



The Neuroeconomics of Anger

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Abstract This paper employs neurobehavioral and psychological evidence to argue that anger is an emotion associated to significant cognitive processing in relation to economic decision-making. The medial and possibly other prefrontal cortex regions play an important role in anger processing, whereas the amygdala does not. Dichotomies between emotions and cognition are likely to be illusory, and care should be taken in generalizing mechanisms applying to one emotion to other emotions.

JEL Classification C91, D11

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1. Introduction

There is a growing interest in the role that emotions play in economic decision-making (e.g., Elster 1998, van Winden 2001, Hanoch 2002). This interest is influenced, in part, by the lessons of neurobiologists such as Damasio (1994) and LeDoux (1998). It leads to emphasize an apparent dichotomy between warm blood and cold thought, emotion and reason, perhaps with the additional twist of thinking emotion as prior to reason (Damasio 1994), though others still believe emotions as essentially fumbling children at most solving out the problems that they themselves create (Elster 1998).¹

Any debate on the rationality of emotions will heavily depend on the definitions use both for rationality and for emotions. But it is unclear that such a scientific construct exists as ‘emotions’, and even if it did there are still significant reasons to believe that different emotions can be very different children, not

¹ I criticize Elster’s view in Zizzo (2004a).

brothers but perhaps at most just distant cousins (see Griffiths 1997, 1998, Elster 1998, Russell and Feldman 1999, Panksepp 1998). A humbler approach at this stage may be just to focus on single emotions that are known to matter for economic decision-making, and to analyse them in the context of economic decision-making settings. This humbler approach is the one I take in this paper, and have taken in Zizzo (2003, 2004a): I focus on the neuroeconomics of anger rather than of emotions in general.

The rest of this paper is structured as follows. Section 2 is on largely based on the analysis conducted in Zizzo (2004a) about the relationship between anger, cognition and rational choice. Section 3 is the core of this paper and deals with the neural basis of anger. The conclusion in section 4 summarizes the findings.

2. The psychology of anger²

Anger is an emotion potentially of considerable importance for economic decision-making, in fields as diverse as bargaining behavior (Pillutla and Murnighan, 1996), tax payment choices (Bosman and van Winden, 2002) and work efforts in the context of the fair-wage effort hypothesis (Akerlof and Yellen, 1990). As I argue in Zizzo (2004a), if we simply focus on anger, and we use a standard definition of economic rationality as based on the maximization of a stable and reasonably parsimonious utility function, anger-driven behavior can, in principle, be modeled as a preference in the utility function. As far as this is a successful strategy, anger is consistent with rational choice, whatever the problems there might be in using other notions of rationality. Problems from rational choice come from the possible intertemporal inconsistency of preferences induced by anger (Loewenstein 2000), from the relationship between anger and cognitive effort (Kaufman 1999) and possibly from other cognitive distortions; importantly, they may come from the complexity of the cognitive processes producing anger. In bargaining, tax payment or wage effort settings, what will matter for anger to be elicited is that the agent feels slighted and that there is someone that deserves to be blamed for the slight. This is *not* to say that in a given setting it may not happen that anger may conceivably be elicited with only ‘thin’ cognitive involvement; nor does it imply that blame has to be at the root of any anger episode, for we can agree with Parkinson (1999) that it probably is not. What this *does* mean, however, is that the typical economic settings in relation to which anger is likely to be relevant are such as to be heavily underpinned by ‘thick’ cognitive processing. In bargaining or other settings, such as work relationships

² This section is largely based on Zizzo (2003, 2004a).

or tax payment, an array of factors may affect perceptions of deservingness in economic decision-making, and this may interact with other cognitive factors (Zizzo 2003, 2004a). Judgements of deservingness are not purely determined by relative payoffs. For example, in Guth and Tietz (1986) the positions of proposer and receiver in an ultimatum game were auctioned off. As a result of that, it was understood that proposers had 'earned' their bargaining advantage and, therefore, more uneven splits resulted. Schotter et al. (1996) had the four top earning proposers in a first round of ultimatum bargaining play a second round of bargaining. Lower proposals than usual were observed. The 'need to survive' or 'to stay in business' was why lower proposals were justified. A host of other papers shows the role of entitlements at work in bargaining settings (e.g., Hoffman and Spitzer 1985, Hoffman et al. 1994, 1996, Ruffle 1998) and in other experimental work (e.g., Zizzo and Oswald 2001, Zizzo 2004b).³ There is also evidence from questionnaire and field studies, showing the importance of procedural fairness and its interaction with other factors in determining, for example, aggressive retaliatory behavior in companies (e.g., Greenberg and Scott 1996). 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 relative favourability of outcomes (e.g., Brockner and Wiesenfeld 1996), intentionality (e.g., Falk and Fischbacher 2001), and social comparison and social identification variables (e.g., Lamertz 2002). One can always dummy out factors in the utility function, but a serious difficulty for rational choice would seem to be not so much with anger as a 'hot' motivational force as much as with the cognitive determinants of anger episodes. It is more generally true that it is from the cognitive distortions that are related to emotions that the problems for rational choice arise. The dichotomy between emotions and cognition can hardly be more illusory.

3. The neuroeconomics of anger

3.1 *Temptations*

It is tempting to talk of emotions as a single scientific category implying that what applies to the mechanisms underlying one emotion should also underlie other emotions. It is equally tempting to use what is known about the neurobiological mechanisms of one emotion to draw inferences about other emotions. While the two temptations do not have to go necessarily hand in hand, they may

³ See Zizzo (2003, 2004a) for a more complete review.

very well be related: a belief in emotions as a single scientific category may strengthen a belief in a neurobiological mechanism in common to all emotions, and vice versa.

Of course a sceptic may reply that we can learn nothing about the psychology of decision-making from the neural level. This is an extreme position, and it is not one that I will take in this paper. And, in the same way in which at the psychological level it is not clear how much there is in common among different emotions, it is also clear from the neurobiological level that there is benefit from investigating the role that *specific* emotions have for economic decision-making, rather than emotions in general. Camille et al. (2004) and Coricelli (2004) do this for regret, and in what follows I analyze what is the state of play on the neuroeconomics of anger.

3.2 *The received view*

Only few social scientists and decision theorists have explicitly considered the neurobiology of emotions (e.g., Elster 1998, Hanoch 2002, 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.

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.

3.3 *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 Gächter (2000). Furthermore, the prefrontal cortex may have a larger role to explain anger than usually believed.

3.4 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? The most convincing potential source of evidence comes from lesion studies. It has long been known that bilateral damage to the amygdala is sufficient to produce the Kluver-Bucy syndrome in monkeys, with symptoms such as excessive exploratory and sexual behavior, abnormal dietary changes, and apparent emotional 'tameness' (Weiskrantz 1956). Many of the early studies, however, were not selective enough, and damaged also areas other than the amygdala: the symptoms are reduced with more selective lesions (Aggleton and Young 2002). Meunier et al. (1999) studied the effect of more selective (but not fully selective) bilateral chemical lesions to the amygdala on monkeys' behavior. They found increased fearfulness and reduced aggression, but to a lower degree. In addition, as in earlier studies (e.g., Kling and Brothers 1992), there was *increased* aggressiveness on some occasions where frustration was induced. While amygdala damage does seem to cause some emotional dysregulation, especially in relation to fear, it is unclear from primate studies the extent to which changes in aggressive behavior are induced by increased fearfulness or rather by changes in the capability of experiencing anger.

In humans amygdala damage on its own does not produce anything like the Kluver-Bucy syndrome: indeed very little or even no obvious change in emotionality is observed (Aggleton 1992). While amygdalotomies have been sometimes used to reduce hyperaggressiveness, there has not been much of an attempt to study systematically – rather than purely anecdotally – how amygdalotomies actually affect emotional states (Aggleton and Young 2002). Lee et al. (1998) describe the effect of amygdalotomies on two hyperaggressive patients suffering from epileptic seizures due to prior neural damage. Although the number of aggressive outbursts declined for both patients, both patients still had problems controlling them when they occurred, and in one case the patient assaulted and almost murdered the supervisor of his personal care home, and ended up in the forensic unit of a state psychiatric hospital. Lee et al.'s interpretation of the role of the amygdala is that it affects the fight-or-flight response. This is consistent with the suggestion that the effect of amygdala damage on aggression is mediated by a disruption of the fear mechanism more than it is by a disruption of the anger mechanism.

Lesion studies show that amygdala damage can impair face recognition though not word recognition (Aggleton and Young 2002). Evidence from patients with the Urbach-Wiethe disease (which damages the amygdala) suggests that there may be an impairment with tasks related to the recognition of emotional expression (Young et al. 1995), though the evidence is not unequivocal on this (Siebert et al. 2003).

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. 1999), 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.

The more general, and simple, point is that an inability to *recognize* emotional expression or the like may not have any direct relationship with an inability to *feel* an emotion. It is a truism, known to any eunuch, that people may well recognize things that they are not able to do and feel themselves; the opposite case, surely, is also true. And so for example D.R., an epileptic patient treated with bilateral amygdalotomy, was impaired in matching and recognizing emotional facial expression, but did not display any loss in emotionality herself (Young et al. 1995, Aggleton and Young 2002).

3.5 *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.⁴

3.6 *Cognitive thickness of anger*

One problem with this line of research is the thinness of the cognitive requirements actually required of the subjects in these experiments. As discussed in section 2, anger is an emotion that is usually associated with significant cognitive processing: we would expect that this 'thicker' cognitive requirements would be mapped into a still greater role for the prefrontal cortex. Unfortunately, no neurobehavioral 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

⁴ 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.

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 significantly greater activation of the medial region of the prefrontal cortex with fair rather than unfair offers.⁵ 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. It is still early days in the study of the neural economics of anger.⁶

4. Conclusions

There is increasing interest in both neuroeconomics and the study of emotions in economic decision-making. It is tempting to conceive of anger as just the product of a brain circuit which is in common to all emotions. This may be thought of as to be mapped into a psychological mechanism that would be common across emotions. These temptations, however, need to be resisted. The little we know about the neural basis of anger in economic decision-making suggest, for example, that the amygdala is not directly involved in the experience of anger. 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, and this agrees with the cognitively thick nature of the process of generation of anger in typical economic settings such as bargaining or wage effort. Dichotomies between cognition and emotion are inappropriate, as they hide the fact that anger has a thick cognitive component. Indeed most problems created by anger for rational choice arise from its associated cognitive processes.

⁵ 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 partners).

⁶ Other potentially relevant studies include Greene et al. (2001), Berthoz et al. (2002) and Moll et al. (2002).

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