dolcos & Cabeza, 2002).

Another line of research found that during high emotional states animals and humans release high levels of β-adrenergic hormones – hormones that are a central ingredient in modulating memory storage and are largely connected to activation of the amygdala (Cahill, 2000). More recently, researchers have found that "the degree to which the activity of the human amygdala related to memory increased almost linearly with the degree of subjective arousal induced by the stimuli" (Packard & Cahill, 2001, p. 754). Canli et al. (1998, using functional magnetic resonance imaging) have drawn a similar conclusion, arguing that amygdala activation improves memory as a function of the level of emotional intensity – either positive or negative – of an experience. The above ideas fit nicely with recent neuroscientists' findings that the amygdala has strong and extensive connections with other brain regions involved with memory, such as the hippocampus and lateral prefrontal cortex (LeDoux, 1996; Panksepp, 1998). Though he lacked the necessary sophisticated machinery to test his thesis, William James foreshadowed these modern finding: "An impression may be so exciting emotionally as almost to leave a scar upon the cerebral tissues... The primitive impression has been accompanied by extraordinary degree of attention, either as being horrible or delightful" (James, 1890, quoted in Hamann, 2001, p. 394).

With this in mind, it can be suggested that emotional processing brings about changes in mental and bodily functioning that are necessary for effective and adaptive responses. But emotions can only exercise such capacity if they meet some extrinsic requirements called triggering conditions.

2.2. Triggering conditions for emotional processing

Harré (1970) emphasized that a thing or person has the power to generate a behavior pattern by virtue of its inner properties. Recall the above example of the dynamite – the capacity for explosion is understood in terms of its chemical properties. The existence of these internal attributes, however, does not guarantee the actual exercise of the capacity. Unless a dynamite stick is lighted, it will not perform its capacity for explosion. We extend this line of reasoning to our discussion of the causal powers of emotions.

To us, some triggering conditions, under which some emotion programs operate, resemble Sperber's (1996) initialization conditions. The latter amount to the mental representations that are outputs of sensory and conceptual processes. The functional role of these sensory and conceptual processes is to supply information for one's detection and categorization of an incoming stimulus. With regard to emotion systems, the initialization factors are content-specific mental representations that jointly detect and categorize recurrent adaptive problems a species has confronted throughout its evolutionary history. When such mental representations inform an agent about a recurrent danger or opportunity with survival value, a specialized and specific emotion program will be activated to prepare the agent to behave adaptively. That is, the emotional system produces physiological and cognitive activities that allow agents to behave adaptively. For example, the initialization of the disgust program prepares an agent to avoid the danger of being poisoned by food. This would reveal that there is some content specificity in the conditions that initialize the operation of a specialized emotion system.

The actual triggers of behavior are here assumed to be the mental algorithms activated by the experiences of an emotion. The underlying idea is that an emotion focuses an agent's attention on a selective search for alternatives. It also conditions one's aspiration level by altering perceived goal prioritization and as such determines a criterion by which an agent will make a satisfactory selection of action. Even though the above conditions might generate adaptive behavior, they might also generate maladaptive or biased responses. The latter may occur when the structure of one's chosen choice strategy fails to match the structure of the task environment. Fear, for example, will give rise to an adaptive behavioral response if an emotion-eliciting stimulus (a predator) prompts one to select a choice strategy (at the sight of an approaching lion, run away!) that matches with the structure of a certain environment (e.g. African savannah). When the structure of the decision heuristic is not in tune with the structure of the environment (in which the task is embedded), maladaptive responses will take place. Kelly's work (1955) could offer an additional angle on the role of emotions within the decision-making process. From Kelly's perspective, it is not only how the environmental cues trigger emotional programs, but

how agents construct or view the environment that, in return, affects what emotional program is likely to be activated. This framework suggests that when external conditions (which might be similar to our notion of triggering conditions) are aligned with a person's core construct, decisions will tend to follow a more reflective procedure. In contrast, an emotion-driven behavior is expected to occur when a chasm exists between a person's core construct and the environmental challenges she or he faces (1955, p. 495; for an application of Kelly's work in an economic framework see Earl, 1983, 1986). Examined from this point of view, dysfunctional behavior could be explained as a function of a person's core constructs in relation to the task at hand.

As we can see, a perspective on causal powers highlights the significance of emotions for judgment and decision making in the real world. To some extent, the above conceptual apparatus offers a first step toward an explanation of choice behavior that spells out how emotions shape the various components and inner workings of the decision machinery.

2.3. From mechanism to discourse and back

Harré's (1970) account of causal powers was driven by his enthusiasm for the philosophical doctrine of scientific realism. The latter maintains that we can best explain a phenomenon by unveiling its generative (causal) processes or mechanism and therefore approximate to the truth about the explanandum phenomenon under study. This attitude toward theorizing and explanation promises to improve our understanding of the place of the explanandum in the causal structure of the world (Salmon, 1984).

In the 1980s, however, Harré began raising doubts about the adequacy of a psychological explanation of behavior that captures its underlying causal cognitive processes or mechanisms (Harré, 1983; Harré & Gillett, 1994). This line of explanation, Harré believed, is embedded in a vision of psychological theorizing that reified a non-social account of human action and led to an undersocialized view of humans as a bunch of hidden mechanisms. Inspired by Wittgenstein's (1953) and Vygotsky's (1962) writings, Harré argues for a turn in the study of psychology called the "Second Cognitive Revolution" (Harré, 2001). He characterizes this movement as the abandonment of the form of scientific realism, which motivated earlier cognitive scientists to account for behavior in terms of hidden cognitive mechanisms (with causal powers). Furthermore, he claims that conversation rather than information processing is the key player of human cognition. Thus, he argued that to avoid the danger of conflating causal relations with social rules and regularities that shape psychological phenomenon one needs to employ a different conceptual strategy: a shift from the information-processing approach to a conversational perspective on human thought and action. This led Harré to reject his earlier ideas about scientific psychological explanations and to regard himself as being a conversational realist. Harré came to argue that psychological phenomena are to be explained in terms of social exchange and negotiation processes of symbolic (linguistic) representations, which are in turn shaped by rules of conversation (rather than cognitive processes).

We are not convinced that the conversational alternative to realism can resolve the metaphysical problems associated with the issue of causality in behavioral theorizing and explanation. In addition, Harré seems to make a very partial characterization of the state-of-the-art in contemporary cognitive science. He argues that adherents of the second cognitive revolution have abandoned the information-processing approach to cognition in favor of a neural-processes approach. This is a bold claim that requires empirical substantiation. As far as we can see, current researchers do not reject the computer metaphor suggested by Simon, but rather have shifted their focus to the study of neural processes as a source of information about cognitive processes (mental algorithms) that might be causally productive of behavior. Even though some concentrate on describing behavioral phenomena at the neural level, most recognize the need for complementary levels of explanations of processes and mechanisms so as to avoid the implications of reductive materialism (cf. Marr, 1982).

The merit of recent developments in cognitive sciences is to enhance our understanding of the inextricable links between emotion and cognition. Based on an information-processing framework that is grounded in specialized neural structures, we can argue that the Lazarus–Zajonc debate in the 1980s concerning the primacy of cognition over emotion produced more heat than light. This is partly so because there is now evidence lending support to both sides. It seems that an individual cannot react emotionally unless an incoming stimulus is identified and promptly (automatically, unconsciously) appraised as carrying a specific value. If this is so, Lazarus (1984) is correct in his argument that some type of cognition (information processing) precedes elicitation of an emotional response. But we can also think of studies that substantiate Zajonc's (1980) thesis that some basic emotions prepare an individual to respond immediately (in a reflex-like fashion) before she or he has formed any awareness of the information. Finally, some have attributed the discrepancy between the two approached to the way Lazarus and Zajonc define and employ the terms "cognition" and "emotion" (Nussbaum, 2001; Parkinson & Manstead, 1992). The "heuristic surplus value" of an information-processing approach grounded in neuroscience is that it informs us why and how emotion and cognition are inextricably linked conceptual categories.

The neuroscientist's research strategy, we believe, allows us to extend the information-processing metaphor and add to our understanding of why and how emotion and cognition work together to produce behavior. From this perspective, an emotion amounts to a content- and domain-specific processing system that is activated if and when certain sensory and conceptual inputs are met. Besides, an information-processing approach to the mental architecture of the brain presupposes a different conceptualization of cognition: It refers to all brain information-processing activities. [7]

[7] According to Cosmides and Tooby (2000, p. 98), "the term cognition is often used to refer to a particular subset of information processing – roughly the effortful, conscious, voluntary, deliberate... However, from an evolutionary cognitive perspective, ... cognition refers to a language describing all of the brain's operations, including emotion and reasoning... If the brain evolved as a system of information processing relations, then emotions are in an evolutionary sense, best understood as information processing relations (programs)."

As a result, emotions can be viewed as information-processing systems just like memory and perception. However, they differ from each other by the peculiarities of their mode of processing (e.g. controlled, automatic, informationally encapsulated) and the functions they serve.

LeDoux (1996), for example, has specified two complementary neural pathways involved in detection (appraisal) of a dangerous stimulus: the short road (thalamus–amygdala) and the long road (thalamus–neocortex–amygdala). They seem to work parallel to one another. However, the emotional system will "take over" depending on the nature of the input received. He tries to explain what is at stake:

> In situations of danger, it is very useful to be able to respond quickly. The time saved by the amygdala in acting on the thalamic information, rather than waiting for the cortical input, can be the difference between life and death... From the point of view of survival, it is better to respond to potentially dangerous events as if they were in fact the real things than to fail to respond. (1996, p. 166)

Quite similarly, Damasio (1994) also studies the cognitive architecture of the brain in order to understand the interconnections between emotion and cognition. Based on systematic research with patients suffering from brain lesions, he found that the neural structures used for emotion processing – amygdala, orbital cortex, and anterior cingulate cortex – also play an important role in processing activities involved with higher forms of cognition like decision making.

The developments in emotion research reported above challenge Harré's claim regarding the possibility of providing a mechanistic explanation of psychological phenomena. Our proposed guidelines offer some grounds for the study of specific processes and mechanisms significant for choice behavior. Our conceptual framework is fine tuned with the causal picture of human thinking and acting that contemporary behavioral scientists endorse. More importantly, it provides a theorizing strategy that aims to offer understanding of why (and how) we should put together emotion, cognition, and motivation as powerful constituents of the trilogy of the mind.

3. A place for emotions in the BR framework

The concept of bounded rationality has been used in quite a broad fashion and it makes reference to very different things (even Simon (1992, p. 18) acknowledges the vagueness of the term). Rather than committing to one definition, Simon tackles the issue by contrasting BR with the neoclassical economic approach to rational behavior, while advocating a more realistic account of human decision-making behavior.

Simon's theory has gained popularity among economists and other decision researchers (Camerer, 1995; Conlisk, 1996). However, most economists tend to interpret BR as synonymous with optimization under constraints. This follows from the idea that agents make choices that involve time constraints and limited knowledge and cognitive capabilities. From this standpoint, individuals are assumed to calculate

an optimal stopping rule (Stigler, 1961). [8] It seems to us that a careful reading of Simon's work reveals the problems with this vision of BR. Optimization under constraints requires even more demanding cognitive processing than the approach idealized by standard rational choice theory. In his writings on BR in the 1980s and 1990s, Simon rejected such interpretations (Simon, 1983, 1992) because of their reliance on an Olympian version of rationality.

Another popular interpretation of BR makes reference to human irrationality. [9] This phenomenon is often related to violations of Bayesian reasoning or deviations from expected utility theory (Kahneman, Slovic, & Tversky, 1982; Thaler, 1991). Although a broad notion of BR seems to accommodate empirical evidence about cognitive errors, there is no need to equate BR with the heuristics and biases program. As we understand it, this conceptualization would reduce the scope of BR theory (see Gigerenzer & Selten, 2001).

3.1. Rationality as an adaptive toolbox: A fast and frugal alternative

Another model of BR (see Gigerenzer et al., 1999) has been built on Simon's (1990, p. 7) understanding of behavior as a pair of scissors whose blades are an agent's computational facilities and the structure of the environment. More recently, Gigerenzer et al. (1999) have elaborated on this vision of BR. One interesting implication of Gigerenzer et al.'s alternative concerns the evaluation of two complementary routes to the study of human (bounded) rationality. on the one hand examining the mind's architecture with the hope of capturing the principles that govern decisions in the real world; and on the other hand, studying what lies outside the mind – the environmental structure – that exert influence on proximate mechanisms for behavior.

The above interpretation of BR is embedded in a theoretical perspective called the adaptive toolbox of fast and frugal heuristics (Gigerenzer & Selten, 2001; Gigerenzer et al., 1999). It assumes that individuals rely on decision strategies that economize on an agent's cognitive processing capabilities, since they exploit information within particular environmental structures. One may wonder in what sense heuristics are thought to be fast and frugal. They are fast because they rely on few cues, thus dispensing with much computational effort. They are frugal for they make selective

[8] Stated briefly, the idea is that one stops searching for information about prospects when the cost of further information is greater than or equal to the benefit of gaining additional information.

[9] Anticipating the confusion that might arise, Simon wrote: "We may deem behavior irrational because, although it serves some particular impulse, it is inconsistent with other goals that we may deem more important. We may deem it irrational because the actor is proceeding on incorrect facts or ignoring whole areas of relevant facts. We may deem it irrational because the actor has not drawn the correct conclusions from the facts. We may deem it irrational because the actor has failed to consider important alternative courses of action. If the action involves the future, as most action does, we may deem it irrational because we do not think the actor uses the best methods for forming expectations or for adapting to uncertainty. All of these forms of irrationality play important roles in the lives of every one of us, but I think it is misleading to call them irrationality. They are better viewed as forms of bounded rationality" (1985, p. 297).

search for cues and alternatives within the environment using a minimal number or at times a single cue. The core premises (P) of the adaptive toolbox framework can be summarized as follows:

- P_1. *Psychological plausibility*. The adaptive toolbox is built upon realistic assumptions about human behavior that specify the processes whereby real people make judgments and choices. The idea is to offer richer descriptions of decision behavior by making explicit reference to real humans' cognitive, behavioral, social, and emotional repertoires.
- P_2. *Domain specificity*. The adaptive toolbox of heuristics, as the name suggests, is assumed to be a collection of mental shortcuts – composed of cognitive and affective building blocks that deal with specific information-processing tasks.
- P_3. *Ecological rationality*. At the conceptual level, one implication of the view of rationality as a pair of scissors concerns the notion of ecological rationality. The latter is defined by its degree of fit with the real world. From this perspective, performance of a certain outcome is evaluated in terms of the match between a heuristic and the structure of the task environment. To put it another way, a heuristic will be ecologically rational to the degree that it is adapted to the structure of a specific environment.

The above theoretical perspective on bounded rationality attempts to unveil the (causal) processes underlying actual behavior. It assumes that actual decision makers rely on heuristic processes, which provide three functions: (i) a searching rule, (ii) a stopping rule, and (iii) a decision rule.

Search for information amounts to a twofold process of exploration: The decision maker first must discover the options available and then look for cues to evaluate and rank the possible alternatives.

Models of BR are built on the premise that information search is selective and necessarily ends at some point. Therefore, they try to specify what stopping rules look like. Some seem to dispense with the fiction of optimization, such as Simon's satisficing heuristic, which assumes that information search stops when the first alternative that meets or exceeds an agent's aspiration level is found. Gigerenzer and his colleagues have discovered heuristics simpler than satisficing, such as the Take-The-Best heuristic (TTB). It specifies that a search for alternatives ends as soon as one encounters a cue that discriminates between two options (Gigerenzer et al., 1999).

Behavioral models inspired by Simon's ideas also assume that an individual selects a satisfactory course of action based on specific choice criteria, typically called selection decision heuristics. By virtue of the domain specificity and simplicity of such mental procedures, they often trigger quick and effective responses. Our next task is to show that emotions serve as the building blocks of certain fast and frugal heuristics.

Finally, Kaufman (1999; but see Hanoch, 2002a) presents an additional source of bounded rationality, one that stems from high emotional arousal rather than the traditional cognitive constraints. According to Kaufman, emotions, or rather high

emotional arousal, can interfere with rational thinking, for it hinders one's success in various tests and in problem solving.

3.2. Emotions as built-in and learned computational devices

In what follows, we discuss two important functions of emotions – cognitive guidance and behavior preparation – from an evolutionary perspective. It is argued that emotions exert systematic influence on thinking and choice. Just like a toolbox of specialized cognitive shortcuts, emotions give direction to search, stopping, and decision rules that produce choice behavior. This perspective revives Simon's (1967, 1983) view that emotions play a role in information processing: They alter one's goal prioritization (Simon, 1967), determine the relative salience of aspects of a task (Hanoch, 2002b), shape cost–benefit assessments (Loewenstein, Weber, Hsee, & Welch, 2001), often tell us when to stop processing information (Ketelaar & Todd, 2000), and "rule out of court" or render unthinkable many options for the decision maker (Earl, 1986, pp. 96–100).

We can think of at least three reasons for studying the rationality of emotion on the basis of its functionality and fit with the task environment. First, it helps to clarify under what conditions an emotion leads to effective behavior and under what conditions it fails to do so. Second, it exposes the complex connections between emotions and cognition. Finally, by specifying the processes that people actually rely on in drawing inferences and making decisions, we can improve our understanding of how rationality works in the real world and the role emotions play within rationality.

To illuminate the functionality of emotions, we draw upon recent insights from evolutionary psychology. According to Tooby and Cosmides (1995, p. 1189), the mind resembles a "confederation of hundreds or thousands of functionally dedicated computers, designed to solve problems endemic to the Pleistocene, [more than it resembles] a single general purpose computer equipped with a small number of general purpose procedures." More recently Cosmides and Tooby (2000) have compared the human mind to a crowded zoo of specialized programs – emotions being some of them. Just like a specialized cognitive program that guides and coordinates behavioral processes, emotions are a vital component of our mental architecture.

To understand the "logic" of emotion, we use the example of one emotion: disgust (Rozin, Haidt, & McCauley, 1993). Detection of an incoming stimulus that is appraised as a potentially significant danger of ingesting harmful food will elicit a specialized computation program called disgust. This "program" has evolved to resolve (at least one) recurrent adaptive information-processing problem: how to distinguish healthy from noxious food and to avoid being poisoned by contaminated food (for a discussion on the role of disgust in the moral domain see Haidt, 2001). From an evolutionary cognitive perspective, we assume that individuals whose mental architecture accommodates the disgust program tend to achieve higher reproductive success than others unable to experience the emotion of disgust. As Rozin et al. (1993) rightly put the issue, the disposition to feel disgust can be taken as a comparative advantage. This is because this specialized computational program enables an

individual to automatically detect and appraise the ecological significance of an important stimulus (harmful food); to be ready to concentrate physiological and cognitive efforts on search for alternative ways that have led to adaptive outcomes (throughout the course of the species' evolutionary history); and to make quick cue-based inferences and choices about the consequences associated with salient courses of action. It is in this sense that it can be said that a disgust program plays a functional role that it is to solve a recurrent information-processing problem with adaptive implications. As a result we are inclined to disagree with the view that there can only be a selective pressure operating on the evolution of emotion programs (e.g. disgust) when individuals are able to "cognize much" about the emotional reactions, states, and behaviors. Alternatively, we think that some emotional programs have been shaped by natural selection to help individuals resolve adaptive problems observed as far back as the Pleistocene era (rather than to represent some bits of information about an important event). Likewise, anger is an example of a specialized program that helps individuals resolve a recurrent adaptive problem of self-binding commitment. The emotional reactions to violations of an approved norm and the negative feeling of anger guarantee credible promises of social cooperation in environments that lack the necessary (modern) legal apparatus to guarantee binding contractual relations (Frank, 1988).

Quite similarly, Kelly (1955, pp. 502–508; see also Elster, 1999) suggests that guilt serves as an alarm signal that inform us when we are about to depart (or already have) from one of our core structures; and anxiety emerges when events appear to lie outside our core construct systems, motivating us to keep within the confines of familiar and controllable environments. Kelly's main concern, in contrast to the one focused on here, lay with individuals striving to preserve and maintain their self-concept, image, or identity, rather than preserving the physical self, thus it seems that his writing might reflect on issues that rest outside the framework developed here. However, recent research on impulsive purchasing by Dittmar and Drury (2000) fits very nicely with Kelly's ideas concerning personal construct, attempts to regulate anxiety, and desires to maintain self-identity. In their study, Dittmar and Drury argued that material goods are linked to a person's self-concept for they convey important information about one's personal and social identity. Impulse buying can be explained, accordingly, by consumers' desires to regulate emotions (Elliott, 1994), express a sense of uniqueness and self-identity (Dittmar, 1992), and increase ones self-image rather than by price or usefulness (Dittmar & Drury, 2000).

These examples illuminate situations in which emotional reactions can be ecologically rational. Emotion programs were selected for because they gave rise to action patterns that are good solutions to domain-specific adaptive problems, for they are well engineered to carry out evolved functions. As Tooby and Cosmides (2000) argue:

> Natural selection has retained neural structures on their ability to create adaptively organized relationships between information and behavior (e.g., the sight of a predator activates inference procedures that cause the organism to hide or flee) or between information and physiology

> (e.g., the sight of a predator increases the organism's heart beat rate, in preparation for flight). (p. 1172)

This evolutionary approach offers us an insightful strategy for grasping the role of emotions in human rationality. It is worthwhile to stress that an explanatory evolutionary account of behavior promises to uncover proximate and ultimate causes of behavior. Both sets of causes need to be spelled out for us to have a complete understanding of a phenomenon (Mayr, 1988, p. 28). Roughly, proximate causes (e.g. emotions and norms) refer to processes (cognitive and physiological) that trigger or initiate a particular behavior pattern. Ultimate causes, in turn, refer to those that reveal the adaptive value of a particular design trait.

Marr (1982) argues that there are three levels of analysis within an evolutionary explanation of the human mind. They correspond to the algorithmic, the hardware implementation, and the computational levels of analysis. He maintains that the first two levels capture proximate causes. The computational level, in turn, is expected to uncover ultimate mechanisms. Marr emphasizes that we need to devote careful attention to the third level to understand the nature of information processing (Marr, 1982, p. 27). Our discussion of the significance of emotions for bounded rationality is centered upon the algorithmic level. Remember that our assumption is that emotions function as cue-based heuristic processes that provide solutions to specific decision tasks.

More recently, cognitive neuroscientists have contributed to an account of emotions at the hardware level. By specifying the neural pathways (physical properties) through which emotions modulate real judgments and decisions, brain researchers identify neural structures that are involved in both emotion processing and decision making. The amygdala and the ventromedial prefrontal cortex are involved with automatic, fast, and involuntary information processing often associated with processing of emotionally arousing tasks and cues. But these same structures also play a central role in controlled, complex, voluntary systems of information processing, often associated with higher-order cognitive activities like planning and decision making (Adolphs & Damasio, 2001, p. 29). Adolphs and Damasio's research provides additional support for our view that emotions are the foundation of bounded rationality. As they frame the issue,

> Through circuits including components of amygdala, striatum, and basal forebrain, emotion may thus help to select particular aspects of the stimulus environment for disproportionate allocation of cognitive processing resources; namely, an organism should be designed to preferentially process information about those aspects of its environment that are most salient to its immediate survival and well-being. (Adolphs & Damasio, 2001, p. 33)

The above passage suggests that a description of the neural machinery reinforces our thesis that emotions are proximate mechanisms for boundedly rational behavior. Unfortunately, little can be said about ultimate processes or mechanisms. This is partly because this research agenda is still in its infancy, with many questions still

to be tackled. A complete account of the nature of emotion processing and its significance for human behavior might require us to completely map emotion programs onto the complex adaptive tasks that their domain-specific heuristics were designed to solve – a task that far exceeds the scope of this paper.

4. Theoretical implications

Analyzing the significance of emotions for decision making carries several implications for the study of human BR. In this section, we briefly consider some ideas that arise from our suggested perspective on explanation by mechanism and BR.

The study of emotions as activators of domain-specific heuristic processes that lead to quick and adaptive decisions goes against a long-standing tradition that contrasts emotion with human rationality. Our approach calls for re-conceptualizing the links between emotion, thinking, and rationality, for emotions can lead to ecologically rational outcomes. However, our argument does not imply that emotions never distort thinking and choice patterns. To be fair, there is yet no full understanding of the conditions that cause emotions to enhance or undermine the rationality of human judgments and decisions. With that in mind, let us discuss some conditions under which emotions do lead to adaptive outcomes.

The very elicitation of a specialized emotion program is dependent on the way an organism's situation detector module explores information about an external (or internal) stimulus (which can be shaped by evolution as well as culture). The cluster of perceptual and conceptual processes that constitute the system evolved to extract information about environmental regularities and therefore to enable an individual to draw inferences about the available prospects and to decide on a satisfactory alternative.

To put it differently, the function of the situation detector is to promote quick evaluations about whether a particular stimulus represents a "friend or foe." When the detector system perceives an ecologically important threat or opportunity, a specialized emotion program will be activated. This process puts into motion changes in cognitive and physiological functioning so as to produce quick and adaptive behaviors. It can be said that emotions will lead to distorted outcomes (they are non-functional) when they give rise to mental procedures that fail to exploit relevant pieces of information in the environment (in which the task is embedded) and therefore select a behavioral strategy that is not a proper solution to the faced decision problem.

It is worthwhile to stress that our proposed criterion to evaluate performance is not based on internal consistency but on a sort of external correspondence. [10] In a sense, this deviates from the standard analysis of economic rationality as expected utility maximization. Gigerenzer et al. (1999) claim that studies of rationality in the real world should replace the coherence criterion with a correspondence one,

[10] Sen (1994/1987) provides an interesting discussion about consistence-based and correspondence-based criteria of rationality.

where performance is assessed in terms of the match between a strategy and an environment.

Despite our sympathy toward the alternative notion of ecological rationality, it is doubtful that it can perfectly replace the view of rationality as inner consistency. The standard interpretation of rationality as coherence has important descriptive and normative dimensions that are not captured by ecological rationality. For that reason, we believe that coherence should be supplemented rather than replaced by correspondence. Both carry insights about the "rationality requirements on the nature of human reflection regarding what one should want, [believe], value or aim at" (Sen, 1994/1987, pp. 13–14, no. 9).

Another theoretical implication of our proposed approach to rationality concerns a different understanding of rational decision making. Unlike the paradigmatic notion of rationality as (expected) utility maximization, the "two-blade" conception of BR portrays decision making as a sequence of cognitive and emotional processes (with a neural counterpart) rather than the outcome of the optimization of a general-purpose algorithm (expected utility maximization).

5. Methodological implications

What are the methodological implications of conceiving emotions as one of the building blocks underlying the theory of bounded rationality? To address this issue, we need to explain what we mean by methodology.

Economists make at least two uses of the term "methodology." One has to do with the study of analytical tools for theoretical elaboration; and another concerns the analysis of models and theories at the "metatheoretical level." We are here interested in reflecting on the second "view" of methodology. We attempt to scrutinize philosophical issues related to pragmatic considerations that drive economic theorizing and the purposes of scientific explanations.

There seems to be agreement that formal tractability and parsimony are two pragmatic considerations that are valued highly during model or theory construction. Economists often appeal to tractability and parsimony as reasons against psychologizing decision theory and specifying psychological mechanisms that give rise to observed behavior. Camerer (1995, p. 676) has wisely drawn our attention to the fact that we cannot know how much tractability is lost in the generation of behavioral decision models without trying them out. One of the advantages of our proposed treatment of emotions, in terms of domain-specific heuristics, lies in its ability to offer a way of avoiding the tractability problem.

It is also likely that economists of conservative inclination would point out to us that a BR perspective cum evolutionary insight carries a deleterious implication – a heuristic approach is expected to conflict with the economist's goal of explaining behavior by means of parsimonious formulations. To call this line of reasoning into question, Rabin's (1998) work can be of help. He offers substantial evidence that economists respond to simple psychological hypotheses by constructing baroque alternative explanations of phenomena relying exclusively on traditional economic

assumptions. Rabin's comment might resonate with Adam Smith's earlier work on the "origin, development, and replacement of the first astronomical system" (discussed in Skinner, 1979, p. 114) – work that could reflect on the development of theories in other domains. This early astronomical system was acceptable as long as no other heavenly bodies were discovered. More bodies, however, have been found "leading to gradual increase in the number of spheres needed to account for them until a situation reached where the theory itself attained a degree of complexity that rendered it unacceptable to the imagination: unacceptable because it violated the basic condition of simplicity" (Skinner, 1979, p. 114).

In our interpretation, one consequence of developing an alternative theoretical perspective (one that captures the underlying mechanism governing behavior) concerns the prospect of improving the predictive and explanatory powers of economic theories and models. Unlike mainstream economists, we share the behavioral economists' skepticism and their interest in explaining how individuals actually make choices within and outside the market reality.

Behavioral economists acknowledge that the economic theory of choice has broader scope but it has failed to predict important phenomena even at the microeconomic and macroeconomic levels (Loewenstein, O'Donoghue, & Rabin, 1999; Thaler, 1992). In an effort to accommodate rational choice anomalies, behavioral economists have come up with models of choice built upon refined psychological assumptions (e.g. hyperbolic discounting, preference reversal). Some of them have overcome problems with tractability and parsimony to hypothesize (and test) explicitly psychological processes productive of recurrent puzzles within the body of economic choice theory, such as the cooperation even in large groups with impersonal (anonymous) interactions. For example, in a recent paper, Fehr and Gachter (2002) try to explain their experimental findings of high rates of social cooperation by hypothesizing a behavioral process called altruistic punishment. They claim that an individual's behavioral predispositions to reciprocate cooperative attitudes and to punish defectors even at a personal cost are what ultimately sustain the emergence and perpetuation of prosociality. [11] They go on to stress that emotions – anger, guilt, and shame – constitute proximate causes (mechanisms) of altruistic punishment and therefore of cooperative behaviors. To us, such a research strategy is a promising way of exploring the roles of emotions and bounded rationality in the real economic world, characterized by complex causal interdependencies.

6. Conclusion

Until quite recently, the economic discourse has been largely mute on the role of emotions in decision making. It was almost taken for granted that if emotions play

[11] Based on an evolutionary definition of altruism – any act that increases the average payoff of the group to the detriment of one's own payoff – Fehr and Gachter interpret individuals willing to punish defectors or free-riders even at a personal cost as displaying altruistic behavior.

any part in reasoning, it would be to put sand into the rational choice machinery. How could emotional reactions lead to non-random rational outcomes?

Starting in the late 1950s, researchers on decision making began to question the Olympian model of rationality and argued that real agents have limited memory, time, and cognitive capabilities. At the same time, another group of choice theorists emphasized that there was no need to specify the processes or mechanisms whereby individuals come to make decisions – for they lead to outcomes consistent with the expected utility maximization algorithm (Friedman & Savage, 1948).

Inspired by Simon's (1967, 1983) theory of BR and recent developments within neuroscience and evolutionary psychology, we have advanced the thesis (instead of argued) that emotions need to be explicitly incorporated in formal models of boundedly rational choice. To substantiate our argument, we have showed that emotional processes perform activities that put into motion information-processing activities, which antecede actual decision making.

Via our discussion on the enabling and triggering conditions under which the emotional mechanism works, we highlighted the complex ways in which emotions might modulate behavior. This philosophical analysis was meant to pave the way to the claim that emotions constitute important building blocks of our mental architecture. Just like activators of domain-specific algorithms, emotions mobilize search, stopping, and choice heuristics. Emotions pick up and highlight certain cues within a given environment; they interrupt on-going activities; and they initiate cognitive and physiological changes to respond to these opportunities or hazards.

We have offered one framework that can be utilized to explore the circumstances under which emotions lead to effective and nonfunctional outcomes, while acknowledging the need for further attempts to integrate emotion into theories of choice behavior. This discussion attempted to reinforce our claim that economic explanations of human behavior could flourish by paying closer attention to the role of emotions. Elster (1999), Frank (1988), Loewenstein et al. (2001), and Thaler (2000) are among the researchers who have stressed that explanatory accounts of various instances of economic behavior – ranging from cooperation to intertemporal choice to decision making under risk – require us to dig deeper into the nature and structure of agents' preferences, beliefs (expectations), and rationality.

Even though more empirical research is necessary for us to understand exactly how emotions shape decision problems posed by economic reality, we hope that our analysis highlights the need to treat emotions as cognitive and motivational foundations of human judgment and decision making.

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