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Anger, Rationality and Neuroeconomics

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Abstract

This paper employs neurobehavioral and psychological evidence to argue that anger is an emotion arising from significant cognitive processing, one that, in relation to economic decision-making, may be subtly mediated by many factors (including intentions). Anger is an emotion implying a higher likelihood of a behavioral response directed against the object of anger. The medial and possibly other prefrontal cortex regions play an important role in anger processing, whereas the amygdala does not. Any eventual difficulty for rational choice may come more from the difficulty of understanding the cognitive underpinnings of anger than from understanding the emotional process itself.

Keywords: anger, emotions, neuroeconomics, rationality.
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Anger, Rationality and Neuroeconomics

1. Introduction

There has been a growing interest in the role that emotions play in economic decision-making (e.g., Elster, 1998; van Winden, 2001; Hanoch, 2002a). This interest has been influenced, in part, by the lessons of neurobiologists such as Damasio (1994) and LeDoux (1998). Emotions have been variously viewed as opposed to rational decision-making but actually helping out rational choice (Damasio, van Winden), as opposed to cognitive aspects of decision-making (Sanfey et al., 2003), as playing a role in bargaining behavior (Pillutla and Murnighan, 1996) or individual investment decisions (Bosman and van Winden, 2001), as well as in tax payment choices (Bosman and van Winden, 2002) and possibly in deciding work efforts in the context of a well-known efficiency wages setting (Akerlof and Yellen, 1990). Emotional decision-making has been perceived as one creating problems for the standard theory of rational choice, sometimes on the grounds of being related to "hot" rather than "cold" reasoning, and sometimes on other grounds: for example, because it may induce time inconsistency in choices (Loewenstein, 2000). Neuroeconomic evidence has been called into play to support what we may label a received view of emotions as essential to decision making, as possibly 'cognition-free' or anyway 'cognition-thin', and as in conflict with the standard view of rational choice (e.g., Hanoch, 2002a, and van Winden).

This is a paper on the neuroeconomics of anger. In common with the recent literature, we believe that trying to understand the neuroeconomics of emotions may enable us to better understand decision-making. But, after having provided some precise definitions to put our discussion into context, we focus our attention on a *specific* emotion, anger, rather than on emotions in general; we believe this approach to be a potentially more productive exercise and one that shows some potential pitfalls when one tries to draw inferences from neurobiological evidence.

What neuroeconomic evidence there is on anger suggests that it is an approach emotion arising from 'thick', not 'thin', cognitive processing, and one that may be

subtly mediated by a variety of interacting and only limitedly understood factors. Anger is likely to be *directed towards* the object of anger, and hence implying a higher likelihood of a behavioral response other things being equal; if the offending party committed her action intentionally, there is evidence of an effect of this at the neural level, consistently with theories of other-regarding preferences that stress the role of intentions for decision making, such as Falk and Fischbacher (2001). The emphasis by some researchers on emotion *vs.* cognition may be misplaced: the difficulty for conceptualizing anger within a rational choice framework, if there is any, may come more from the difficulty of understanding the cognitive underpinnings of emotions than from the emotional process itself. Certain areas of the prefrontal cortex are likely to be more involved with anger processing than the amygdala, the subcortical "emotional computer" of LeDoux. Caution is required in generalizing the neuroeconomic results on one emotion to other emotions.

Section 2 defines the notions of rational choice and of emotions and clarifies the terms of the debate. Section 3 discusses neurobiological evidence on anger. Section 4 concludes.

2. Emotions, anger and rationality

The issue of the rationality of emotions has received considerable attention, but it may be hard to settle in the lack of a clear definition of rationality or emotions.

2.1 Defining rational choice

By (perfectly) rational choice by the economic agent I shall refer to any choice that maximises her utility, as defined by a stable and reasonably parsimonious utility function. The first part of this definition is simple enough, but the second may require a word of explanation. *Any* choice could be rationalized by *some* utility function if this were allowed to be unstable or unparsimonious. Even a violation of the weak or strong axiom of revealed preferences, as displayed by two consecutive choices, could be rationalized if we allowed the utility function to change between the two choices, or if we allowed a dummy variable in the utility function explaining away the apparent contradiction.

Obviously different views of rationality are possible. For example, in the presence of cognitive limitations, satisfacing (rather than optimizing) may be optimal. Nevertheless, our primary concern is to analyze the implications, if any, of the study of anger for mainstream, general economists, and so it makes sense to restrict ourselves to a definition of rationality as rational choice.

2.2 Defining emotions and placing anger in context

The broadest definition of emotions would label them as any source of positive or negative reinforcement (e.g., pleasure and pain), as Rolls (1999) and Gifford (2002) do. Hunger and thirst are, in this sense, as much emotion as anger or fear. As in this view emotions coincide with behavioral preferences (in an ordinal utility perspective) or any source of pleasure or pain (in a cardinal utility perspective), emotions are then perfectly mapped into preferences in the utility function of the decision-maker, and the study of emotion becomes just the study of preferences. Indeed, it appears misleading – from the perspective of economics – to talk of *anything but* preferences if this broad definition is adopted.

Damasio (1994, 2000a, 2000b) distinguishes six "primary or universal emotions" (happiness, sadness, fear, anger, surprise, disgust) from "secondary or social emotions" (such as embarassment or pride) and "background emotions" (such as well-being, calm or tension). This is a rather heterogenous list and brings to mind Elster's or Russell and Feldman Barrett's (1999) warning that there may not be such a single meaningful scientific category as emotion. Insofar as one lumps all of Damasio's emotions together, one gets back to a definition of emotion as inseparably mapped into states of pleasures of pain, and, hence, into preferences. But the classification does suggest that there may be, in some sense, some more prototypical emotions than others, and this suggestion has received the support of studies on common-sense knowledge about emotions (e.g., Fehr and Russell, 1984; Shaver et al., 2001).

To say "he reacted with anger", "she's in an angry mood" and "he tends to be an angry person" reflect very different, if possibly correlated, concepts of anger, and should be treated as such (Goldsmith, 1994). One can distinguish between emotions,

moods and traits (e.g., Ekman, 1994). Definitions and terminology vary, and so what Ekman labels as emotions would be defined as immediate emotions, a subtype of visceral state, by Loewenstein, who however does not define what makes emotions different from other visceral factors; and they would be defined as prototypical emotional episodes by Russell and Feldman Barrett, as discrete emotional reactions by Goldsmith, as emotion episodes by Frijda (1994), and so on. Similarly, moods could also be referred to as affect (Watson and Tellegen, 1985), as core affect (Russell and Feldman Barnett), and undoubtedly in other ways, including as emotions (Frijda, 1994). And emotion traits could be linked to notions such as that of temperament (Goldsmith), or could be differentiated from it (Watson and Clark, 1994). In this plethora of names some regularities emerge, and it is to those that I now turn.

A key feature of emotions as such is their typically transient nature (e.g., Ekman, 1984; Kagan, 1994; Scherer, 2000; Loewenstein). Emotions can last just seconds or minutes (Ekman, 1984); they may perhaps last hours or occur repeatedly in a longer timespan; but even evidence brought by psychologists who tend to downplay their short time-scale (such as Frijda, 1994) actually suggests that, by and large, emotions do not last long: Frijda et al. (1991) asked subjects how long a recent emotional episode went on for and found that 50% of them lasted no longer than 1 hour and 78% no longer than one day. Kagan defines emotions as a "temporary change in psychological and biological process to particular class of incentives". Changes will be in subjective feelings, neurophysiological activities, and possibly cognitive processes, body expressions and behavioral responses. Emotions can translate into behavior, anger can translate itself into aggressive behavior. However, this needs not always occur; in agreement with this intuition, van Winden presents a simple model of anger-driven 'emotional hazard', where the likelihood of aggression is seen as a positive function of emotion intensity and a threshold.

Moods last longer than emotions. They provide the "affective background, the emotional color, to all that we do" (Davidson, 1994). According to Goldsmith, they can last minutes to days. A mood can precipitated by an emotion: feeling unfairly rejected for a job promotion may lead to an episode of anger, and, if later cognitive

appraisal of the situation does not lead the agent to reframe the situation in a way that makes anger a less warranted reaction, the episode of anger may become an angry mood. The converse is also true: being in an angry mood may make agents more likely to appraise other agents as worthy objects of anger, i.e. it makes anger episodes more likely.

By *traits*, in relation to emotions, I shall refer to "characteristic individual differences in the way basic emotions are experienced and expressed" (Goldsmith). Someone with a tendency to be angry in a stable way (for months or years) and across a variety of relevant contexts is someone who has 'anger-proneness' as an emotion trait. Agents with an emotion trait are more likely to be in the corresponding mood and to feel the corresponding emotions. The tendency to be angry would probably come from a combination of genetic factors and of learning, especially in early development (see Zizzo, 2003a).

2.3 Rationality of emotions and anger

2.3.1 Avoiding the fate of Buridan's Ass

We can use our definitions to address the quandary of the relationship between rationality and emotions (and, specifically, anger). Kaufman (1999) notes that, while a traditional view of emotions saw them as opposed to reason and rationality, and as forces to be controlled and tamed, the contemporary view is that emotions play a more positive role, for example in motivating agents by raising the "saliency of certain desires, wants and outcomes". There is certainly a philosophical tradition, starting from Plato and going through the Stoics and Thomas Aquinas, that views emotions as requiring control by reason; there is also an old tradition, dating back to Aristotle, highlighting how at least some emotional involvement can play a positive role in decision-making (Solomon, 2000). But the relevance of most of the philosophical debate is marginal for our discussion, because of our definition of rational choice: rationality implies a maximisation exercise *given* preferences, and preferences can be defined (also) in terms of emotions; rationality is not, in itself, rationality *of* preferences. From the vantage-point of economic rationality, there is no reason to

oppose emotions to 'rational decisions' interpreted as purely cognitive decision mechanisms, as Damasio (1994), Hanoch (2002a) or Sanfey et al. appear to do.

Nor can one use evidence on emotion-based decision-making in support of bounded-rational decision making, at least as long as these satisfy properties of temporal stability and reasonable parsimony of specification that we referred to earlier on. They are non-trivial properties and the implications of relaxing them will be discussed below. Nevertheless, as long as these properties are satisfied, even if the Stoic philosopher Seneca considered anger as necessarily opposed to reason and St. Thomas treated it as a Christian sin, anger is consistent with rational choice. It is easy to build fairly parsimonious utility functions which may lead to aggressive behavior, as might be explained by negative emotions such as envy or anger. The simplest would be just a utility function with a negative other-regarding preference component, i.e. one which puts a negative weight on the payoffs of other agents either in general (e.g., Clark and Oswald, 1998; Frank, 1985) or under some range (because, for example, of inequality aversion or social preferences of some sort, as in Fehr and Schmidt, 1999, and Charness and Rabin, 2002). Self-interest and economic rationality are, in principle, orthogonal matters: there is no reason why an agent should not be rational *and* pursue objectives other than self-interest.

There is, of course, also no reason why they should pursue such other objectives: an agent may or may not have a preference. But if she is indifferent among all possible courses of action, a 'closure' problem arises on how a rational agent should choose in this case. Damasio (1994) discusses the neurological case of "Elliot", a patient with damage to the prefrontal cortex (specifically, to the medial and orbitofrontal areas) severely affecting his ability to feel emotions, intensely, for long or at all. In relation to anger, he reports that Elliot showed anger only rarely and in short bursts (p. 45). If given a decision problem, Elliot was able to analyze alternative prospects and their consequences, but he was unsure how he would *actually* decide among them. Another neurological patient with the same kind of damage was asked to choose between two dates for his next appointment with Damasio, and he spent a good part of half a hour discussing the pros and cons of the two options without

actually taking a choice. When finally the decision was taken for him, he calmly acquiesced. The type of neurobiological impairment may depend on the location of the damage, but the thrust of the analysis is that, as a result of their neurobiological impairment to feel at least some emotions, agents appear more likely to be facing what Bacharach (2001) labels "Buridanic problems": situations where an agent is required to take a choice but there is a perfect indifference among outcomes. This appears a natural implication of conceiving emotions as preferences, as a preference of any kind would avoid the indifference among outcomes that characterizes Buridanic problems. In itself, the potential role of emotions in reducing the likelihood of Buridanic problems is consistent with economic rationality as much as it is consistent with Hanoch's (2002a) and Gigerenzer et al.'s (1999) view of bounded rationality as based on 'fast and frugal heuristics'.

Elster criticizes Damasio by noting that rules of thumb other than 'gut feelings' can help agents to make decisions. This of course is true, but does not prevent gut feelings from potentially playing an important role in practice in various settings, as he himself admits.[1] The extent to which anger plays this role is not clear; in the end, this is an empirical matter, and should be addressed as such. Damasio himself believes that the ability to feel anger (as other primary emotions) is not compromised in his Buridanic patients with damage in the medial region of the prefrontal cortex.

2.3.2 Rationality and instability of preferences

Traits are stable, mood less so, and emotions least of all. What are the implications of the instability of emotions, and specifically of anger, for rational choice? Even if we model emotions as preferences, instability of emotions is not equivalent to instability of preferences. Assume, for example, that Jane becomes angry whenever she feels wronged.

If we could parsimoniously identify the set of circumstances in which Jane feels wronged (as we shall see, a big if), then one could try to subsume these in a specialised utility function. This utility function may imply, for example, retaliatory

[1] See also Hanoch (2002a).

behavior whenever the subject feels she has been intentionally mistreated, as in Falk and Fischbacher. But there are potential qualifications to this position, qualifications that are likely to be particularly relevant with emotions in general and anger in particular because of their short and potentially acute nature.

First, according to Kaufman (1999), emotions may affect the cognitive ability of agents, quite possibly in a non-linear way, with a rise in performance up to a certain point (that will depend on the emotion and on the agent involved) followed by a decline beyond it. He notes that "an increase in emotional intensity, such as a shift from depression toward anger or from boredom toward excitement, reduces or alleviates these barriers to optimal decision making, at least up to a point" (p. 138). This position makes no distinction between emotions and moods (see Hanoch, 2002b); it leaves underdetermined which emotions are related to which on the arousal scale; and by not determining at what point such transition (say, from depression towards anger) would occur and on how this relates to the "best" arousal level, it is difficult to say whether, in Kaufman's theory, anger would or should be considered as enhancing performance up to some level, or otherwise. But it is not hard to believe that having some motivation, whether induced by anger or by some other emotion, may create the incentive for rational agents to put in more effort in a task. Nor is it hard to believe that being 'too angry' may hinder performance, although being able to prove or disprove this statement in an experimental laboratory may be difficult for ethical reasons. Such hindering of performance would be inconsistent with a reduction of emotion to mere preferences, and hence with rational choice.

Second, according to Loewenstein agents may underestimate the effect of emotions such as anger (he explicitly cites 'road rage') on their current and future behavior. In part, Loewenstein seems to have in mind the possibility of non self-interested behavior, but, as we explained earlier on, this is not really problematic for rational choice. The more serious point is that insufficient introspection (between a state where the agent is angry and a state where she is not) may lead to intertemporal inconsistency in the utility function. For both Loewenstein and Gifford, emotions may subsume hyperbolic or quasi-hyperbolic discounting with its associated problems of

self-control. Jane may not normally believe punching another car driver a good idea (for example, because of the legal penalties associated to doing so); but, if she is in a road rage, it is rational (in the sense of her utility function at *that* point in time) for her to do so. The problem for rational choice lies in the resulting conflict between short-run utility and long-run planning. If intertemporal introspection were complete, although the agent planning its 'long-run' utility maximisation could try to reduce it, for example, by taking measures to reduce the likelihood of becoming too angry. But the problem does not disappear in practice, because technologies to do so may be partial, if more so for some people than others. Nor does the problem disappear in theory: rational choice is based on preferences, and so one cannot, without evading its logic[2] or being circular, evaluate the rationality of preferences on the basis of rational choice. It may or may not be easy to dismiss episodes of anger as irrational, but rational choice does not provide the grounds for adjudicating this.

Third, the problem of instability of preferences may be more general: it is far from obvious that one *can* parsimoniously identify the set of circumstances in which Jane feels wronged and, hence, anger is induced. There is not much work which has investigated how questionnaire responses on anger are affected by framing effects in economic settings. An exception is Bosman et al. (2000). As in Bosman and van Winden (2002), they considered a two-player power-to-take game where player 1 decided a taxation rate over the endowment of player 2, and then player 2 decided how much of her endowment to destroy (thus reducing tax revenue). They varied across conditions how the endowment was obtained. In one condition, (equal) endowments were earned with a prior task; in another, they were simply allocated money by the experimenter. Bosman et al. found that self-reported anger and the money destruction rate was greater the higher the taxation rate, but, also, that there was more destruction if endowments were not based on own effort; this was seemingly driven by an expectation of lower taxation.

[2] For example, by having an extended view of rationality and making a distinction between preferences and meta-preferences (Sen, 1977).

There is a larger, and potentially relevant, body of research showing that, if aggressive behavior is determined by perceptions of deservingness of the parties involved, judgements of deservingness are not purely determined by relative payoffs (Zizzo and Oswald, 2001). Zizzo (2003b) presented the results of an experiment where an unequal wealth distribution was created and then subjects could act to change this wealth distribution. Subjects received money by betting and possibly by arbitrary ("undeserved") gifts; they could then pay to reduce, redistribute and, in half of the sessions, steal money from others. Perceptions of fairness changed according to whether a subject was undeservedly advantaged or otherwise, with the fraction of subjects that could be classified as self-interested varying dramatically across conditions, from 0% to almost 50%. Results from bargaining experiments also endorse a rich view of deservingness and its impact on behavior (Hoffman and Spitzer, 1985; Hoffman et al., 1994, 1996; Guth and Tietz, 1986; Schotter, 1996; Ruffle, 1998). The less deserving the proposer is relative to the receiver, the more equitable the splits of the cake have to be to be accepted. Having earned a role or the endowment is a source of entitlement, a finding replicated in a public good contribution setting (Van Dijk and Wilke, 1993, 1995); but so is the 'need to survive' to the next stage of the experiment is considered enough as to make receivers accept lower offers (Schotter, 1996). Tyler and Degoey (1993) interviewed Californians during the 1991 water shortage. The object was to determine their willingness to restrain from excessive water consumption and otherwise follow the authority's rules to deal with the shortage. Their degree of compliance was significantly correlated with considerations of procedural fairness followed by the authority. Tyler and Lind (1992) discussed a study of dispute resolution in a federal court. The cases involved amounts between 5000 and 5 million dollars, with decisions being made (for example, whether to accept an arbitration award) that could result in transfers of ten or hundred thousand dollars. When procedures were perceived as fair, 77% of the awards were accepted, but only 54% if they were perceived as unfair.

Brockner and Wiesenfeld's (1996) review of an organizational behavior and experimental literature is consistent not only with an important role for procedural

fairness, but also with the interaction between procedural fairness and relative favourability of the outcomes. If the agent perceives she has been treated unfairly (e.g., evaluation of wage fairness) or simply unfavourably (e.g., evaluation of wage satisfaction) in terms of outcomes, the fairness of the procedures leading to that outcome becomes particularly salient. Empirical evidence from field studies shows that agents that feel they are unfairly treated by firms or other authorities are more likely to engage in overt retaliation such as theft or vandalism (e.g., Greenberg and Scott, 1996; DeMore et al., 1988), or more covert one such as not engaging in discretionary behaviour important to promote the efficient functioning of an organization (e.g., Organ, 1989; Jermier et al., 1994). Gilliland (1994) found that procedural justice influenced job performance. Organizational psychologists have recently analyzed the relation between deservingness and aggressive retaliation (e.g., O'Leary-Kelly et al., 1996; Robinson and Bennett, 1995). Skarlicki and Folger (1997) investigated the relation between perceived fairness and behavioral measures of retaliation towards the firm (e.g., theft, vandalism and "medical" absences) in a sample of 240 manufacturing workers. Skarlicki and Folger found that a nested model in which each of the three dimensions of fairness (one concerning outcomes, two concerning procedures and "dignity" with which the worker is treated) are entered individually and as two-way and three-way interaction terms explained a full 68% of the variance in "effort". Omitting the three-way interaction led to a small but significant drop in R^2 (by 3%). Further omitting the two-way interactions led to a dramatic drop in R^2, to only 39%.

Perceptions of deservingness appear to mediate aggressive, potentially anger-driven retaliation, and deservingness itself appears a multi-dimensional notion; furthermore, it may be one that interacts with other cognitive dimensions, such as whether the other players are perceived as members of the same group or of another group relative to that of an agent. While one can always dummy out factors in the utility function, the difficulty for rational choice would seem to be not so much with anger as a motivational force (as a preference), as much as with the determinants of

anger episodes. And obviously the same problem may not arise, or not to the same extent, with other emotions.

3. The neuroeconomics of anger

3.1 The received view

Only few social scientists and decision theorists have explicitly considered the neurobiology of emotions (e.g., Elster; Hanoch, 2002a; van Winden, 2001), although some recent neuroeconomic work has focused on Damasio's somatic marker hypothesis (Leland and Graffman, 2003; Rustichini et al., 2002). Insofar as a received view is being formed, it has one or more of the following beliefs: (a) a view of the neurobiological mechanisms underlying emotions as broadly in common to all emotions; (b) a belief in the role of the amygdala as crucial for any theory of emotion generation, under the influence of LeDoux; (c) a more general emphasis on the fact that emotions can be generated without mediation, or with little mediation, of the prefrontal cortex, an emphasis which is used to downplay cognitive processes in the generation of emotions. We shall try to show (1) that these beliefs are either incorrect or inapplicable to anger in economic decision making, and (2) that we can learn from how the neurobiology of anger differs from that of other emotions.

A sophisticated presentation of the received view can be found in van Winden, and is largely based on LeDoux and on the assumption that similar neural networks will hold for anger as for fear, the emotion studied by LeDoux. The thalamus is seen as "a relay station for sensory messages" and hence for emotional stimuli. The emotional stimulus, relayed by the thalamus, then follows either a 'low road', operating purely at the subcortical level, or a 'high road' involving a greater cognitive role. The sensory message then may get processed directly at the subcortical level by the amygdala ('low road'), a quick response route for situations where "we react rather than think". Alternatively, the sensory message may benefit from neocortical cognitive information processing, although even then the amygdala plays an important role in influencing cognitive processing both directly and indirectly. As a result, the amygdala is seen as the "central emotional computer that performs the primary

appraisal of the emotional significance of emotional stimuli" (van Winden, p. 498). The conclusion of the analysis is that cognitive processing is just one possible input in the process, with no influence on behavior unless emotions are generated.

The neurobiological evidence refers mainly to anger as an emotion, not anger as a state or as a trait. The exceptions relate to neurological and neurophysiological dysfunctions affecting anger as an individual trait (e.g., Fava and Rosenbaum, 1999), and will not be reviewed here. We now turn to the evidence on anger as an emotion.

3.2 Brain asymmetry and anger as an approach emotion

According to Panksepp (1998, 2000), neurobiological theories of emotions can be classified according to whether they rely on general brain processes that are shared by all emotions (e.g., LeDoux), whether they assume that there are different neurobiological mechanisms for different basic emotional systems (e.g., MacLean, 1990), or whether they adopt an intermediate position between these two (e.g., Lang, 1995). For example, there have been claims that the amygdala works as an "emotional computer" (LeDoux); at the same time, though, different parts of the so-called limbic system are activated when different emotions are involved, and the activation of anger does have its specific areas of activation according to neuroimaging studies (section 3.3). From a neurophysiological viewpoint, there are both neurotransmitters that *generally* regulate emotions, such as serotonin, and others that are more specifically produced when an agent is angry (Panksepp, 2000).

Caution is required in applying to the specific emotion of anger common generalizations that are believed to apply to emotions in general. One of such generalizations is that right brain hemisphere activation is related to 'negative' (unpleasant) emotions, and left brain hemisphere is related to 'positive' (pleasant) emotions (e.g. Heller, 1990, and Frank, 1997). This has led to the suggestion that differential activation might be used to measure cardinal utility on a neurobiologically objective scale: there are a variety of reasons why this is not the case (Zizzo, 2002). Still, as no one doubts that anger is a 'negative' emotion, one would then predict that anger implies more activation of prefrontal cortex networks in the right brain hemisphere. Unfortunately, this does not appear to be so in studies of

electroencephalographic (EEG) activity. Waldstein et al. (2000) found no evidence of systematic more activation of the left prefrontal cortex relative to the right prefrontal cortex in the presence of mildly anger-inducing events. In Waldstein et al., subjects were shown a 1 minute film clip designed to elicit anger (involving the mistreatment of a man by several bullies) and were then asked to describe and recall the experience of a personally relevant angry incident. Harmon-Jones and Sigelman (2001) had a stronger treatment to induce anger. After a baseline EEG recording, subjects had to write an essay on a social issue, among those in a list (e.g., reducing the drinking age or the legality of smoking in public places), which they found most important to them. They were told that another subject would then provide comments on what they had written. Deception was used and no subject actually provided comments; subjects received either neutral evaluations and comments, or strongly negative evaluations and comments (e.g., "I can't believe an educated person would think like this. I hope this person learns something while at U.W. [University of Wisconsin]"). EEG activity was then recorded again and questionnaire measures of emotional states were also taken. Unsurprisingly, feelings of anger were found in the 'negative comments' condition. In this condition, unequivocally more EEG activation was found in the *left* than in the right prefrontal cortex. This result agrees with Harmon-Jones and Allen's (1998) finding that subjects who tend to be angrier as a personality trait are also subjects with greater left prefrontal cortex activation. Van Honk et al. (2002) noted the left lateralization of anger as a stylized fact, and provided some correlational evidence that left brain activation drives activation of the right brain hemisphere when recognition of an angry face is involved. Intuitively, neural networks dealing with anger may be helpful for other neural networks that are involved in the *recognition* of anger, though the second are not required for the first. Dougherty et al. (1999) used a different methodology, based on PET screening, to verify activation in different parts of the brain when a weak manipulation of anger (similar to Waldstein et al.) was employed. The PET screening was sufficiently accurate to detect a significant activation of the left - but not the right - orbitofrontal cortex. In conclusion, the evidence suggests that, contrary to the common generalization, parts of the left rather

than the right prefrontal cortex are more activated when a decision maker experiences anger.

Harmon-Jones and Allen (1998) suggest that that asymmetries in brain activation may not relate to whether an emotion is positive or negative, but rather to whether the emotion entails a propensity to approach or to avoid the target of the emotion. If this interpretation were true, anger would be an *approach* emotion, which can be understood by viewing anger as *anger towards a target the agent may wish to aggress*. For example, if an agent were angry because of another agent defecting in a repeated group social dilemma interaction, and if a punishment technology is available, anger may bring the agent to exercise the punishment, solving the free rider problem of who is to enforce the punishment when this is agreed, explicitly or implicitly, to sustain cooperation. Thus, anger may be part of the reason why the availability of a punishment technology is so effective in sustaining cooperation, as shown for example by Fehr and Gachter (2000). Furthermore, the prefrontal cortex may have a larger role to explain anger than usually believed.

3.3 Anger and the amygdala

Does the amygdala play an essential role in the experience of anger in the same way that the left prefrontal cortex does? Perception of anger-inducing visual stimuli may result in amygdala activation (e.g., Rosen et al., 2002); indeed, Adolphs et al. (1994, 1996) present PET scan evidence suggesting that the recognition of angry faces is impaired when the amygdala is damaged. However, according to Berthoz et al. (2002), no fMRI functional imaging study has been able to detect amygdala activation in response to angry faces (e.g., Kesler-West et al., 2001; Blair et al., 1999), and Sanfey et al.'s fMRI study on ultimatum game play is consistent with this negative finding. Furthermore, in PET studies where anger was induced without the aid of visual stimuli, the amygdala was not activated (Dougherty et al., 1999; Damasio et al., 2000). The same result of no amygdala activation was replicated in a PET study where subjects had to recall events that would make them angry, and were subsequently shown three angry faces (Kimbrell et al., 1999). A possible reply to these negative findings would be that no anger was actually elicited, even fleetingly.

Nevertheless, the elicitation of emotions was successfully verified with psychological scales (e.g. the Spielberger-State Anger scale in Kimbrell et al.), and meaningful changes in activation were found elsewhere in the brain. Adolphs and Damasio (2000) believe that the amygdala is not associated with the experience of emotions; while this may not be an uncontroversial statement (LeDoux, for example, may have a different view in relation to fear, the object of his research), it certainly appears to be true in relation to anger.

3.4 Emotion-specific brain mechanisms

If one wants to move beyond the findings on the asymmetric activation of the prefrontal cortex, what are the brain areas that are activated when anger is induced? Dougherty et al. (1999) found increased activation in paralimbic prefrontal areas, specifically the left orbitofrontal cortex, the right anterior cingulate cortex and the bilateral anterior temporal lobes. Kimbrell et al. (1999) investigated the brain activation of anger and anxiety. In both cases increases in left inferior prefrontal and left temporal pole regions were found, with decreases in the corresponding right hemisphere regions; anxiety had a further effect on the anterior cingulate and on other areas which anger did not affect, while anger, and only anger, increased activation in the right temporal pole and thalamus. Damasio et al. (2000) studied the effects of four emotions (anger, and also sadness, happiness and fear) on a variety of brain areas. Although they stressed the involvement of somatosensory cortices and the upper brainstem nuclei as generally providing support for the somato-marker hypothesis of emotions, there were significant differences in brain activation across different emotions. Anger affected activation in a variety of areas in the prefrontal cortex, in a way consistent with hemispherical asymmetry in activation. It affected the orbitofrontal and cingulate prefrontal regions, in a way partially though not entirely consistent with the Dougherty et al. and Kimbrell et al. (e.g., the left rather than right anterior cingulate cortex). How anger was elicited was not identical in the three papers, and this may provide at least a partial explanation for the differences in the findings across them. But one qualitative feature that emerges from this work is that different emotions are likely to involve different neurobiological mechanisms, so that

unidimensional approaches to emotion just in terms of arousal, as in Kaufman (1999), are unlikely to hold.[3]

3.5 Cognitive thinness, intentionality and economic decision-making

One problem with this line of research for us is the thinness of the cognitive requirements actually required of the subjects in these experiments. Anger is an emotion that is usually associated with significant cognitive processing: following Cornelius (1996), it is not by accident that psychologists who minimize the role of cognition in generating emotions do not typically refer to anger, whereas psychologists who stress the role of cognition do. As Power and Dalgleish (1997, p. 305) note, anger is a "moral" emotion, occurring as "the result of an appraisal of some deliberate, negligent, or at least avoidable, slight or wrongdoing", "most usually directed at another person", and directed towards "punishment for, or correction of, the wrong that has been carried out". Averill (1983) argues that anger is related to the violation of social norms. Ortony et al. (1988) stress the importance of the disapproval of, and displeasure at, someone's blameworthy action. Views of anger not based on blameworthiness exist, but do not escape the relevance of cognitive factors (e.g., Stein and Levine, 1990); Berkowitz (1999) stresses the importance of unpleasant and frustrating experiences in generating anger experiences that may affect anger as an *emotional state*, but higher cognitive processing still plays an important role in his scheme in the generation of anger *episodes*. In bargaining or other settings, such as work relationships or tax payment, an array of factors may affect perceptions of deservingness in economic decision-making, and how this may interact with other cognitive factors (see section 2.3.2). As a result, it is only plausible to assume that cognitive requirements are greater within the richer setting of an economic decision-making problem.

We would expect that this 'thicker' cognitive requirements would be mapped into a still greater role for the prefrontal cortex. Unfortunately, no neurobehavioral

[3] This point, however, may not be crucial to Kaufman's analysis, insofar as this may be rephrased in terms of arousal of specific emotions rather than generic emotional arousal.

studies have been done specifically on anger in relation to economic decision-making problems. In an fMRI imagining experiment where some deception was used, Sanfey et al. analyzed the effect of equal or unequal offers in the ultimatum game, but unfortunately they did not isolate what might behaviorally be due to anger and what might be due to other emotions. Subjects were led to believe that some offers were from human partners while others came from a computer partner; they also did a control task where subjects simply received money for a button press. The focus of their paper is on the activation of prefrontal cortex areas (the dorsolateral region and the anterior cingulate cortex) and a limbic system area (the anterior insula), with the anterior insula being activated more when offers by supposed human partners were rejected. Sanfey et al. seem to believe that the activation of the dorsolateral region of the prefrontal cortex would reflect cognition whereas that of the anterior insula would reflect emotion, but the data they report is at least equally consistent with the view that the activation of prefrontal cortex, cognition-thick areas is essential for emotion-based decision making. Although Sanfey et al. do not mention this in their paper, their data also shows a significant greater activation of the medial region of the prefrontal cortex with fair rather than unfair offers.[4] Unfortunately, they provide very little information on how the general level of activation in brain regions (other than the anterior insula) was affected in subjects while playing the ultimatum game with human partners relative to the other tasks. In addition, it would have been useful to have a control treatment where subjects played a task of comparable cognitive complexity to that of the ultimatum game, since the computer partner treatment may have removed the emotional involvement only partially and the 'button-pressing' treatment was purely mechanical.

Some further information may be obtained from Berthoz et al. (2002) and Moll et al. (2002), who studied the processing of the transgressions of social norms: they found that, apart from temporal regions, two parts of the prefrontal cortex - the medial

[4] This result emerges from an accompanying table available electronically on the *Science* website. (The table refers to human partners offers only; no corresponding table is provided for computer parners).

prefrontal cortex and the lateral orbitofrontal cortex - are crucially implicated when a fMRI functional imagining analysis is made. This appears to support the importance of cognitive requirements in economic settings where anger is induced as the result of violations of social norm (e.g., that of appearing fair in ultimatum bargaining). It is consistent with Damasio's own view that the medial prefrontal cortex and the orbitofrontal cortex play an important role for the regulation of emotions, such as anger. The classical example is that of Phineas Gage, a successful and well trusted engineer who in 1848 due to a work accident had the medial part of his prefrontal cortex perforated by an iron rod, with very little other brain damage (Damasio, 1994). He was then unable to keep his previous job because of his unreliability and (in his doctor's words) "manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating". Anger could be generated but was not so in socially appropriate circumstances. As a result of his impairment, he was never able to get again and hold to a secure and well paid job of the kind he once had. Another case discussed by Damasio is that of patient Elliot, who had massive damage both to the medial and the orbitofrontal regions, and who was able to become angry, but only (Damasio claims) infrequently and not for long.

Berthoz et al. (2002) note that the medial prefrontal and temporal regions have been found to be responsible for the representation of the mental state of others. It is then of interest that, in their study, *intentional* violations of social norms induced more pronounced activation than *unintentional* violations. This can be ascribed to the cognitive processing of the intentions of others rather than simply to different degrees of arousal, as the physiological measures of arousal appeared identical for the two settings (Berthoz et al.). This may be consistent with the one difference between human partner treatment and computer partner treatment that Sanfey et al. report (namely, in anterior insula activation). These results support the claim by Falk et al. (in press) that the intentions attributed to the other players matter in deciding how to behave towards her. They also show one dimension in which the role of cognitive processing has been specifically identified. But they also provide a warning: they

suggest that the cognitive processing involved in anger-induced economic decision-making is likely to be thick, and that therefore only by a getting a better understanding of how the former occurs will we be able to understand the latter. In this sense, the emphasis of behavioral economists on emotions vs. cognition may be somewhat misplaced: the trouble for rational choice may come from the difficulty of understanding the cognitive underpinnings of emotions, rather than the emotional process itself.[5] In line with these findings, Greene et al. (2001) found greater activation of the medial prefrontal cortex with what they label "personal" moral dilemmas (such as throwing people off a sinking lifeboat or stealing one's person organs) than with what they label "impersonal" moral ones (such as keeping money found in a lost wallet).

4. Conclusions

This paper employed standard definitions of rationality and emotions to argue that, if any tension exists between anger-driven decision making and rational choice, it is due to the potential implied intertemporal inconsistency in preferences and, maybe more so, to the difficulty of understanding the cognitive underpinnings of emotions. Talking about the rationality of emotions makes little sense as long as emotions can be parsimoniously and stably encompassed in a utility function the maximisation of which defines a choice as being rational. Dichotomies between cognition and emotion are inappropriate, as they hide the fact that anger has a thick cognitive component. When anger is generated the left brain hemisphere tends to be activated more than the right hemisphere; this is consistent with interpreting anger as an emotion directed towards an object of anger. The medial and possibly other prefrontal cortex regions are involved in the generation of anger, while the amygdala is not. The prefrontal cortex regions appear to be activated more when the target of anger is perceived to have behaved intentionally.

[5] In the specific case of intentions, attempts have been made to build complex, if a little unparsimonious, specialized utility functions trying to explain them (such as Falk and Fischbacher's).

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