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Fairness considerations are activated by social
information: the feedback negativity in the context of
the Ultimatum Game

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Abstract

The feedback negativity (FN) is a component of the event-related brain potential (ERP) that is associated with stimuli indicating unfavorable outcomes like losses in monetary gambling tasks or negative performance feedback. A recently proposed theory of reinforcement learning holds that the FN is generated whenever ongoing events are evaluated as 'worse than expected'. The work at hand investigated the role of the FN in the context of the Ultimatum Game (UG). In this game, two players split a certain amount of money (10 Euros in the present research); one player (commonly entitled the proposer) suggests a division and the other (called the responder) can either accept or reject it. We were interested in the question whether the perception of (un)fairness, as experienced by responders being confronted with different types of UG offers, was reflected in the amplitude of the FN. Additionally, we tried to assess the impact of social distance (manipulated via information provided to the responders about their presumed counterparts) on behavioral and neural responses of our subjects.

We recorded electroencephalograms (EEGs) while participants were in the role of the responder, facing fair (a proposed split of 5-5), midfair (7-3) or unfair (9-1) offers. We sought to generate (or additionally enforce) expectations in our UG subjects by providing information about their presumed counterparts in half of the trials. This manipulation was accomplished to reduce the degree of social distance among the players, which has been shown to have strong influence on economic game behavior.

We found that the perception of different types of UG offers generated an FN, being less pronounced for fair as compared to midfair and unfair offers. Social distance crucially influenced brain responses to the three offers, as differences in the FN amplitude were only apparent when social information about the responders' counterparts was revealed.

We propose that the FN in the context of this study reflects the violation of general expectations and fairness considerations of our subjects which are activated by social information. It is further suggested that the amplitude of the FN depends on the size of the prediction error, growing with the magnitude of deviation from the fair 50-50 split.

Theoretical Part

1 Economic decision-making

The question of how people make decisions and judgements has occupied scientists for centuries. Based on different models and assumptions diverse efforts have been undertaken to analyze and explain human decision-making behavior. Classic economic theory has developed the well known concept of the *homo oeconomicus*, a rational, self-interest-guided and unemotional maximizer (Kenning and Plassmann, 2005).

The influence of emotions and other psychological factors on (economic) decision-making has traditionally been underestimated or even ignored and it is the field of *behavioral economics* which emerged in the 1970s that started to challenge the idea of the decision-maker as "a perfectly rational cognitive machine" (Sanfey et al., 2003).

Extensive experimental research in behavioral economics (see for example Camerer, Loewenstein and Rabin, 2003 for an overview) has made clear that it is not only personal material payoff that motivates people in their actions – as proposed by standard economic theory – but that other constructs like fairness or reciprocity play a decisive role when people make decisions. Deviations from the predictions of traditional concepts like subjects showing non-opportunistic behavior or other "anomalies" and "paradoxes" (Camerer and Thaler, 1995) led to the integration of psychological ideas and concepts into economic theory, creating broader models of economic behavior.

One main point of criticism coming from traditional economics addressed the fact that theoretical constructs like "intuition" and "reasoning" (Kahneman, 2002; cited after Kenning and Plassmann, 2005) have been postulated based on the "observation and analysis of behavior, which in turn is used to explain behavior" (Kenning and Plassmann, 2005). Economists did not only resent this *circular reasoning* but also complained about the mentioned theoretical constructs neither being directly observable nor measurable in an objective way.

An interdisciplinary framework which has evolved in recent years seems to have the potential to integrate economic theories and direct measurement of thoughts and feelings: Neuroeconomics. This discipline seeks to analyze economically relevant behavior using neuroscientific techniques like brain imaging and has the "ultimate aim of providing a single, general theory of human behavior" (Glimcher and Rustichini, 2004).

The following chapters try to shortly overview some findings from behavioral economics, game theory (especially one of its most prominent paradigms, the so-called Ultimatum Game) and neuroeconomics to create a theoretical embedment for the work at hand.

1.1. Behavioral economics

Experimental studies have highlighted shortcomings of classic economic theory, like for example its assumptions about stable, well-defined preferences and rational choices of decision-makers. The field of behavioral economics is mainly concerned with the bounds of rationality, self-interest and self-control of economic agents and points out that concepts like fairness and reciprocity cannot be ignored in social interactions (Fehr and Schmidt, 2006).

It was in the 1960ies that cognitive psychology put the brain as an information processing unit into the focus of interest – in contrast to behaviorist models defining it as a black box whose functioning would not be known. Consequently, cognitive psychologists like Daniel Kahneman or Amos Tversky started analyzing economic decision making and expressing psychological principles and constructs in simple formal terms. Thus, bounded rationality could be modeled in terms familiar to economists and economic theory was linked more and more to psychological foundations (Camerer, 1999).

"Prospect theory", as presented by Kahneman and Tversky (1992), tries to explore how people make choices when confronted with alternatives involving risk. According to the authors, the evaluation of potential gains and losses implies weighting their probabilities nonlinearly: People integrate their experience and thus utilities are determined from some reference point. Prospect theory has shown that people are "loss-averse", which means that losses are disliked about twice as much as equally-sized gains are liked. Furthermore, people overestimate low probabilities, which may be of help in explaining the widespread desire to gamble for example on lottery tickets (see Camerer, 1999).

Economic models generally assume that people are pursuing their material self-interest and do not worry about "social" goals per se (Fehr and Schmidt, 1999). That people do

not only behave rationally but care about others in social exchange is demonstrated in laboratory experiments operating with game theoretic paradigms like the *Ultimatum Game*. Some of these findings are reported in the next part of this work.

1.2. Game theory

As a sub-discipline of applied mathematics, game theory investigates systems with various agents, trying to mathematically comprehend behavior in strategic situations, in which an individual's success in making decisions or choices depends on those of other "players".

A formalized analysis of parlour games by the Hungarian-American mathematician John von Neumann can be seen as the fundament of modern game theory. Together with the Austrian economist Oskar Morgenstern he published *The Theory of Games and Economic Behavior* (von Neumann and Morgenstern, 1944), "the birth cry of game theory", as Karl Sigmund put it (Sigmund, 2004).

According to Camerer, Loewenstein and Prelec (2005), there are four central assumptions on which game theoretic predictions are based: (1) players have accurate beliefs about what others will do; (2) they have no emotions or concern about how much others earn; (3) players plan ahead and (4) learn from experience.

The methodology of game theory mainly consists of modelling human interaction as a game ("game" in this context means a mathematical model describing procedures, in which several agents influence each other in the outcome of their decisions). Predictions of game theory are quite similar to those of classical economics: People behave rationally and are anxious for maximizing their personal benefit. Addressing von Neumann's and Morgenstern's theory of rational behavior and its incompatibility with experimental findings of actual human behavior, Sigmund stated that game theory is "a mathematical tool more useful for description than for prediction" (Sigmund, 2004).

The Ultimatum Game is among the established and most studied tasks of game theory.

1.2.1. Ultimatum Game

The so-called Ultimatum Game is a well known experiment which clearly demonstrates that the self-interest hypothesis is hard to argue for human behavior in economic decision-making. The Ultimatum paradigm (see Güth et al., 1982) is quite simple. Two players are allocated a sum of money. The first player, commonly entitled the proposer, offers some amount of the money to the second player, called the responder. If the offer is accepted, the sum is divided accordingly. If the responder rejects it, neither of the players is donated any money.

Assuming two rational players motivated purely by self-interest and not caring about the outcome of the other (in other terms: two income maximizers), game theoretic predictions are: The responder accepts any offer made and the proposer, aware of this, will offer a minimum – the smallest nonzero amount – and keep the rest for himself. In fact these predictions are at odds with observed behavior: The modal offer is a 50/50 split (average offers are about 40 to 50% of the total amount), and low offers of less than one-fifth have a chance of about 50% to be rejected (Güth et al., 1982, Camerer and Thaler, 1995; Roth, 1995). These patterns have been replicated in several studies and can be considered as robust (Fehr and Schmidt, 1999). Interestingly the regularities do not even change with rather high stake sizes, as for example Hoffman, McCabe and Smith (1996a) pointed out, and can be found in different countries and cultural areas, as Roth et al. (1991) demonstrated comparing bargaining behavior in the Ultimatum Game in Jerusalem, Ljubljana, Pittsburgh and Tokio.

Obviously there are circumstances under which people are motivated to actively refuse monetary reward. But why do people reject low offers? According to Fehr and Schmidt (2006) it is because they view them as unfair. Proposers on the other hand act generously because they anticipate their playfellows' rejection of low offers. Even in the Dictator Game, a version of the Ultimatum Game where responders have to accept any offer made by the proposer, people did allocate a portion of the total amount although their payoff was not dependent on the placet of their partners (Forsythe et al., 1994).

Rabin (1993) provided a model of fairness based on findings from social psychology. He integrated "intentions" and "attributions" of economic agents: People differentiate between intentional acts of meanness, which they will punish, and an unintended mean act, which will be tolerated. This reciprocal fairness view is complemented by the idea

that responders in the Ultimatum Game primarily react to the "manners" of the proposer (Camerer and Thaler, 1995). Camerer and Thaler (1995) presumed that the tendency to reject insulting low offers is learned, as manners are. The authors cited a study (Murnighan and Saxon, working paper, 1994; published 1998) that seems to support this view: Playing Ultimatum Games for a small amount of money or candies, kindergartners accepted minimal offers about 70% of the time, compared to about 40% for third- and sixth-graders.

People turning down low offers are objecting to unfairness. They are willing to pass on material gain in order to punish their partners for their unfair behavior. Negative emotions induced by unfair condition in the Ultimatum Game are thought to be an explanation for this behavior. Sanfey et al. (2003) argued that unfair offers induce conflict between cognitive and emotional motives in the responder, between tendencies to "accept" and "reject". The next chapter of this work tries to explore which psychological and neural processes mediate such behavior in social exchange.

1.3. Neuroeconomics

The field of Neuroeconomics integrates findings and principles from economics, psychology and neuroscience in order to develop more accurate models of choice and decision. It is the brain and its role in evaluating decisions, categorizing risks and rewards and social interaction in general that is of main interest. While economists and psychologists provide conceptual tools for comprehending and modeling behavior, neurobiologists offer tools for the study of mechanisms (Glimcher and Rustichini, 2004).

Social decision-making has been investigated by various disciplines applying different theoretical frameworks and measurement techniques, but with comparatively little integration of results (Sanfey, 2007). It is important to state that explanations of choice behavior by economists, psychologists and neurobiologists usually operate at different levels of analysis. Neuroeconomics is considered to be a promising way to correct this lack of integration (Glimcher and Rustichini, 2004; Sanfey, Loewenstein, McClure and Cohen, 2006; Sanfey, 2007). By combining mathematical decision models and tasks that

have been formulated by economics with cognitive and neural limitations as explored by psychology and neuroscience, neuroeconomics tries to deepen the understanding of decision-making (Sanfey, 2007).

Sanfey et al. (2006) expected that economics' unified theoretical framework for understanding human behavior may prove most useful for neuroscientists – in particular the interpretation of behavior as choosing alternatives aiming at maximizing utility. According to the authors, economics presumes two dimensions of decision-making: *choice* (the evaluation of options and selection of actions) and *judgment* (information processing and probability estimation). In this sense making decisions could be understood as comparing utility signals for each of the decision alternatives. Neuroeconomics seeks to investigate the underlying brain mechanisms – the neural substrates of cognitive and emotional processes which are engaged in economic decision-making.

If we conceptualize neuroeconomics as the application of neuroscientific methodology to capture and decode economically relevant behavior (Camerer et al., 2005), we should take a short look at applied neuroscientific methods.

1.3.1. Neuroscience methods

There are several kinds of neuroscientific methods that are capable of investigating economic decision-making. Predominant tools currently used in neuroeconomic research can be classified into two categories (see Kenning and Plassmann, 2005): Procedures for measuring electromagnetic activity of the brain and techniques which are sensitive to cerebral blood flow or metabolism changes.

Electroencephalography (EEG) and *Magnetoencephalography (MEG)* are prominent examples of the first group: EEG records electric activity (voltage fluctuations) along the scalp produced by ion fluxes in surface-near cortex areas whereas MEG is sensitive to magnetic fields induced by the electrical brain activity. Both of these techniques are able to detect time courses of different brain events precisely because of their temporal resolution of milliseconds and below.

Brain imaging techniques of the second group are *Positron Emission Tomography (PET)* and *functional Magnetic Resonance Imaging (fMRI)*. PET visualizes the distribution of a weakly radioactively marked substance (so-called *tracer*, like modified

glucose (FDG)), which is injected or inhaled, in the organism. From this distribution, information about metabolism or brain perfusion can be deduced and visualized in tomograms. The currently most popular neuroscientific method is fMRI, which tracks blood flow in the brain using changes in magnetic properties due to blood oxygenation (the "BOLD – Blood Oxygenation Level Dependent – signal"). The big advantage of PET and fMRI is their high spatial resolution, whereas their temporal resolution is comparatively low.

The mentioned techniques are complemented by various others like *Single-Neuron Recording* or *Transcranial Magnetic Stimulation (TMS)*.

The long-run goal of neuroscientific research is to provide explanations for how the brain solves different types of problems and especially how different parts of the brain interact in doing so. Current research topics in neuroeconomics are diverse and scientists have addressed matters like *preferences, utility and the reward system*, as well as dynamic concepts like *learning* or *strategic reasoning* (Kenning and Plassmann, 2005; Sanfey, 2007).

As the work at hand deals with the Ultimatum Game and the perception of (un)fairness, some findings concerning the "social" brain will be presented in the following.

1.3.2. Ultimatum bargaining and the brain

Anger seems to be the reason why responders often reject unfair offers in the Ultimatum Game (Pillutla and Murnighan, 1996). This finding supports the notion that emotions play a crucial role in social decision-making. As Sanfey (2007) pointed out, emotional processes appear to cover a network of brain structures including reward-processing mechanisms as well as midbrain and cortex areas like the ventromedial prefrontal cortex (VMPFC) and the anterior cingulate cortex (ACC). The prefrontal cortex (PFC) receives inputs from most of the other regions, integrates them to form goals and plan actions (Shallice and Burgess, 1996; cited after Camerer et al., 2005) and is therefore sometimes called the "executive" region. According to Bush, Luu and Posner (2000), the ACC is involved in the evaluation of emotional and motivational stimuli and the regulation of emotional answers.

Emotional states make people reject low offers in the Ultimatum Game or – in other

words – provoke them to avoid inequity. Nowak, Page and Sigmund (2000) argued that objecting to unfairness and punishing those who try to take advantage of others may have evolved as a mechanism to maintain a social reputation and to strengthen reciprocity. Neuroscience tries to explore the neural correlates of complex affective reactions and investigate the causal relationship between emotional reactions and ensuing decisions. An fMRI-study by Sanfey, Rilling, Aronson, Nystrom and Cohen (2003) shed light on the substrates of economic decision-making in the Ultimatum Game: 19 participants were scanned, being in the role of the responder and confronted with fair and unfair offers by human and computer partners. Sanfey et al. (2003) demonstrated that perceived unfairness correlated with activations in certain regions of the brain: Comparing unfair with fair offers from human proposers, bilateral anterior insula, the dorsolateral prefrontal cortex (DLPFC) and the ACC were among the areas with greater activation.

The *anterior insula* is often associated with negative emotional states such as pain, distress or disgust. Sanfey et al. (2003) interpreted the activity in this area as a reflection of the responder's negative emotional response to an unfair offer and showed that anterior insula activation predicted rather reliably (correlation of 0.45) whether players reject unfair offers or not.

The *DLPFC* appears to be an area involved in planning ahead, goal maintenance and executive control (Miller and Cohen, 2001; Wagner et al., 2001; cited after Sanfey et al., 2003). Sanfey et al. (2003) argued that the activation of the DLPFC could be due to the cognitive demand of the task, specifically the aim of accumulating as much money as possible.

According to the authors, ACC activity can be linked to the detection of cognitive conflict (Botvinick et al., 1999) and may mirror the conflict between cognitive and emotional motivations in the Ultimatum Game.

Camerer, Loewenstein and Prelec (2005) offered a catchy interpretation of the interaction of the mentioned brain areas sensitive to unfair offers:

"Therefore, it appears that, after an unfair offer, the brain (ACC) struggles to resolve the conflict between wanting to accept the money because of its planned reward value (DLPFC) and disliking the 'disgust' of being treated unfairly (insula)."

There is further evidence suggesting a central role of the prefrontal cortex (PFC) in

social decision-making. Koenigs and Tranel (2007) investigated Ultimatum decision-making in patients with ventromedial PFC (VMPFC) damage and found a significantly higher rejection rate of unfair offers for patients than a control group. Similar results were obtained by Harle and Sanfey (2007) after having primed normal players with negative emotional states. Strong support for a causal relation between activation in frontal brain regions and social decisions has also come from studies employing transcranial magnetic stimulation (TMS): After a temporary lesion to the DLPFC has been induced, responders in an Ultimatum Game setting were ready to accept significantly more unfair offers as compared with control situations (Van't Wout et al., 2005; Knoch et al., 2006).

Polezzi et al. (2008) investigated Ultimatum bargaining behavior recording event-related potentials (ERPs) while subjects were in the role of the responder. The authors reported that a fast initial distinction between fair and unfair offers was reflected in the amplitude of the so-called *feedback-related negativity (FRN)*, being larger for mid-value (a proposed split of 7/3) than for fair (5/5) offers. The difference between fair and unfair (9/1) offers approached significance (Polezzi et al., 2008).

The following section compiles findings concerning the FRN and related frontal negativities.

2 Frontal negativities and the anterior cingulate cortex (ACC)

As reported in the preceding chapter, Sanfey et al. (2003) found the ACC as one of the brain regions showing more activity when responders in the Ultimatum Game were confronted with unfair offers as compared to fair ones. ACC is ascribed an important role in *performance monitoring* and *error detection*. Oliveira, McDonald and Goodman (2007) identified three different views of how performance monitoring leads to an increase in ACC activity: Miltner et al. (1997) argued that information signaling errors in performance activates an error-detection system of which the ACC is part. Another approach defined the ACC as one component of a conflict-monitoring system that is activated by response competition rather than solely error detection (Botvinick, Cohen and Carter, 2004; Yeung, Cohen and Botvinick, 2004; Botvinick, Braver, Barch, Carter, and Cohen, 2001). A third view was presented by Holroyd and Coles (2002): Together with other brain structures the ACC forms a reward-prediction system being activated when ongoing events are evaluated as worse than expected.

Scientific research on the neural substrates and functioning of performance monitoring and error detection has described a number of components of the event-related potential (ERP) being elicited by errors and negative feedback regarding task performance. In a review article, Folstein and Van Petten (2008) divided these anterior negative components into the response-locked *error-related negativity (ERN)* and the *feedback-related negativity (FRN)*, which is time-locked to a feedback stimulus.

The ERN is a negative deflection peaking around 50 to 100 milliseconds after a response. As Falkenstein et al. (1990, 1991) as well as Gehring et al. (1993) showed, the component is larger for errors than correct responses in choice reaction tasks. The ERN is recorded at fronto-central scalp areas, being maximal in amplitude over the supplementary motor area (Holroyd and Coles, 2002).

The FRN is a negative brain potential which is localized in fronto-central scalp regions and is peaking around 250 milliseconds after stimulus-onset. Miltner, Brown and Coles (1997) reported an FRN following the presentation of negative performance feedback in a time estimation task, the feedback indicating that the subject's time estimation was

incorrect. The FRN seems to be sensitive to the quality of feedback only, regardless of sensory modality of the feedback signal. As studies employing gambling tasks showed, the FRN is also elicited as a response to monetary losses but interestingly does not appear to be sensitive to the magnitude of the loss but rather to whether an outcome is positive or negative (Yeung and Sanfey, 2004; Gehring and Willoughby, 2002 and 2004; Hajcak, Moser, Holroyd and Simons, 2006).

Converging lines of evidence suggested that both components, the ERN as well as the FRN, were generated in the medial frontal cortex, even though the data were more convincing for the ERN (Folstein and Van Petten, 2008). A meta-analysis by Ridderinkhof, Ullsperger, Crone and Nieuwenhuis (2004) reviewed functional neuroimaging studies on response errors and negative feedback, and found reported activation in medial prefrontal cortex, namely Brodmann's areas 24 and 32 of the ACC and motor areas 6 and 8 (see Figure 1). Source localization analyses to ERP-data (Miltner et al., 1997; Gehring and Willoughby, 2002) have also identified the generator of the FRN in or near the ACC.

It is not only the assumed common generator of the ERN and FRN, but also their similar fronto-central scalp distribution and morphology that led Miltner et al. (1997) to the proposal that the two components were associated with the same neural and cognitive process of error-detection. Holroyd and Coles (2002) suggested an influential extension of Miltner et al.'s (1997) view hypothesizing that the medial frontal negativities are produced by a dopamine system for reinforcement learning. The reinforcement learning theory ("RL-ERN theory") holds that both the ERN and FRN are generated by a dopaminergic signal conveyed to the ACC to inform it that a given outcome was worse than expected. Before discussing the RL-ERN theory in more detail, some other theoretical concepts concerning the ERN/FRN will be presented.

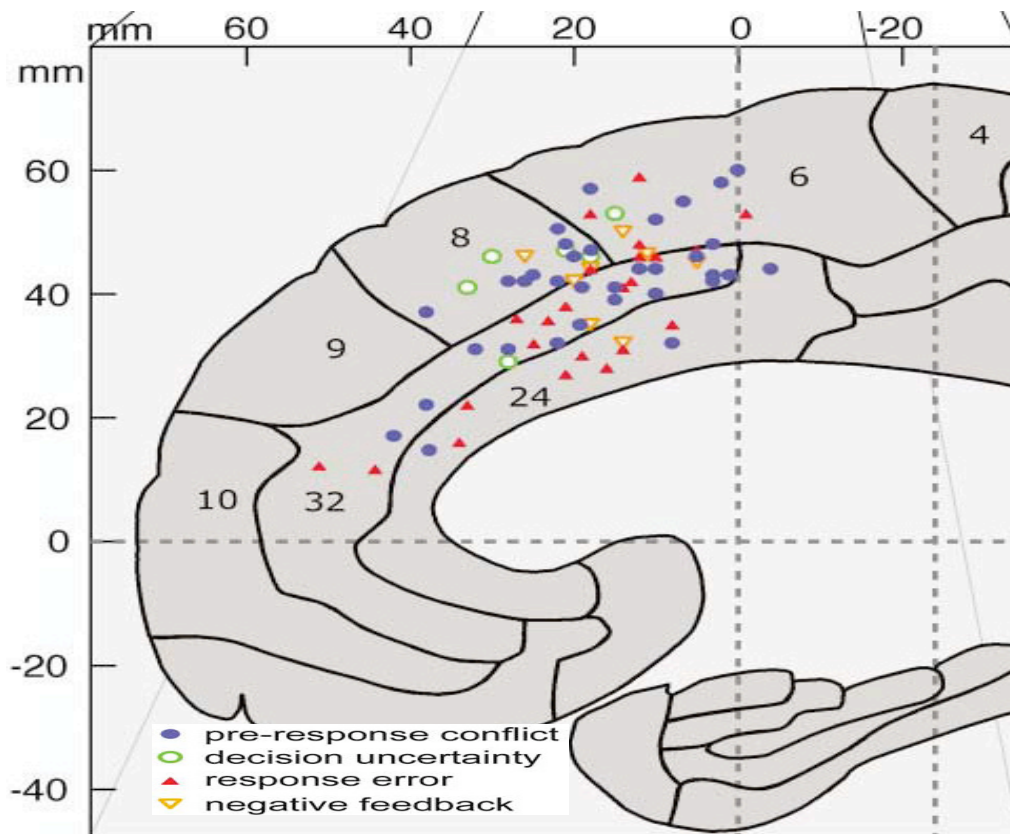


Figure 1: Reported activations (midline foci) in 38 fMRI studies published between 1997 and 2004 investigating brain activity associated with pre-response conflict, decision uncertainty, response errors and negative feedback. The activation foci are superimposed on the enlarged schematic area map. The majority of activations cluster in the posterodorsal medial frontal cortex, in the region where Brodmann areas 8, 6, 32, and 24 border each other (adapted from Ridderinkhof et al., 2004).

2.1. *ERN as a mismatch signal*

Increasing interest in event-related brain potentials associated with the commission of errors in choice reaction time tasks has been encouraged by the pioneering work of Falkenstein and his colleagues (1990, 1991) and Gehring et al. (1993).

Apart from using different nomenclature for their error-related potentials (Falkenstein et al.: Ne; Gehring et al.: ERN), both groups identified a negative component following errors in choice reaction tasks and peaking up to 100 milliseconds after the onset of the

response. Further research of the two mentioned groups led to the formulation of a model of error-related processing, which was additionally supported by the work of Coles, Scheffers and Holroyd (2001).

This model (Coles et al., 2001; see also Figure 2) incorporates the specific ERN or Ne process and consists of two major components: a monitoring system detecting errors and a remedial action system. The monitoring system compares representations of the correct or appropriate response with those of the actual response. When a mismatch is revealed in this comparison, an error signal is conveyed to the remedial action system. This second error-processing component is responsible for initiating remedial actions, construed to inhibit, correct or compensate the error. According to Coles, Scheffers and Holroyd (2001), the ERN is generated by the arrival of the error signal at the remedial action system.

As choice reaction time tasks call for rapid answers, it seems that committed errors are due to guessing or other forms of impulsive responding. Thus responses are executed before all the information needed to guide the correct response is extracted from the stimulus.

Representations of the actual response are probably derived from a central feedback system and when the motor command is issued to initiate the response, an 'efference copy' is sent to the monitoring system. Representations of the correct or intended response on the other hand are thought to follow from ongoing processing of the stimulus after the incorrect response is produced.

Errors occur when responses are executed impulsively, i. e. before stimulus processing is completed and a final representation of the correct response has been determined by the response selection system. Coles et al. (2001) proposed that the mismatch process is triggered by response execution itself and that the comparison system uses whatever information is available at the time of the response instead of waiting until all possible informations about the appropriate response are at hand.

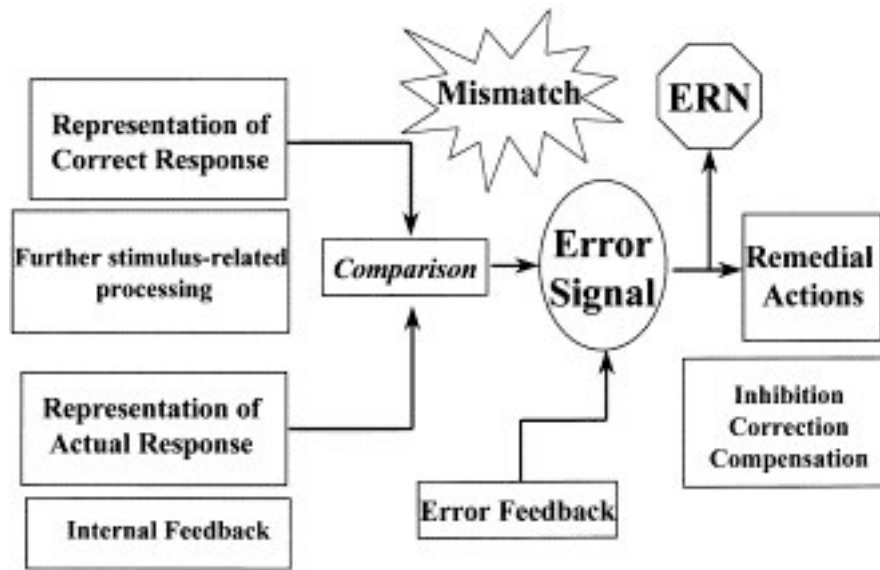


Figure 2: Schematic representation of the mismatch theory of the ERN. See text for explanations (Coles, Scheffers and Holroyd, 2001)

2.2. *Conflict-monitoring theory of the ERN*

The conflict-monitoring theory of ACC function (Botvinick et al., 2001; Yeung, Botvinick and Cohen, 2004) contradicted the mismatch hypothesis and assumed that the ERN was not signaling the occurrence of an error but rather reflected the continuous evaluation of response conflict. *Response conflict* is understood as the simultaneous activation of incompatible response channels and considered to be monitored by the ACC. In this sense, the ERN may not reflect the output of a system for error-detection only, as the mismatch theory proposed, but is associated with the process of conflict monitoring that also occurs on correct trials. Yeung, Botvinick and Cohen (2004) defined the ERN as "the input to, rather than the output from, the error detection system."

Holroyd and Yeung (2003) abstracted the conflict-monitoring theory of the ERN (see also Figure 3) as follows: The ACC is accountable for monitoring response-conflict. Whenever there is co-activation of competing responses (conflict), the ACC sends this

information to brain areas engaged in cognitive control, e. g. lateral prefrontal cortex.

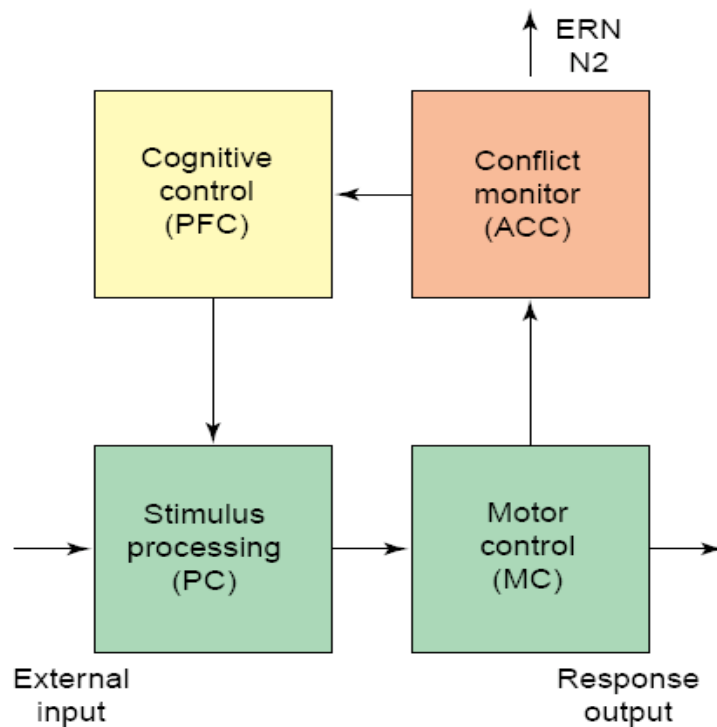


Figure 3: Schematic representation of the conflict-monitoring theory of the ERN. Abbreviations: ACC, anterior cingulate cortex; MC, motor cortex; PFC, prefrontal cortex; PC, posterior cortex. See text for explanations (Holroyd and Yeung, 2003)

Stimulus processing takes place in the posterior cortex and the resulting information is mapped to a corresponding response in the motor cortex. Sometimes, an incorrect response is activated by noise in the system before the stimulus is fully processed, but ongoing stimulus-related processing leads to the generation of the correct response (an "error correction"). If both responses are simultaneously activated for a short period of time after error commission, post-response conflict evolves. Whenever the ACC detects such a conflict, it generates the ERN (Holroyd and Yeung, 2003).

The described theory explains the ERN in terms of a continuous evaluation of response conflict whereas mismatch detection is considered to be a discrete process that occurs only at the time of response execution (Coles et al., 2001). Because of their proposal

that response conflict is monitored continuously, Yeung, Botvinick and Cohen (2004) also accomplished to explain the relationship between the ERN and another component of the event-related potential: the N2. The N2 is a negative potential peaking between 200 and 350 milliseconds after stimulus onset and with fronto-central scalp distribution. Research traditions have focused on attention and novelty or perceptual mismatch as determinants of N2 amplitude (for a review see Folstein and Van Petten, 2008). Yeung et al. (2004) suggested that the N2 is produced by the ACC when it detects pre-response conflict on correct trials. The authors assumed a common underlying mechanism of conflict monitoring for the N2 and the ERN.

2.3. *Reinforcement learning theory of the ERN*

Performance feedback elicits a negative ERP-component that is maximal over medial frontal scalp locations. The amplitude of the FRN is larger following incorrect responses or monetary losses, than following positive feedback (Miltner et al., 1997; Gehring and Willoughby, 2002; Holroyd and Coles, 2002; Nieuwenhuis et al., 2004b). Because of the deflection's assumed generator, the ACC, it has been suggested that the FRN is functionally similar to the error-related negativity (ERN) (Miltner et al., 1997).

Emphasizing the reward-signaling function of feedback, Holroyd and Coles (2002) formulated the so-called *reinforcement learning theory of the ERN (RL-ERN theory)* holding that a dopamine system for reinforcement learning generates both the response ERN and the FRN (or feedback ERN). The authors located a response-monitoring system in the basal ganglia which produces error signals that activate the mesencephalic dopamine system. The ERN is evoked by the impact of phasic changes in dopamine activity on the anterior cingulate cortex (ACC) (see Holroyd and Yeung, 2003). According to Nieuwenhuis, Holroyd, Mol and Coles (2004a), who referred to previous research (e.g. Schultz, 2002), the basal ganglia are responsible for the evaluation of ongoing events and the prediction of their outcome (success or failure; good or bad) based on information received from the external environment and an efference copy of the response (see also Figure 4, Holroyd et Yeung, 2003). If these predictions are revised (e.g., by an external stimulus), phasic increases or decreases in the activity of

midbrain dopaminergic neurons are induced, depending on whether events are categorised as "better" or "worse than expected". These error signals, coded as changes of the tonic activity of the mesencephalic dopamine system, are conveyed to the ACC where they reinforce performance on the task at hand and in this way serve the adaptive modification of behavior. Furthermore, the dopamine signals are carried back to the basal ganglia, where they are used to improve predictions (see Holroyd and Yeung, 2003 and Nieuwenhuis et al., 2004a).

The RL-ERN theory assumes that the impact of the dopamine signals on the ACC modulates the ERN amplitude: If ongoing events are assessed to be worse than expected, phasic decreases in dopamine activity occur. These error signals are associated with large ERNs. Phasic increases on the other hand, indicating that events are better than expected, are accompanied by small ERNs (Holroyd and Coles, 2002).

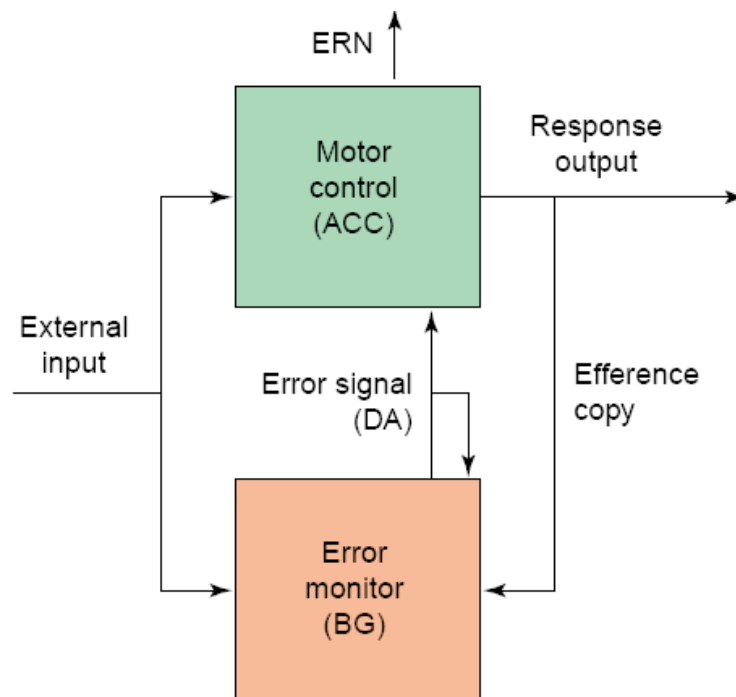


Figure 4: Schematic representation of the reinforcement learning theory of the ERN. Abbreviations: ACC, anterior cingulate cortex; BG, basal ganglia; DA, mesencephalic dopamine system. See text for explanations (Holroyd and Yeung, 2003)

Based on the work of Holroyd and Coles (2002), Nieuwenhuis et al. (2004a) reviewed findings about the feedback ERN resulting in the formulation of four predictions of the reinforcement learning theory. The following are central for the study at hand:

- *The feedback ERN reflects a good-bad evaluation:* The RL-ERN theory proposed that the ERN was sensitive to any feedback information indicating favorable or unfavorable outcomes. Taking the results of several studies (Nieuwenhuis et al., 2004b; Gehring and Willoughby, 2002; Yeung and Sanfey, 2004) into account, it seems that the ERN reflects a rapid evaluation of events along an abstract good-bad dimension. Addressing the debate regarding whether or not the response ERN and the feedback ERN are the same phenomenon, Nieuwenhuis et al. (2004b) demonstrated that the fronto-central negativity elicited by feedback stimuli can be selectively sensitive to monetary losses or to performance errors, depending on which was emphasized by the feedback stimulus, or in other words, depending on the context in which the information was provided.
- *Feedback ERN amplitude depends on the relation between actual versus expected outcome:* Studies involving gambling tasks (see for example Holroyd, Nieuwenhuis, Yeung and Cohen, 2003; Holroyd, Larsen and Cohen, 2004) suggested that the feedback ERN is not sensitive to the absolute magnitude of the reward but to deviations from the expected value. Nieuwenhuis et al. (2004a) stated that "the feedback ERN behaves as if it reflects a reward prediction error."
- *The feedback ERN is generated in the anterior cingulate cortex (ACC).*

The RL-ERN theory argues that the FRN (or feedback ERN) is generated when outcomes are evaluated as worse than expected. Holroyd and Coles (2002), as well as Gehring and Willoughby (2002) related the FRN to the processing of reward value and the motivational significance of ongoing events. The latter employed a simple monetary gambling task and found a negative frontal deflection (de facto an FRN but termed *medial frontal negativity, MFN* by the authors) greater in amplitude for losses than gains and presumably generated in the ACC. Gehring and Willoughby (2002) proposed that the MFN may reflect an evaluation of the motivational impact of outcome events. A study by Yeung, Holroyd and Cohen (2005) pointed into a similar direction also indicating that motivational factors influence processing in the ACC.

Running different versions of monetary gambling tasks, the authors demonstrated that even if participants had no influence on the outcome (*no-response task*: participants' only requirement was to attend to the outcome), an FRN – or simply *feedback negativity (FN)*, as the authors named it (the nomenclature of Yeung et al. (2005) shall be used in the following) – was observed differing significantly between loss and gain trials. The amplitude of the component was smaller in the no-response task than in the *choice-task*, where participants could actively select one of the alternatives and thus experienced contingency upon their response choices and the outcome. The reduction in FN amplitude in the no-response task was correlated with reduced participants' ratings of subjective involvement in the task. According to Yeung, Holroyd and Cohen (2005) this finding indicates that the evaluative process indexed by the FN is sensitive to the motivational significance of ongoing events.

By observing the feedback negativity in the absence of response choices, Yeung et al. (2005) addressed the question of whether FNs are also generated when the subjects' task is to simply look at stimuli which inform them about monetary rewards and punishments (Nieuwenhuis et al. 2004a). Based on their results, Yeung, Holroyd and Cohen (2005) suggested that the FN reflects the reward signal alone and not, as speculated by Holroyd and Coles (2002), its use to reinforce or punish a recent response. Proposing an extension of the reinforcement learning framework, Yeung et al. (2005) presumed that the ACC also uses reward signals to learn about contingencies in the external environment. Expectations about these environmental contingencies are seen as covert responses that may be reinforced or punished. On this note Yeung, Holroyd and Cohen (2005) advocated an inclusion of learning that is not specifically related to recently executed actions into the reinforcement learning theory of the ERN/FN.

Before developing research questions concerning the FN and Ultimatum bargaining, some findings about *anonymity* and *social distance* in experimental economics shall be summarized.

3 Economic games and the influence of social factors on decision-making

Growing scientific interest concerns the influence of social preferences on economic behavior. Laboratory subjects frequently choose not to maximize their own material gains in the presence of social influences, as for example demonstrated by responders in the Ultimatum Game who reject positive monetary offers, presumably to punish their unfair partners (Güth et al., 1982, Camerer and Thaler, 1995; Roth, 1995).

Solnick and Schweitzer (1999) presented experimental findings that Ultimatum bargaining is affected by physical attractiveness and Hoffman, McCabe and Smith (1996b) showed that behavior in the Dictator Game (a modified version of the Ultimatum Game, where responders do not have the chance to reject offers) is sensitive to whether the dictator feels observed by the experimenter in his choices or not.

Van't Wout and Sanfey (2008) listed some research on the *Trust Game* (Berg, Dickhaut and McCabe, 1995) demonstrating the influence of several experimental variables on game behavior. In a standard Trust Game two anonymous players, an investor and a partner, interact with each other. Being endowed with a certain amount of money, the investor can allocate any share of the total amount to the partner. The money transferred is multiplied by the experimenter, usually by a factor of 3 or 4. Subsequently the partner has the chance to return any portion of the multiplied amount. Honoring trust, he can allocate more money than transferred by the investor and both players end up with a higher payoff. If the partner abuses trust, he gains a lot while the investor ends up having less than the primary endowment. Labeling the game mate "opponent" or "partner", implying cooperation or competition, affected the investor's decision-making, resulting in half as much trusting behavior interacting with an "opponent" (Burnham, McCabe and Smith, 2000). Delgado et al. (2005) found that the investors' willingness to trust is modulated by information about the social and moral status of their counterparts. Partners described as having high moral character were trusted more often. Van't Wout and Sanfey (2008) themselves could demonstrate that high facial trustworthiness, as subjectively rated by investors, leads people to transfer bigger amounts of money.

3.1. Social distance and anonymity

Although almost every field interaction takes place with protagonists having full knowledge of their counterparts, the standard procedure in experimental economics continues to be anonymity among participants. There are some studies (see for example Bohnet and Frey, 1999; Burnham, 2003; Charness and Gneezy, 2008) seeking to vary the degree of social distance between the protagonists in economic games by manipulating the amount of information which players receive about their counterparts. Charness and Gneezy (2008) compared gambling behavior in Dictator and Ultimatum Games with anonymity among the players with the same games involving subjects who were told the family names of their partner. It could be shown that dictators behaved more generous, providing a significantly bigger share, when names were revealed. The fact that this kind of social information did not have an effect on Ultimatum Game offers was explained with the "nature" of the game. Charness and Gneezy (2008) argued that impulses of generosity are crowded out by strategic considerations.

Burnham (2003) also ran Dictator Games, but these consisted of three different conditions: "no photo", "dictator photo" and "recipient photo". While in the second condition the recipient was given a photograph of the dictator together with his decision, dictators saw an instant photograph of their counterparts before making a decision in the third one. The results were in line with those of Charness and Gneezy (2008). Dictators' giving behavior in the two photo conditions differed significantly from the "no photo" condition: 25 % of the dictators in each of the photograph conditions allocated half of the total amount compared to 3.8 % in the "no photo" condition. Burnham (2003) presumed, referring to Schelling's observation that people give more when they know particulars about the recipient ("identifiable victim" concept; Schelling, 1968), that dictators in the "recipient photo" condition felt more empathy towards their photographed and thus identifiable game partners. An fMRI-study by Rilling et al. (2004) may be of interest in this context. The authors scanned participants while they were playing the Ultimatum Game (and the Prisoner's Dilemma Game) with human and computer counterparts, investigating whether partner decisions activated different brain areas. Being confronted with offers from human partners (who were introduced via a photograph), responders showed stronger activity (as compared to computer offers) in brain areas associated with a presumed theory of mind neural

network. Responders also rejected unfair offers from human partners more frequently. These results may be linked to studies manipulating the degree of social distance in economic games, as responders in the Rilling et al. (2004) study showed different behavior and cortical activity after being confronted with offers of a partner whom they were able to identify. Thus one could hypothesize that social closeness may also have some explanatory value for the findings of Rilling et al. (2004).

Bohnet and Frey formulated a hierarchy of "institutional characteristics" (1995) which defines the extent to which fairness considerations are active: In an anonymous setting, people only have an intrinsic motivation to behave fairly; the fairness norm is partially activated when people are given the chance to identify each other; and with the possibility to communicate, the fairness norm is strongly active (cited after Charness and Gneezy, 2008). In one of two related experiments, Bohnet and Frey (1999) employed the Dictator Game in three condition conditions: "Anonymity", "One-way identification" and "One-way identification with information". In the second and the third variant of the game, dictators knew who their potential recipients were but not vice versa. One-way identification was realized by giving dictators the possibility to visually identify their respective recipients, while in the other session they additionally received information (for example name and provenance) about their game mates. Bohnet and Frey (1999) observed that dictators offered most when they were given the chance to learn more about who their counterpart was; visual identification alone led to higher solidarity rates as compared to the anonymous variant of the game.

The reported studies clearly indicate that social distance or closeness, as manipulated via information that players in economic games receive about their counterparts, plays a crucial role in decision-making. Indeed most of the research focused on the proposer (respectively the investor or dictator) and how knowledge about his game partners affects his behavior. The work at hand concentrates on responders in an Ultimatum Game setting and tries to investigate how varying degrees of social distance influence their fairness considerations and behavior.

4 Research question

The preceding chapters presented a compendium of findings from behavioral economics and neuroscience concerning bargaining behavior, negative ERP-components sensitive to errors and performance feedback, and social factors influencing decision-making. In an attempt to integrate these insights, the work at hand addresses the question whether the perception of (un)fairness, as experienced in an economic game, is influenced by the degree of social distance among the interacting players. We recorded electroencephalograms while participants were in the role of the responder in an Ultimatum Game setting (Güth et al., 1982). Social distance was manipulated via information provided to the subjects about their presumed counterparts. Proposers were either introduced via a photograph, accompanied by social information (name and age), or presented anonymously (simply entitled as "Proposer"). We expected that Ultimatum Game offers generate a feedback negativity (FN) and that the variation of social distance is reflected in the amplitude of this component.

The central research question of this diploma thesis was motivated by Nieuwenhuis et al.'s proposal (2004a) to investigate whether FNs are also elicited when participants' assignment is to *solely* look at stimuli informing them about monetary rewards or punishments. In fact, there is empirical evidence suggesting that an FN is also generated in the absence of choice or responding. As mentioned above, Yeung et al. (2005) observed an FN in a monetary gambling task, without active response choice or action being required from the participants. Donkers, Nieuwenhuis and van Boxtel (2005) also reported an "FRN-like mediofrontal negativity" being elicited by outcomes that were not contingent on any preceding choice or action. Running a slot-machine task, in which three digits, successively presented on a screen, informed participants about gains and losses, the authors could show that the outcomes were associated with a FN, although they were not preceded by any choice or action, i. e. no response was required of the subjects.

Employing a modified version of the Eriksen flanker task (Eriksen and Eriksen, 1974), van Schie, Mars, Coles and Bekkering (2004) demonstrated that committing an error as well as watching others committing an error elicited an ERN, supporting the hypothesis

that this component can occur even without preceding action or response.

Analyzing responders' behavior and neural activation patterns while they view Ultimatum Game offers before deciding whether to accept them or not could also be an appropriate way to follow Nieuwenhuis et al.'s suggestion.

Any accepted UG offer results in a material gain for the responder. Nonetheless, low offers may in their perception be equivalent to monetary losses or punishments, taking into account that 50-50 splits are deemed to be a social norm or a fair outcome (Burnham, 2003; Chang and Sanfey, 2009). If responders expect a fair share, low offers probably equal a violation of their assumptions concerning their counterparts' behavior. Following the diction of the reinforcement learning theory, low offers may be considered to be 'worse than expected' and therefore provoke the generation of an FN.

Nieuwenhuis et al. (2004a) presumed that the FN reflects a good-bad evaluation and that its amplitude depends on the relation between actual versus expected outcome. Based on these predictions and keeping in mind that responders have been reported to count on a fair outcome (a 50-50 share) in the Ultimatum Game, we expect the FN amplitude to be influenced by the type of offer made. In this sense, unfair offers should be associated with large FNs, fair offers with small ones.

Perceived social closeness among participants in experimental games affects their behavior. As Bohnet and Frey (1995) pointed out, fairness considerations are more active when people have the possibility to identify each other compared to an anonymous setting. Here we check responders' perception of different Ultimatum Game offers coming from identifiable versus anonymous proposers. Receiving information (photograph, name and age) about the counterpart may additionally activate responders' fairness considerations and add to form expectations about the other player's behavior. Hence it could be assumed that low offers from identifiable proposers are considered to be more unfair than the numerically identical offers from an anonymous counterpart. We expect this difference to be reflected in the FN amplitude, with unfair offers ascribed to familiar proposers being followed by larger FNs.

This study also investigates the neural substrate for the perception of (un)fair offers in the Ultimatum Game. In line with several studies (e. g. Miltner et al., 1997; Gehring and Willoughby, 2002), we expect the FN to be generated in or near the ACC.

Summing up, the aims of this diploma thesis are twofold: First, we attempt to replicate the results reported by Polezzi et al. (2008), who directly linked the Ultimatum Game and the FN and found that a distinction between fair and other kinds of offers was reflected in the FN amplitude. Second, the influence of social closeness versus anonymity on the perception of Ultimatum Game offers shall be investigated.

Empirical Part

5 Materials and methods

5.1. *Participants*

Thirty right-handed subjects – fifteen women, fifteen men – with normal or corrected-to-normal vision participated in this study. Handedness was assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). Participants were recruited on a volunteer and informed consent basis, meeting federal and local ethic standards. All subjects were free of neurological diseases and had no psychiatric history. To achieve higher homogeneity and comparability of the sample, we recruited participants similar in age for the experiment. In fact, the volunteers' age ranged from 18 to 31 years, with a mean of 24.27 (standard deviation [SD] = 3.94). Prior to participation, subjects were briefed about the procedure and possible risks of an EEG-study and written informed consent was obtained from each participant. Subjects were instructed that individual remuneration would depend on choice behavior in the task (with a possible range from 5 to 10 Euros). Essentially, every participant received 10 Euros after the experiment was concluded, independent of actual choices.

5.2. *Task*

Before the experimental session started, subjects were asked to complete a personality questionnaire (NEO-FFI, Borkenau and Ostendorf, 1993), the results of which are not included in the current diploma thesis.

A modified version of the Ultimatum Game (UG) was administered. As Rilling et al. (2004) put it, the UG is a two-player game in which the responder learns whether the proposer is generous or greedy. Here a single-shot version of the game was used with players splitting 10 Euros in each round. Subjects played as responders and received a single offer from each proposer. After being confronted with proposers' offers of how to split the money, the participants' task was to decide whether to accept or reject the

proposed division. A 3 x 2 design was realized, containing three different OFFER conditions (see Polezzi et al., 2008) and two SOCIAL DISTANCE conditions, resulting in six different modes of item configuration (see Table 1).

Offers	"Social distance" conditions	Modes of item configuration
● Fair (5-5 split) ● Midfair (7-3) ● Unfair (9-1)	● Anonymity ● Information	✓ Fair/Anonymity ✓ Midfair/Anonymity ✓ Unfair/Anonymity ✓ Fair/Information ✓ Midfair/Information ✓ Unfair/Information

Table 1: Conditions of our modified Ultimatum Game.

Participants were told that the proposers' offers had been collected in a pilot study. In fact, offers were manipulated by the experimenter in order to guarantee the same number of trials for every condition. Each of the six conditions contained 48 items, resulting in a total of 288 Ultimatum Game rounds to play. In the course of the experiment, responders were confronted with 144 identifiable proposers (72 women and 72 men: condition *information*: photograph (frontal view of the face), first and second name and age of the proposer were presented), as well as with 144 non-identifiable counterparts (entitled as "Proposer"; condition *anonymity*). Photographs were in black-and-white and aligned in the center of the screen, 8,5 centimeters in height, and 7,5 centimeters in width (vertical and horizontal resolution: 72 dpi). Mean age of female and male proposers was 24.81 ([SD] = 3.31), respectively 27.18 years ([SD] = 3.91).

Fair, midfair und unfair offers were equally distributed on the two SOCIAL DISTANCE conditions, i. e. responders viewed the same number of different types of offers (48 each) made by identifiable and anonymous proposers (see also Figure 5). In our *information* condition, the number of fair, midfair and unfair offers was counterbalanced between female and male proposers (24 offers for each offer-gender combination).

The item material (including photographs) was entirely generated by ourselves and stimulus presentation and synchronization with the EEG data collection was controlled by E-Prime 2.0 (Psychology Software Tools, Inc.; <http://www.pstnet.com>).

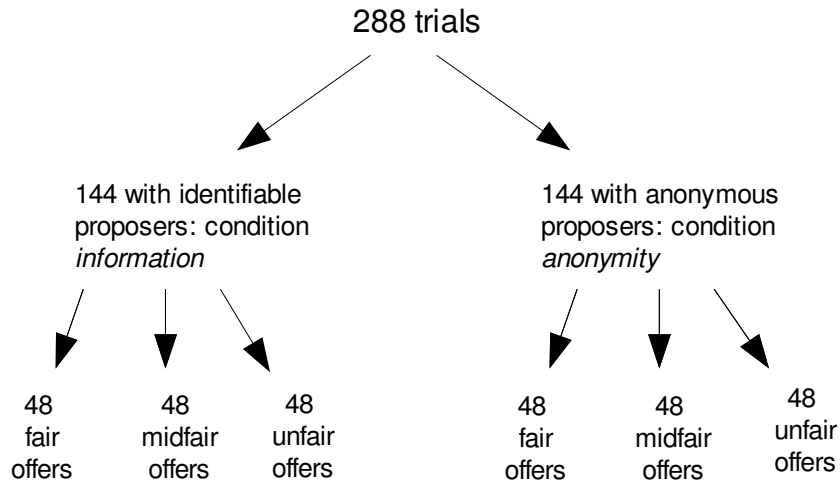


Figure 5: Trial structure in our modified UG version. See text for explanations.

5.3. Procedure

Participants performed the Ultimatum Game being comfortably seated about 70 centimetres in front of a 19-in. CRT computer monitor in a sound-attenuated room. Before data collection started, the instructions were presented in written form (see Appendix A for instructions in German).

The experiment consisted of four blocks with 72 trials each, offers being presented in randomized order. After each block, a pause was provided in which subjects were informed about the amount of money they had gained so far. Prior to the experiment, participants were instructed that individual payoff would be calculated via a predefined key to convert game money amounts and would be determined by their choice behavior, being maximal (10 Euros) for accepting all offers and minimal (5 Euros) for rejecting every single one. In fact, every subject was rewarded 10 Euros for the participation in our study. Financial compensation was intended to advance participants' motivation on the task (see Hertwig et al., 2001) and to achieve a closer approximation to real economic behavior.

An *information* trial (see also Figure 6 (a)) was made up by the following sequence: It started with a black asterisk on a grey screen, having a duration of 2 seconds. Subsequently, the proposer was introduced via a photograph, and her/his name and age

(written in black letters) for another 2 seconds. Then, the proposer's offer appeared on the screen, showing two numbers, framed in black and arranged one below the other. The digit on the bottom of the screen corresponded to the part of the 10 Euros provided to the responder. After 1.5 seconds, the German words for accept and reject (see Appendix A for instructions in German) were shown in the right respectively left lower corner of the screen. In the course of the experiment, the positions of the two possible answers varied at random. Participants were asked to press a button on the keyboard (either '1' or '2') according to the location of the alternative they had chosen ('1' for the alternative appearing on the left side and '2' for the alternative on the right). After having decided to accept or reject an offer, participants were asked to what extent their expectations concerning their counterparts' offering were met. The German words for 'Expectations met?' were presented, together with the alternatives 'disappointed', 'met' and 'exceeded', arranged next to each other in the lower section of the screen (4 seconds). Participants had to decide by pressing key '1', '2' or '3', corresponding to the screen-position of the choice alternative they had opted for. The question concerning responders' expectations was added to the classic Ultimatum Game design in order to check ex post whether social information effectively formed expectations and whether effects of this manipulation would be observed in choice behavior. To allow a comparison between *anonymity* and *information* trials, the expectations-question was also administered in trials with non-identifiable proposers. Subjects were asked to act based on their general assumptions regarding social exchange situations. They were instructed to decide according to their general expectations (probably considerations of fairness and reciprocity) concerning counterparts' behavior in an economic setting like the Ultimatum Game. A single *information* trial lasted approximately 12 seconds.

In principle, an *anonymity* trial (see Figure 6 (b)) was very similar in structure: Again a black asterisk on an grey screen was blended for 2 seconds, before the responders' counterpart was presented. To ensure anonymity, no social information was provided but the word 'Proposer' appeared on the computer monitor for another 2 seconds. The offer and associated choice alternatives were followed by the presentation of the question concerning responders' expectations accompanied by possible answers. Procedure and timing were identical compared to an *information* trial.

Altogether, the experiment had a duration of around 65 minutes (pauses included).

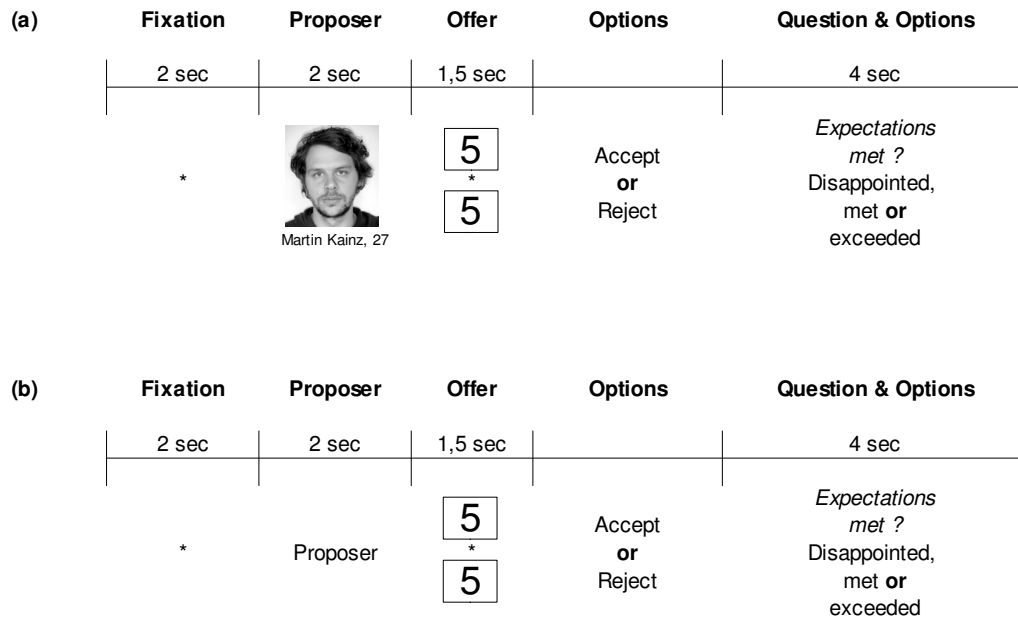


Figure 6: Timeline for a single (a) *information* UG trial and (b) *anonymity* UG trial. Each trial lasted approximately 12 seconds. See text for explanations.

5.4. EEG recording

The electroencephalogram (EEG) was recorded using 61 Ag/AgCl electrodes equidistantly embedded in an elastic electrode cap (EASYCAP GmbH; <http://www.easycap.de>, model M10). Prior to the participant's preparation for the EEG-session, we measured the individual three-dimensional coordinates of 17 pre-defined electrode locations (referenced to nasion, inion, and the two preauricular electrodes) using a photogrammetric head digitizer (3D-PHD; Bauer et al., 2000). Off-line a standard head model was fit into these pre-defined electrode positions in order to interpolate missing electrodes based on the equidistant electrode montage.

A balanced sterno-vertebral reference (Stephenson and Gibbs, 1951), positioned above the seventh vertebra and the right sterno-clavicular joint, was used to obtain a true non-cephalic recording reference. Vertical and horizontal electrooculograms (EOGs) were recorded with a bipolar setting to allow the elimination of artifacts related to eye movements and blinks. Electrodes were placed 1 centimeter above and below the left

eye, and on the outer canthi of both eyes. The subjects' scalp was cautiously scratched at each electrode site employing a sterile single-use needle (Picton and Hillyard, 1972) in order to minimize skin potential artifacts and to ascertain homogeneous and stable electrode impedances below 2 k Ω . Electrodes and adaptors were filled with degassed electrode gel (Electro-Gel, Electro-Cap International, Inc., Eaton/OH, USA). In succession, impedances were checked for each electrode using an impedance meter. If necessary (impedance > 2 k Ω), the skin scratching procedure was repeated. All signals were recorded within a frequency range of 0.1 to 125 Hz and sampled at 250 Hz for digital storage.

5.5. Data analysis

5.5.1. Behavioral data

For the analysis of reaction times (RTs) between the presentation of the UG offer and the decision whether to accept or reject it, a 2 x 3 repeated measures analysis of variance (*ANOVA*) was performed with the factors SOCIAL DISTANCE (anonymity vs. information) and OFFER (fair, midfair and unfair). Before, RTs were transformed using a logarithmic function (as suggested by Knutson et al., 2007; cited after Polezzi et al., 2008). We additionally calculated planned contrasts for the analysis of the different factor levels. Mean absolute frequencies of acceptances for the different offers were checked with the non-parametric Friedman Test. Post-hoc analysis was accomplished employing Wilcoxon signed-rank tests applying a Bonferroni correction. To investigate whether acceptances differed with the type of offer in both SOCIAL DISTANCE conditions, six comparisons were conducted. Additionally, we were interested in the acceptance behavior for numerically identical offers made by identifiable and non-identifiable proposers, which is why three more tests were computed (*fair-anonymity* vs. *fair-information*, *midfair-anonymity* vs. *midfair-information*, *unfair-anonymity* vs. *unfair-information*). As nine comparisons were carried out, all effects are reported at a $P = 0.006$ level of significance.

In our Ultimatum Game design, subjects had four seconds to decide whether their

expectations concerning the offer of their counterparts were 'disappointed', 'met' or 'exceeded'. This time window was apparently not long enough for all participants in every single trial. We dealt with the issue of missing data by calculating 3 separate ANOVAs for the examination of RTs, excluding missing values if necessary. These ANOVAs were computed with the factors (1) SOCIAL DISTANCE (anonymity vs. information), (2) OFFER (fair, midfair and unfair) and (3) EXPECTATION (disappointed, met and exceeded). Again RTs were transformed using a logarithmic function and planned contrasts were calculated. Five subjects were excluded due to missing data in analysis (3). To address the question whether frequencies for choosing the alternatives 'disappointed', 'met' and 'exceeded' were affected by SOCIAL DISTANCE (anonymity vs. information), nine Wilcoxon tests were performed. All effects are therefore reported at a $P = 0.006$ level of significance (Bonferroni correction). The following comparisons were calculated: *fair-anonymity-disappointed* vs. *fair-information-disappointed*; *fair-anonymity-met* vs. *fair-information met*; *fair-anonymity-exceeded* vs. *fair-information-exceeded*; *midfair-anonymity-disappointed* vs. *midfair-information-disappointed*; *midfair-anonymity-met* vs. *midfair-information-met*; *midfair-anonymity-exceeded* vs. *midfair-information-exceeded*; *unfair-anonymity-disappointed* vs. *unfair-information-disappointed*; *unfair-anonymity-met* vs. *unfair-information-met*; *unfair-anonymity-exceeded* vs. *unfair-information-exceeded*. If necessary, degrees of freedom were adjusted using the Greenhouse-Geisser correction. All effects are reported as significant at $P \leq 0.05$.

5.5.2. EEG data

Prior to the analysis, artifacts due to eye movements and blinks were removed offline using a linear regression approach with channel-specific correction coefficients. EOG parameters were assessed separately for vertical and horizontal eye movements in pre-experimental EOG calibration trials in which subjects performed regular eye movements (Bauer and Lauber, 1979). To calculate blink coefficients, a template matching procedure was used (see Vitouch, Bauer, Gittler, Leodolter and Leodolter, 1997; Lamm, Fischmeister and Bauer, 2005, for a detailed description). Employing these parameters weighted eye movement and blink related signals were subtracted from each EEG channel trial-by-trial (see also Fischmeister and Bauer, 2006).

We carried out off-line analysis using EEGLAB 6.03b (Delorme and Makeig, 2004), implemented in Matlab 7.5.0 (The MathWorks). EEG data were low-pass filtered with a cut-off frequency of 30 Hz (roll-off 6 dB per octave). EEG epochs of 1200 milliseconds were extracted, starting 200 milliseconds before the presentation of Ultimatum Game (UG) offers. The interval of 200 milliseconds preceding the offer's onset served as a baseline.

To exclude artifact contaminated trials, a semi-automatic procedure was applied. Trials meeting the following criteria were labelled and finally rejected after visual inspection: voltage values exceeding $\pm 75\mu\text{V}$ in any channel or a voltage drift of more than $75\mu\text{V}$. Muscular or movement artifact-afflicted trials (if not automatically marked) were also rejected based on visual inspection. Because of high numbers of artifact contaminated trials, 7 subjects (4 women and 3 men) had to be excluded from further analysis. The remaining sample consisted of 23 participants, 11 women and 12 men, with a mean age of 23.96 years ([SD] = 4.07).

5.5.3. ERP data

Artifact-free trials were averaged per condition and subject, and grand averages were calculated for each of the following six conditions: (1) fair offer/anonymous proposer (*fair-anonymity*), (2) midfair offer/anonymous proposer (*midfair-anonymity*), (3) unfair offer/anonymous proposer (*unfair-anonymity*), (4) fair offer/identifiable proposer (*fair-information*), (5) midfair offer/identifiable proposer (*midfair-information*), and (6) unfair offer/identifiable proposer (*unfair-information*).

Subsequently, mean amplitude measures were calculated for the interval of 200 to 300 milliseconds after the onset of the Ultimatum Game offer. This time window for FN measurement was defined after visual inspection of the grand mean (mean across all averages) and in line with relevant literature (see for example Nieuwenhuis et al., 2004b). The mean amplitudes of our 23 participants were subjected to a 4 x 2 x 3 repeated measures ANOVA with the factors LOCATION (electrode sites FCz, Fz, Cz and Pz), SOCIAL DISTANCE (anonymity vs. information) and OFFER (fair, midfair and unfair).

Additionally, we calculated peak-to-peak voltage differences at electrode Fz. We chose this electrode based on visual inspection of the grand mean and consistent with relevant

literature (see for example Gehring and Willoughby, 2002). The difference between the first negative peak 200-300 milliseconds after the onset of the UG offer and the average voltage value of the immediately preceding and following positive peak was measured. This procedure was employed according to Polezzi et al. (2008). We performed peak detection using BRL peak finder v.0.1b, implemented in EEGLAB, and subjected the peak amplitudes to a 2 x 3 repeated measures *ANOVA* with the factors SOCIAL DISTANCE (anonymity vs. information) and OFFER (fair, midfair and unfair). Planned contrasts were calculated subsequently.

FN peak latencies were computed at electrode Fz, from the onset of UG offers to the peak amplitude. With these latency values, a 2 x 3 repeated measures *ANOVA* with the factors SOCIAL DISTANCE (anonymity vs. information) and OFFER (fair, midfair and unfair) was carried out.

For all computations, the Greenhouse-Geisser correction for violations of the *ANOVA* assumption of sphericity was applied when appropriate. The significance threshold was set at $P \leq 0.05$, two-tailed.

5.5.4. Source analysis

Standardized low-resolution brain electromagnetic tomography (sLORETA; Pascual-Marqui, 2002) was used for the localization of the neural generator of the feedback negativity. Mean amplitudes between 60 and 460 milliseconds after the onset of the UG offer were extracted (with a step size of 20 milliseconds), resulting in three-dimensional distributions of cortical activation for each subject and condition.

sLORETA is a distributed source modeling method that computes statistical maps indicating the locations of the underlying source processes with low error. These maps are derived on the basis of a location wise inverse weighting of the results of a Minimum Norm Least Squares (MNLS) analysis with their estimated variances. Estimated source variances are computed from the measurement noise, as well as from prior source variances (Pascual-Marqui, 2002; Wagner, Fuchs and Kastner, 2004). To find single solutions for EEG inverse problems, sLORETA is assuming similar activation of neighboring neuronal sources. Being based on a minimum-norm approach, it does not require any information about the number, localization, configuration or extent of these sources. Under ideal conditions, sLORETA has been proven to have no

or minimal localization bias (Greenblatt, Ossadtchi and Pflieger, 2005; Sekihara, Sahani and Nagarajan, 2005).

VEOG, HEOG and ECG, as well as the preauricular electrodes A1 and A2 were excluded from analysis. The remaining individual electrode coordinates, acquired via 3D-PHD, were cross-registered to the standard Talairach atlas (Talairach and Tournoux, 1988). sLORETA's solution space is restricted to cortical grey matter and hippocampus, defined via the MNI (Montreal Neurological Institute) reference brain. The realistic head model used is subdivided into 6239 voxel, with a spatial resolution of $5 \times 5 \times 5$ mm³. With the algorithm of Brett, Johnsrude and Owen (2002), MNI space is transformed to Talairach space. sLORETA computes the electric activity at each voxel as the squared standardized magnitude of the estimated current density. We chose a regularization parameter of zero for the transformation to achieve the smoothest possible inverse solution. Overall signal-to-noise-ratio was set at a value of 100 within the transformation process.

sLORETA solutions of grand average ERPs were calculated for a descriptive analysis of our six conditions. For the comparison of our conditions we used Statistical nonparametric Mapping (SnPM; Nichols and Holmes, 2002), implemented in the sLORETA software. Different OFFER conditions (fair, midfair and unfair) were contrasted as well as the two SOCIAL DISTANCE conditions *anonymity* and *information*. SnPM compares two groups voxel by voxel across all time-points, separately for all subjects, and calculates dependent-sample t-values using log-transformed sLORETA values. The resulting $T_{\max}$ statistic is based on 5000 permutations, i. e. randomly drawn configurations of data of conditions tested against the original configuration. We set the significance level at $P \leq 0.05$, two-tailed.

6 Results

6.1. Behavioral results

6.1.1. Reaction times – Ultimatum Game offer

As illustrated in Figure 7, RTs differed significantly with the type of OFFER [$F(2, 44) = 23.489$, $P < 0.001$]. Planned contrasts revealed that decisions about fair offers were executed more quickly than midfair [$F(1, 22) = 58.443$, $P < 0.001$] and unfair ones [$F(1, 22) = 15.739$, $P < 0.01$]. Unfair offers were associated with shorter RTs than midfair offers [$F(1, 22) = 7.404$, $P < 0.05$]. Non-transformed mean RTs were 1154 milliseconds for fair, 1448 ms for midfair and 1313 ms for unfair offers. The overall mean RT for the three types of offers was 1305 milliseconds ([SD] = 752.3). No effects for SOCIAL DISTANCE or the interaction of the two factors were observed.

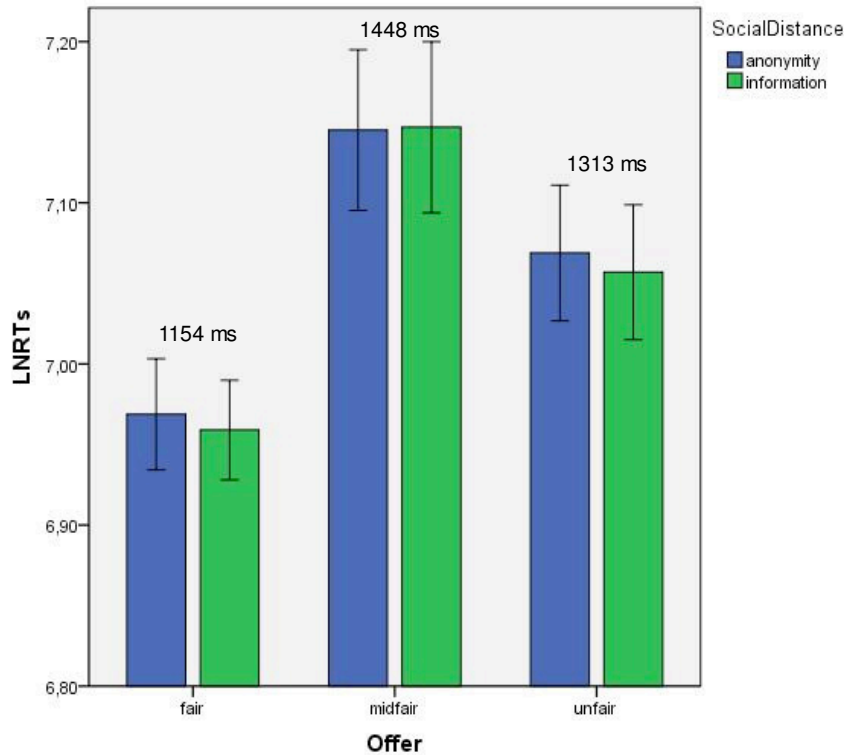


Figure 7: RTs for the different types of offers. Non transformed values are displayed as well. Error bars indicate the 95 % confidence interval [CI].

6.1.2. Acceptances

Acceptances (see also Figure 8) were significantly affected by the type of OFFER [$\chi^2(5) = 89.159, P < 0.001$]. Mean ranks and acceptance rates are displayed in Table 2. Mean absolute acceptance frequencies for fair offers were higher than for midfair, and unfair offers respectively in both SOCIAL DISTANCE conditions [*anonymity*: $T = 6, Z = -3.590, P < 0.001$; $T = 0, Z = -4.217, P < 0.001$; *information*: $T = 3.5, Z = -3.572, P < 0.001$; $T = 0, Z = -4.224, P < 0.001$]. The differences between midfair and unfair offers were also significant in both conditions [*anonymity*: $T = 0, Z = -4.017, P < 0.001$; *information*: $T = 1.5, Z = -4.059, P < 0.001$]. Comparing numerically identical offers between the SOCIAL DISTANCE conditions did not yield any significant differences.

Acceptance rates

condition	mean ranks	percentages
fair-anonymity	5.17	98.73
midfair-anonymity	3.85	66.67
unfair-anonymity	1.67	10.04
fair-information	5.04	98.55
midfair-information	3.70	63.86
unfair-information	1.57	6.52

Table 2: Acceptance rates of different Ultimatum Game offers. Mean ranks and percentages are displayed.

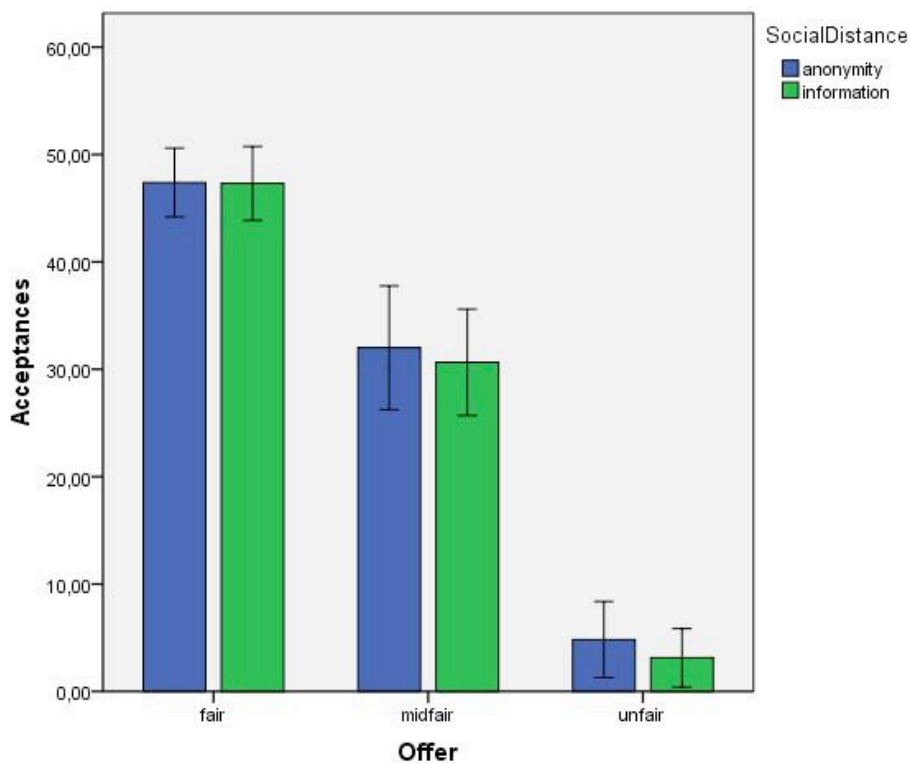


Figure 8: Acceptances for different types of offers, displayed in mean absolute frequencies (maximum = 48, as each of the six conditions contained 48 trials). Error bars indicate the 95 % confidence interval [CI].

6.1.3. Reaction times – Expectations

RTs did not differ significantly between the two SOCIAL DISTANCE conditions [$F(1, 22) = 0, P = 0.999$], different types of OFFERS [$F(2, 44) = 1.930, P = 0.157$], nor with the three alternatives 'disappointed', 'met' and 'exceeded' of the factor EXPECTATION [$F(2, 34) = 2.721, P = 0.080$]. Planned contrasts in the latter analysis indicated that button press '1' (expectations 'disappointed') was associated with longer RTs than button press '2' (expectations 'met') [$F(1, 17) = 7.900, P < 0.05$] (see also Figure 9). Corresponding non-transformed RTs were 953 milliseconds for 'disappointed', 917 ms for 'met' and 945 ms for 'exceeded'. The overall mean RT for the different alternatives was 937 milliseconds ([SD] = 675.83).

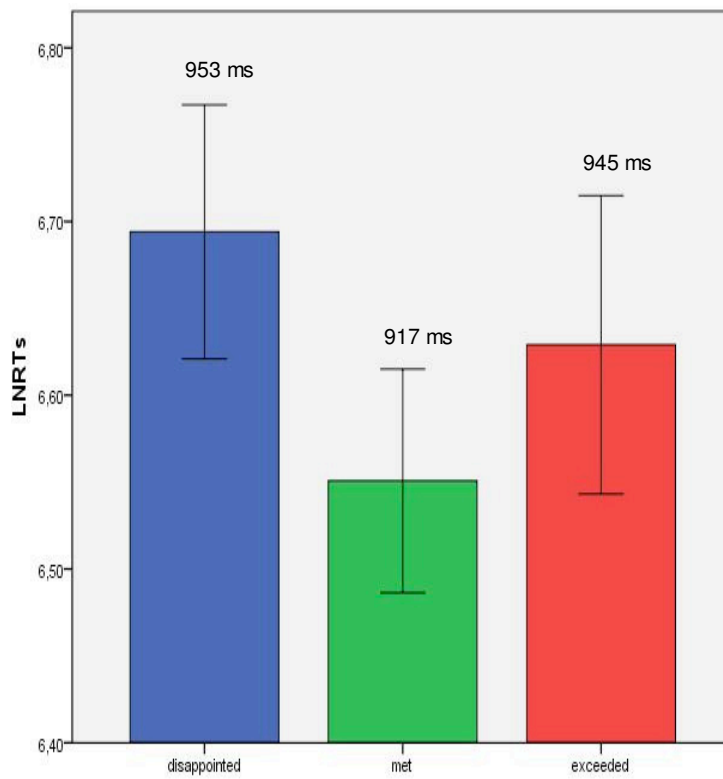


Figure 9: RTs for button press '1', '2' and '3', corresponding to expectations 'disappointed', 'met' and 'exceeded'. Non transformed values are displayed as well. Five subjects were excluded from analysis due to missing data. Error bars indicate the 95 % confidence

6.1.4. Choice behavior

We compared the same types of offers and identical choices regarding the expectations-question between the two SOCIAL DISTANCE conditions (e.g. *fair-anonymity-disappointed* vs. *fair-information-disappointed*). Choice behavior (frequencies) in our six conditions in combination with different EXPECTATION levels is displayed in Table 3.

Choice behavior

condition	expectation	percentages
fair-anonymity	disappointed	1.48
	met	57.60
	exceeded	40.93
midfair-anonymity	disappointed	43.21
	met	54.33
	exceeded	2.48
unfair-anonymity	disappointed	89.47
	met	10.36
	exceeded	0.18
fair-information	disappointed	0.83
	met	57.86
	exceeded	41.32
midfair-information	disappointed	43.40
	met	48.50
	exceeded	8.10
unfair-information	disappointed	80.73
	met	17.73
	exceeded	1.54

Table 3: Choice behavior regarding the expectations-question. Percentages are displayed.

The only difference approaching significance was observed between *midfair-anonymity-exceeded* and *midfair-information-exceeded* [$T = 94$, $Z = -2.612$, $P = 0.009$] (see also Figure 10).

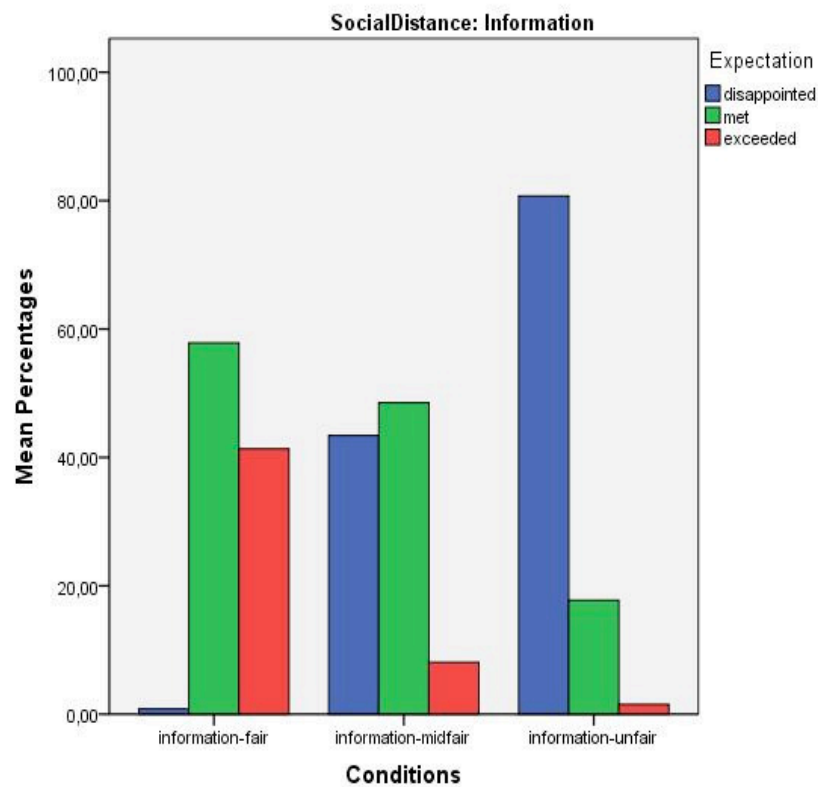
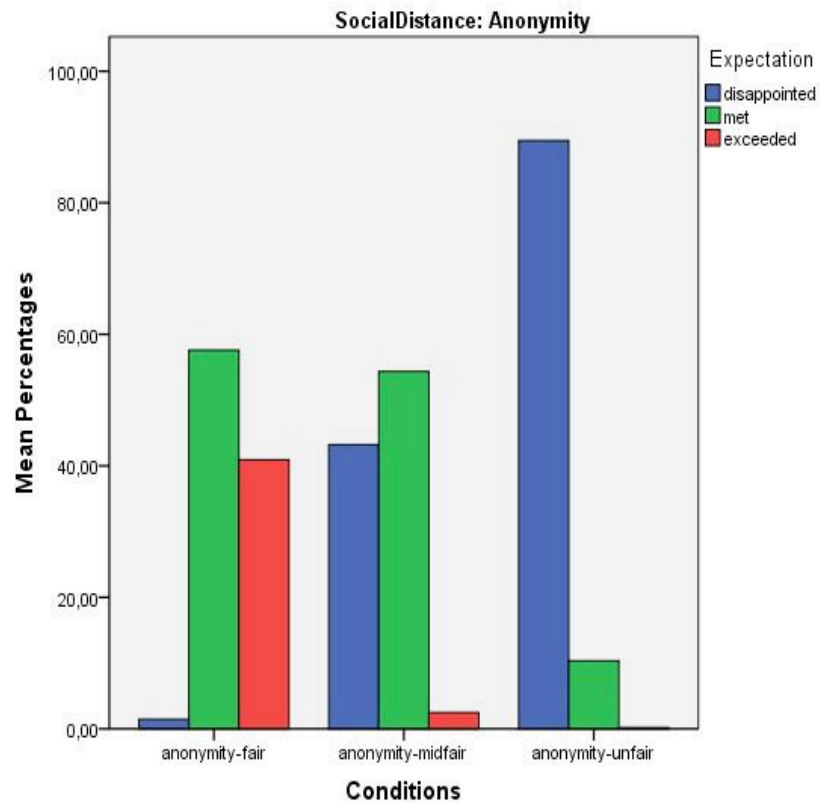


Figure 10: Frequencies for choosing 'disappointed', 'met' and 'exceeded' in the expectations-question, displayed for our six conditions split by SOCIAL DISTANCE. Upper panel: *Anonymity*. Lower panel: *Information*.

6.2. ERP data

ERPs elicited by our six conditions (*fair-information*, *midfair-information*, *unfair-information*; *fair-anonymity*, *midfair-anonymity*, *unfair-anonymity*) are presented in Figure 11 at electrode Fz. As can be seen in this grand mean plot, a distinct FN is apparent in all conditions.

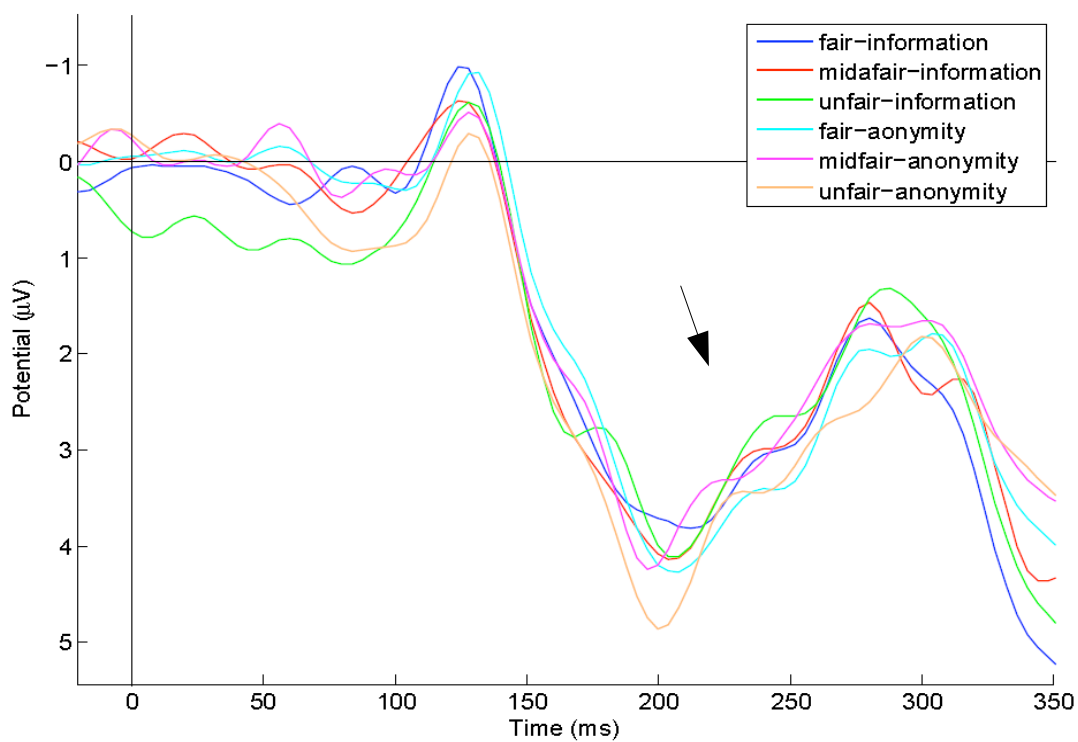


Figure 11: Grand mean ERP waveforms at electrode Fz for the six conditions. Results of 23 subjects are displayed. The presentation of the UG offer started at 0 ms. The FN is indicated by the arrow.

6.2.1. FN mean amplitudes

No significant main effects or interactions could be observed in the analysis of mean amplitudes of the FN.

6.2.2. FN peak-to-peak measures

Peak-to-peak amplitudes of the FN were significantly affected by the type of OFFER [$F(2, 44) = 5.989, P < 0.01$]. Planned contrasts revealed that FN amplitudes were smaller for fair as compared to midfair [$F(1, 22) = 6.158, P < 0.05$] and unfair offers [$F(1, 22) = 13.793, P < 0.01$]. No main effect for SOCIAL DISTANCE could be observed.

The interaction between SOCIAL DISTANCE and OFFER also reached significance [$F(2, 44) = 3.822, P < 0.05$]. Planned contrasts indicated an interaction when comparing *anonymity* to *information* for fair compared to unfair offers [$F(1, 22) = 6.993, P < 0.05$]. Thus, *information* (compared to *anonymity*) augmented FN amplitudes significantly more for unfair offers than it did for fair offers. The remaining contrasts did not yield any significant interactions.

Post-hoc analysis was complemented using the Tukey HSD test. Significant differences were observed comparing fair and midfair, respectively fair and unfair offers in the *information* condition, but not in the *anonymity* condition (see also Figure 12). Peak-to-peak amplitudes were smaller for fair offers than for midfair [$P = 0.030$] and unfair offers [$P = 0.001$].

Figures 13 and 14 show the grand mean ERP waveforms (at electrode Fz) elicited by fair, midfair and unfair UG offers in our *information* and *anonymity* condition.

In Figure 15, scalp topographies of the voltage differences between unfair and fair offers in the *anonymity* and *information* condition are displayed. A negativity with fronto-central scalp distribution is apparent in the *information* condition (especially 240 milliseconds after the presentation of the UG offer).

6.2.3. FN peak latencies

Latency analysis did not reveal any significant main effects or interactions.

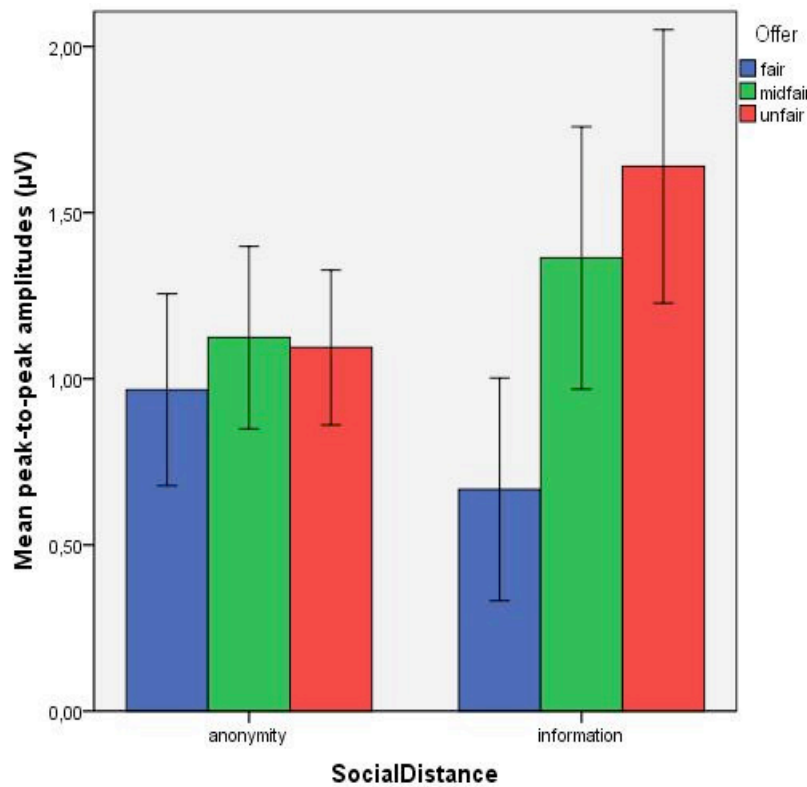


Figure 12: Mean peak-to-peak amplitudes for the six different conditions. Error bars indicate the 95 % confidence interval [CI].

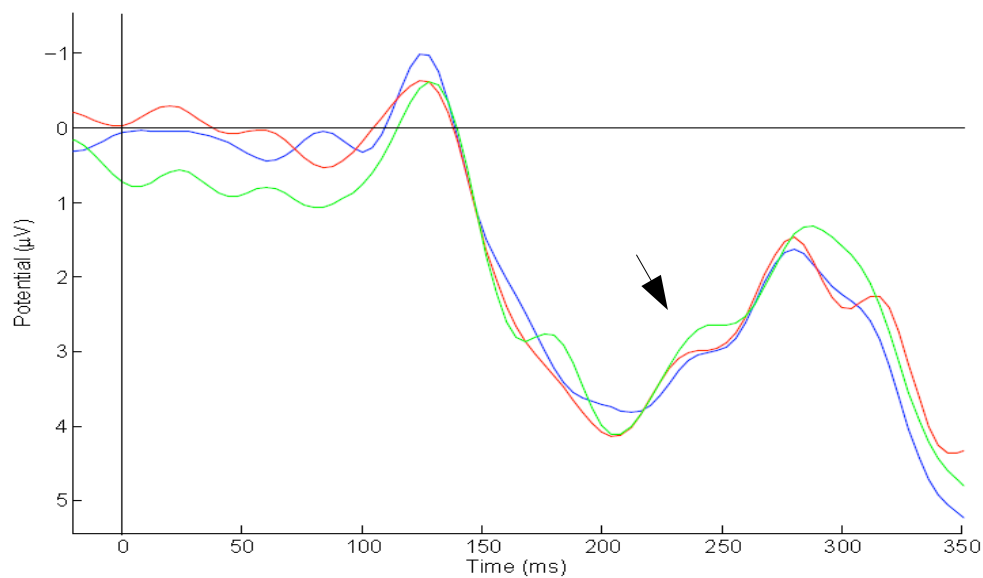


Figure 13: Grand mean ERP waveforms at electrode Fz for the three conditions *fair-information* (printed in blue), *midfair-information* (red) and *unfair-information* (green). Results of 23 subjects are displayed. The presentation of the UG offer started at 0 ms. The FN is indicated by the arrow.

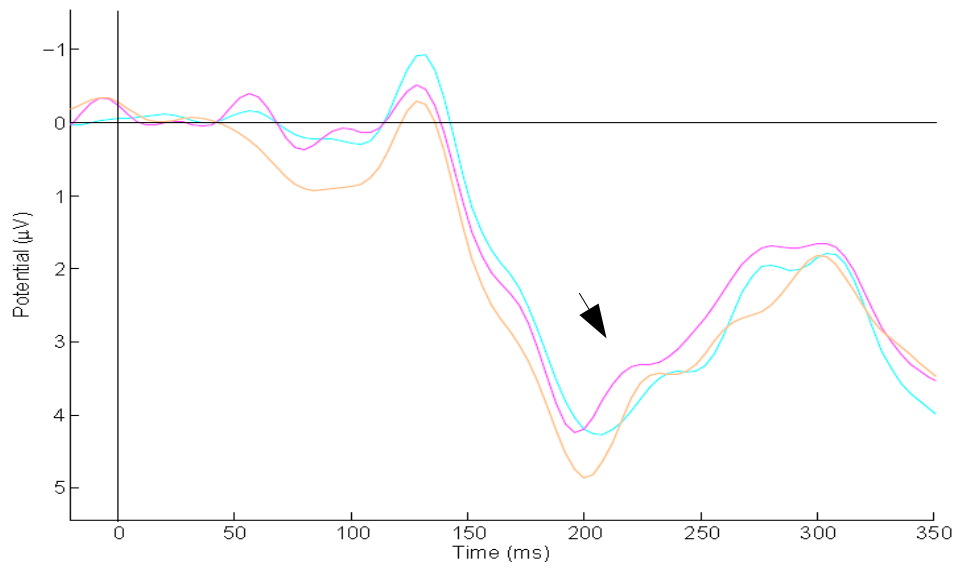


Figure 14: Grand mean ERP waveforms at electrode Fz for the three conditions *fair-anonymity* (printed in pale blue), *midfair-anonymity* (pink) and *unfair-anonymity* (orange). Results of 23 subjects are displayed. The presentation of the UG offer started at 0 ms. The FN is indicated by the arrow.

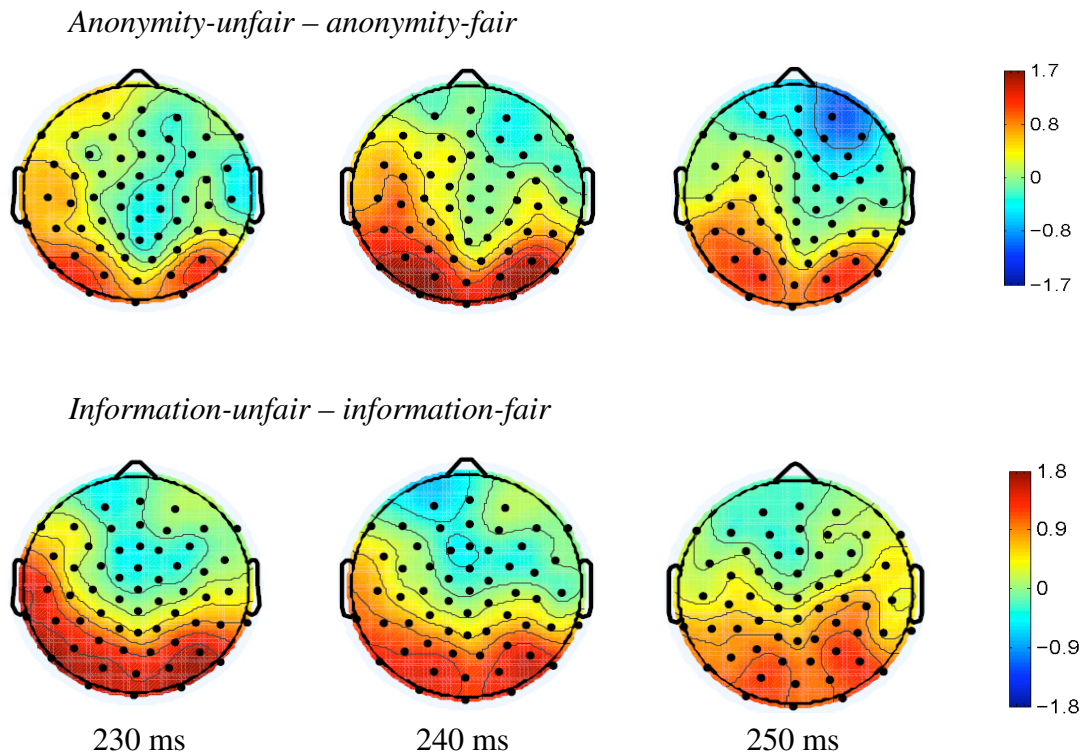


Figure 15: Scalp plots of the voltage differences between unfair and fair offers in both SOCIAL DISTANCE conditions (upper panel: *anonymity*; lower panel: *information*). The times given are relative to the onset of the UG offer.

6.3. Source analysis

6.3.1. Descriptives of sLORETA brain activity patterns

The grand averages of our six conditions (*fair-anonymity*, *midfair-anonymity*, *unfair-anonymity*; *fair-information*, *midfair-information*, *unfair-information*) showed similar activation patterns at FN latency. Stable activity was found in right-hemispheric temporal and parietal regions in time frame 9 (220-240 milliseconds after the presentation of the Ultimatum Game offer). sLORETA images of the grand average for the condition *unfair-anonymity* are presented exemplarily in Figure 16, as activity distributions were quite similar in our data. Images of the condition *midfair-information* are also displayed, showing slightly different patterns of activation (see Appendix for sLORETA images of the remaining conditions).

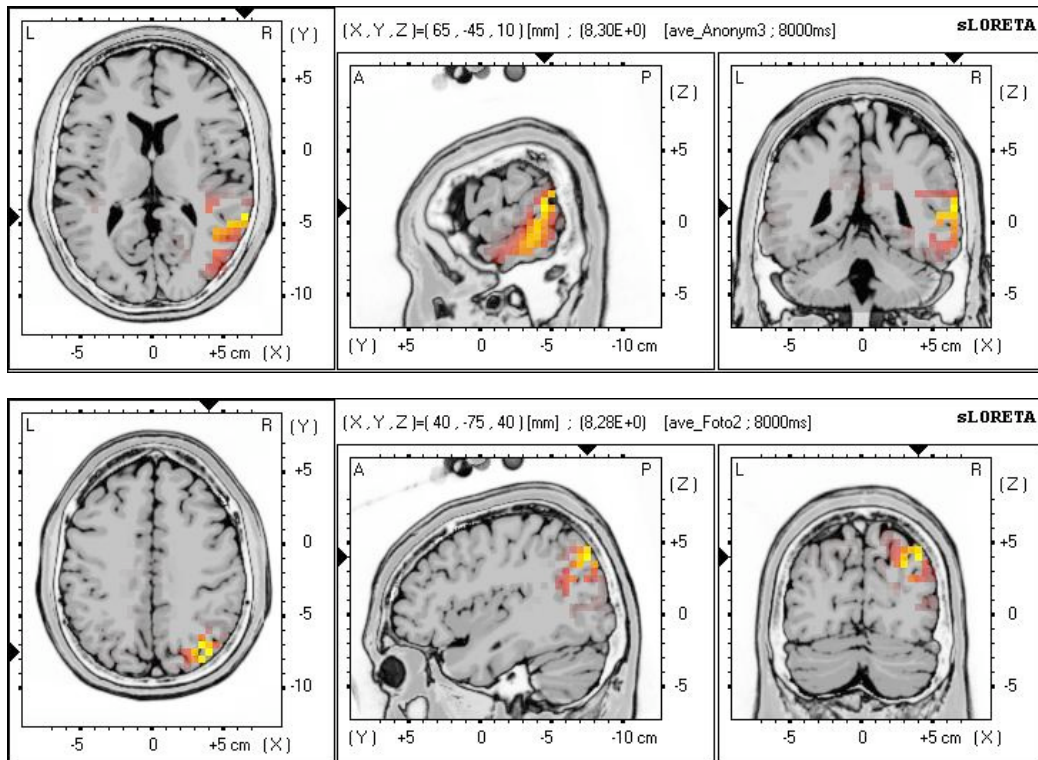


Figure 16: sLORETA images of the grand averages at FN latency (time frame 9: 220-240 milliseconds after the onset of the UG offer) showing current density (estimated voxel activity) maxima for the conditions *unfair-anonymity* (upper panel) and *midfair-information* (lower panel). MNI-coordinates and anatomical structures are presented (see Table 4 for Brodmann areas). Estimated cortical activation is shown from three perspectives (axial, sagittal, and coronal view), displayed with a scale exponent of 5.75. Activation maxima are coded in yellow.

The highest levels of activation in the conditions *fair-anonymity*, *midfair-anonymity*, *unfair-anonymity*, *fair-information* and *unfair-information* were apparent in the temporal lobe (Brodmann areas 21, 22, 39 and 40). The condition *midfair-information* was associated with strong activations in the parietal lobe (Precuneus, Brodmann area (BA) 19). Table 4 summarizes activation maxima for our six conditions.

**Activation maxima with sLORETA
grand averages**

condition	anatomical region (BA)	Talairach coordinates
fair-anonymity	Superior Temporal Gyrus (right BA 22)	X=64, Y=-43, Z=11
	Superior Temporal Gyrus (right BA 22)	X=54, Y=-48, Z=12
	Superior Temporal Gyrus (right BA 22)	X=59, Y=-48, Z=12
midfair-anonymity	Middle Temporal Gyrus (right BA 22)	X=40, Y=-57, Z=17
	Middle Temporal Gyrus (right BA 39)	X=45, Y=-62, Z=17
	Superior Temporal Gyrus (right BA 22)	X=45, Y=-57, Z=17
unfair-anonymity	Superior Temporal Gyrus (right BA 22)	X=64, Y=-43, Z=11
	Middle Temporal Gyrus (right BA 22)	X=40, Y=-57, Z=17
	Superior Temporal Gyrus (right BA 22)	X=64, Y=-43, Z=16
fair-information	Supramarginal Gyrus (right BA 40)	X=59, Y=-52, Z=21
	Superior Temporal Gyrus (right BA 22)	X=59, Y=-57, Z=17
	Superior Temporal Gyrus (right BA 22)	X=54, Y=-57, Z=17
midfair-information	Precuneus (right BA 19)	X=40, Y=-71, Z=40
	Precuneus (right BA 19)	X=35, Y=-66, Z=40
	Precuneus (right BA 19)	X=35, Y=-76, Z=36
unfair-information	Superior Temporal Gyrus (right BA 22)	X=59, Y=-57, Z=17
	Superior Temporal Gyrus (right BA 22)	X=64, Y=-48, Z=12
	Superior Temporal Gyrus (right BA 22)	X=54, Y=-57, Z=17

Table 4: Localization of FN current density activation (estimated voxel activity) maxima (hits 1-3) with sLORETA grand averages of our six conditions. Values are displayed for time frame 9 (220-240 milliseconds after the presentation of the UG offer).

6.3.2. sLORETA within-subject comparisons

SnPM was performed to investigate activation differences between fair, midfair and unfair offers in both SOCIAL DISTANCE conditions. Additionally, we contrasted identical types of offers between the conditions *anonymity* and *information* (e. g. *unfair-anonymity* vs. *unfair-information*).

None of the comparisons accomplished yielded significant results in the time frames of interest (especially time frame 9: 220-240 milliseconds after the presentation of the UG offer).

7 Discussion

This diploma thesis aimed to investigate whether the perception of (un)fairness, as experienced by responders being confronted with different types of UG offers, is reflected in the amplitude of the feedback negativity (FN). Moreover, we tried to assess the impact of social distance (manipulated via information provided to the responders about their presumed counterparts) on behavioral and neural responses of our subjects. The principal findings of the present research and attempts to link them with relevant literature are presented in the following.

The absolute frequencies of acceptances for the different types of offers and associated reaction times (RTs) found in this study were essentially in line with previous research operating with similar designs (see for example Sanfey et al., 2003; Rilling et al., 2004; Polezzi et al., 2008). Responders in our Ultimatum Game accepted almost every offer with a proposed split of 5-5, around two thirds of the 7-3 offers and only few 9-1 offers (10.04 % for *anonymity* and 6.52 % for *information*). Subjects apparently tended to reject offers they judged as unfair, and to accept fair ones. Decisions about fair offers were executed more quickly than about midfair and unfair ones. Unfair offers were associated with shorter RTs than midfair offers. Polezzi et al. (2008) reported a similar pattern of response timing in their Ultimatum Game study.

No significant differences in acceptances and RTs comparing numerically identical offers between the two conditions *anonymity* and *information* could be observed. We therefore conclude that the manipulation of social distance, as accomplished in this work, had no (statistically relevant) effects on a behavioral level, although some findings slightly point in this direction (see for example the acceptances for unfair offers in the two social distance conditions). In fact, the analysis of responders' expectations seems to support this view: Choice behavior was not differentially influenced by the previous presentation of an identifiable or a non-identifiable counterpart. The fact that participants were explicitly instructed to play with *real* human partners throughout the experiment (although half of them were presented anonymously) may contribute to the lack of differences between *anonymity* and *information* conditions in the behavioral data.

As Yeung et al. (2005), as well as Donkers et al. (2005), we tried to address the question raised by Nieuwenhuis and colleagues (2004a) whether FNs could also be observed when participants' assignment is to *solely* look at stimuli informing them about monetary rewards or punishments. As mentioned above, FNs were reported in tasks where no action or response was required from the participants (Yeung et al., 2005; Donkers et al., 2005).

In fact, an ERP component identified as the FN was observed following the presentation of UG offers in our study. Mean amplitude analysis did not yield significant results, likely because of a contamination of the FN with the P3 (the slow-wave positivity upon which the FN is typically superimposed, see Yeung and Sanfey, 2004; cited after Yeung et al., 2005). Peak-to-peak amplitudes of the FN were affected by the type of offer, being smaller in size for fair as compared to midfair and unfair offers. In this sense, the results of Polezzi et al. (2008), who found that a distinction between fair and other kinds of offers was reflected in the FN amplitude, could be replicated. More precisely, we additionally observed a significant difference between fair and midfair offers, which was not reported by Polezzi and colleagues (2008).

The scalp distribution of the FN found in this study largely corresponds to previously reported data (e. g. Gehring and Willoughby, 2002; Hajcak et al., 2006), while its morphology is strongly reminiscent of that presented by Polezzi et al. (2008).

In the context of the present work, the FN amplitude mirrors a rapid distinction between fair and midfair, as well as fair and unfair offers, with smaller amplitudes for fair offers. This is consistent with previous findings of large FNs being associated with unfavorable outcomes, e. g. losses in gambling tasks (Gehring and Willoughby, 2002; Hajcak et al., 2006) or negative performance feedback in a time estimation task (Miltner et al., 1997). Our results can be comprehensively integrated into the *reinforcement-learning theory of the ERN (RL-ERN theory)*, as formulated by Holroyd and Coles (2002). The authors argued that the FN is elicited whenever ongoing events are evaluated as 'worse than expected'. Assuming that responders in the Ultimatum Game count on a fair share (as reported by Burnham, 2003; Chang and Sanfey, 2009) and that deviations from the 50-50 split equal a violation of their expectations (which is clearly indicated by our participants' choice behavior regarding the expectations-question), the RL-ERN theory may also account for the interpretation of our findings. The results are in line with two basic predictions formulated by Nieuwenhuis et al. (2004a): The FN found in our study

actually reflected an evaluation of ongoing events along an abstract good-bad dimension as its amplitude was smaller for fair compared to midfair and unfair offers. Additionally, we observed that the FN amplitude was larger for unfair as compared to midfair offers. Though this difference did not reach statistical significance, it may still support the second prediction of Nieuwenhuis et al. (2004a) that the amplitude of the FN depends on the relation between actual versus expected outcome or – in other words – is proportional to the size of the prediction error. We argue that the more pronounced difference in the FN amplitude between fair and unfair offers (compared to the difference between fair and midfair offers) reflects the proportional growth of the reward prediction error. Our data show that an FN was elicited by different types of UG offers – outcomes that were not contingent on any preceding choice or action by our subjects. This encourages the hypothesis that the FN rather reflects an evaluation of the valence of experienced outcomes than a process of learning about actions that led to those outcomes. The FN in the context of the present study may therefore mirror the violation of general expectations and fairness considerations of our subjects. In this sense we agree with the proposal of Yeung et al. (2005) to extend the RL-ERN framework and include learning that is not specifically related to recently executed actions.

We sought to generate (or additionally enforce) expectations in our subjects by providing information about their presumed counterparts in the Ultimatum Game. This manipulation was accomplished to reduce the degree of social distance among the players, which has been shown to have strong influence on economic game behavior (Bohnet and Frey, 1999; Burnham, 2003; Charness and Gneezy, 2008). Differences in FN amplitudes were only apparent in our *information* condition, in which responders were confronted with identifiable counterparts. This finding supports the notion that social factors play a crucial role in economic decision-making and may also be explained with the motivational significance of ongoing events (see Yeung et al., 2005). We hypothesize that playing with identifiable proposers (and not faceless, anonymous counterparts) enhances subjective involvement in the task, as experienced by responders in our Ultimatum Game. It seems that outcomes gain in importance when the degree of social distance between the protagonists in a social exchange situation is reduced.

The reason why the manipulation of social distance influenced brain, but not behavioral responses of our subjects appears to be still unclear. A fast initial distinction between

fair and midfair respectively unfair offers was reflected in the amplitude of the FN. Nevertheless it seems that the final decision whether to accept or reject an UG offer is guided by various factors and not only the violation of expectations formed via social information.

The ACC has consistently been reported to be the most likely neural generator of the FN (see for example Gehring and Willoughby, 2002; Holroyd and Coles, 2002), larger amplitudes being associated with higher ACC activity. Higher FN amplitudes for unfair and midfair offers found in the study at hand are in this sense consistent with results reported by Sanfey et al. (2003) showing enhanced ACC activity for unfair offers. Activation maxima with sLORETA grand averages for our six conditions were found in temporal and parietal regions (especially Brodmann area 22). Similarly, Polezzi et al. (2008) found the superior temporal gyrus (BA 22) more activated for midfair compared to fair offers. An fMRI study by Rilling et al. (2004) employing the Ultimatum Game reported higher activations in this area when subjects were interacting with presumed human partners compared to computer partners. Like in the studies of Rilling et al. (2004) and Polezzi et al. (2008), activations in the superior temporal gyrus found in the present work could be interpreted in terms of mentalizing (attempts of the responder to understand the proposer's strategy). Though the subjects in our design played 288 one-shot Ultimatum Game rounds, activity in the superior temporal gyrus may still reflect responders' inferences about their partners' intentions. However, as SnPM did not yield any significant differences in activation patterns comparing the different conditions, the results have to be interpreted with reservation.

In summary, the present results show that the perception of different types of Ultimatum Game offers generates an FN, being less pronounced for fair compared to midfair and unfair offers. Social distance crucially influenced brain responses to the three offers, as differences in the FN amplitude were only apparent when social information about responders' counterparts was revealed. We propose that the FN in the context of this study reflects the violation of general expectations and fairness considerations and that its amplitude depends on the size of the prediction error.

Appendix

A Instruction in German

Die Spielregeln

Im Ultimatumspiel erhalten zwei Personen einen bestimmten Geldbetrag, für dessen Aufteilung eine der beiden (Proposer) der anderen (Responder) einen Vorschlag macht. Wird das Angebot angenommen, wird der Betrag entsprechend aufgeteilt. Wird es jedoch abgelehnt, gehen beide leer aus.

Im Vorfeld der Untersuchung wurden die Angebote von knapp 300 Personen (50% weiblich, 50% männlich) eingeholt, die für einen Gesamtbetrag von 10 Euro einen von drei möglichen Verteilungsvorschlägen wählen konnten: 5/5, 7/3 oder 9/1.

5/5 bedeutet, dass der Proposer für sich fünf Euro beansprucht und dir fünf Euro anbietet. Bei 7/3 sind drei Euro für dich vorgesehen und sieben für deinen Spielpartner und analog erhältst du bei 9/1 einen Euro und der Anbieter neun.

Du wirst die Rolle des Responders übernehmen und im Verlauf des Experiments mit diesen Angeboten konfrontiert werden. Die Hälfte deiner Mitspieler wird dir vor der Präsentation des Angebots kurz mit Foto, Namen und Alter vorgestellt; die andere Hälfte ist anonymisiert und wird nur mit „Proposer“ bezeichnet. Deine Aufgabe besteht im Wesentlichen darin, nach eigenem Ermessen Angebote deiner Spielpartner anzunehmen oder abzulehnen. Nach der Vorstellung der Anbieter erscheinen am Bildschirm zwei untereinander angeordnete Kästchen, die den Verteilungsvorschlag enthalten, wobei die Ziffer im unteren Kästchen dem für dich vorgesehenen Betrag entspricht.

Nach jedem Angebot erscheinen am unteren Teil des Bildschirmes zwei weitere, diesmal nebeneinander platzierte Kästchen mit den Antwortmöglichkeiten „annehmen“ oder „ablehnen“. In welchem der beiden Kästchen die jeweilige Antwortmöglichkeit steht, variiert während des Experiments. Solltest du jene Antwortmöglichkeit wählen, die rechts am Bildschirm steht, drücke bitte die Taste „2“. Für die Antwortmöglichkeit, die links

am Bildschirm steht, drücke die Taste „1“.

Nach deiner Entscheidung wirst du befragt, inwieweit deine Erwartungen im Bezug auf das jeweilige Angebotsverhalten erfüllt wurden. Es stehen folgende Antwortalternativen zur Auswahl: „unterboten“, kann ausgewählt werden mit der Taste „1“; „erfüllt“, mit Taste „2“ kodiert und „übertroffen“. Wurden deine Erwartungen übertroffen, drücke bitte die „3“.

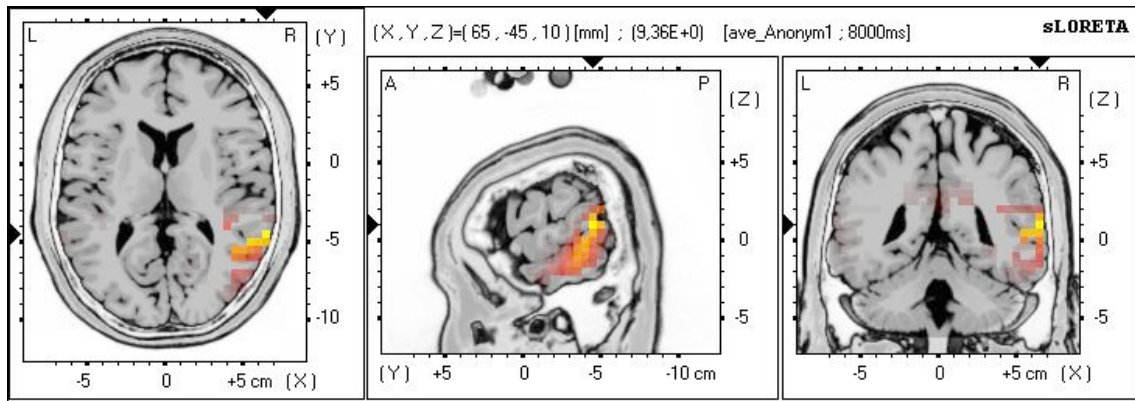
Bezahlung

Die Summe des Gewinnes der Anbieter wird über alle Versuchspersonen errechnet, wobei nur jene 20 Anbieter Geld gewinnen können, die den höchsten Gewinn erzielten. Die Ausbezahlung erfolgt nach einem bestimmten Verteilungsschlüssel. Für dich gilt: Die Höhe deiner finanziellen Entschädigung wird durch dein Spielverhalten bestimmt und reicht von 5 bis maximal 10 Euro. Die im Verlauf des Spiels erzielten „Spielgewinne“ werden über einen zuvor definierten Multiplikator in den tatsächlich ausbezahlten Gewinn umgerechnet.

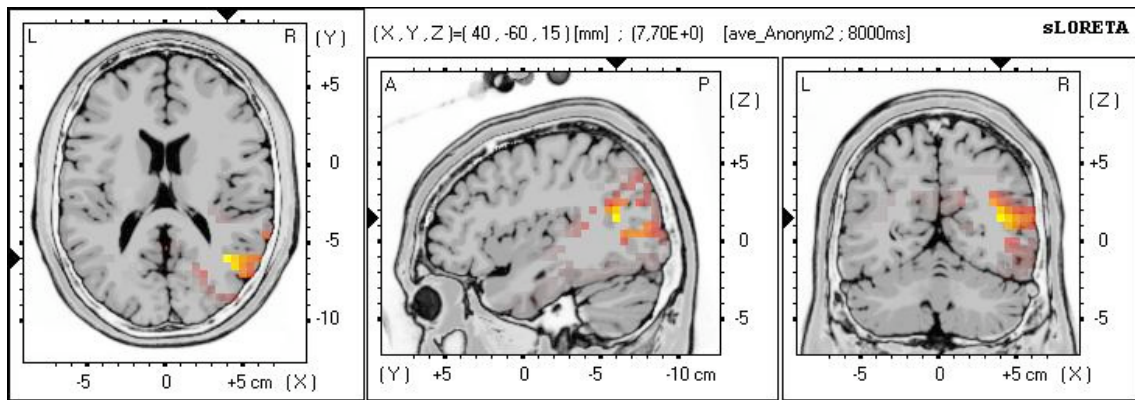
B *sLORETA grand averages*

In the following sLORETA images of the grand averages at FN latency (time frame 9: 220-240 milliseconds after the onset of the UG offer) for our six conditions (*fair-anonymity*, *midfair-anonymity*, *unfair-anonymity*, *fair-information*, *midfair-information* and *unfair-information*) are presented. Standardized current density (estimated voxel activity) maxima, MNI-coordinates and anatomical structures are shown. Estimated cortical activation is displayed from three perspectives (axial, sagittal, and coronal view), using a scale exponent of 5.75. Activation maxima are coded in yellow.

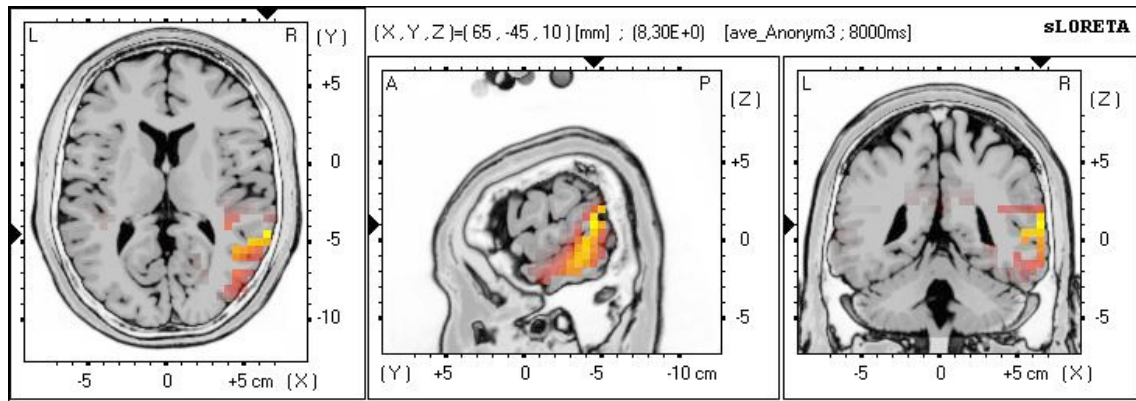
Fair-anonymity



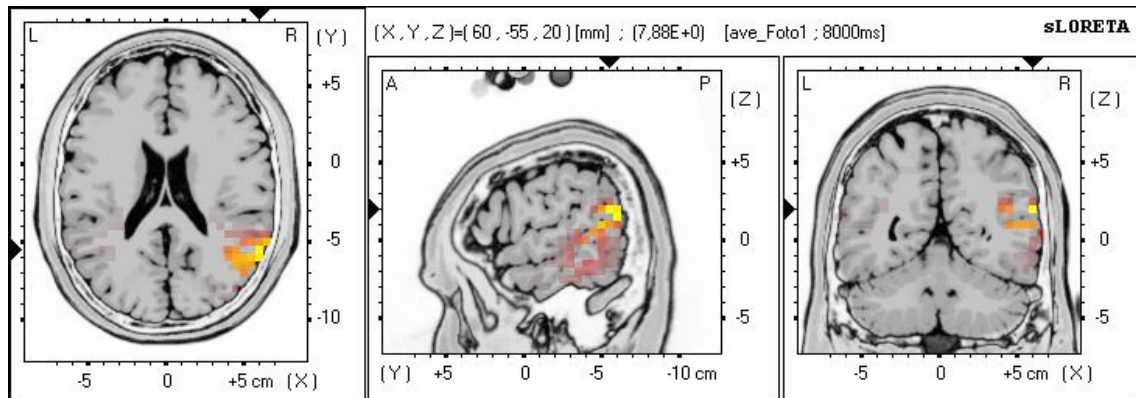
Midfair-anonymity



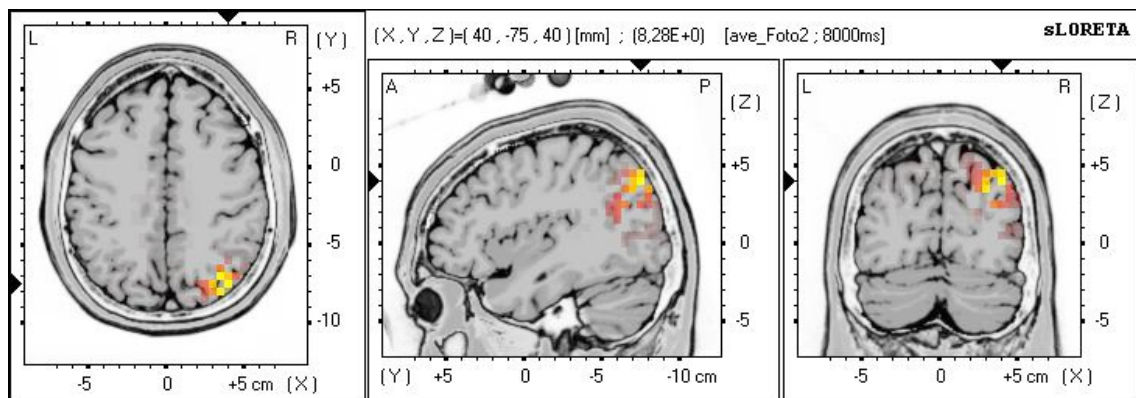
Unfair-anonymity



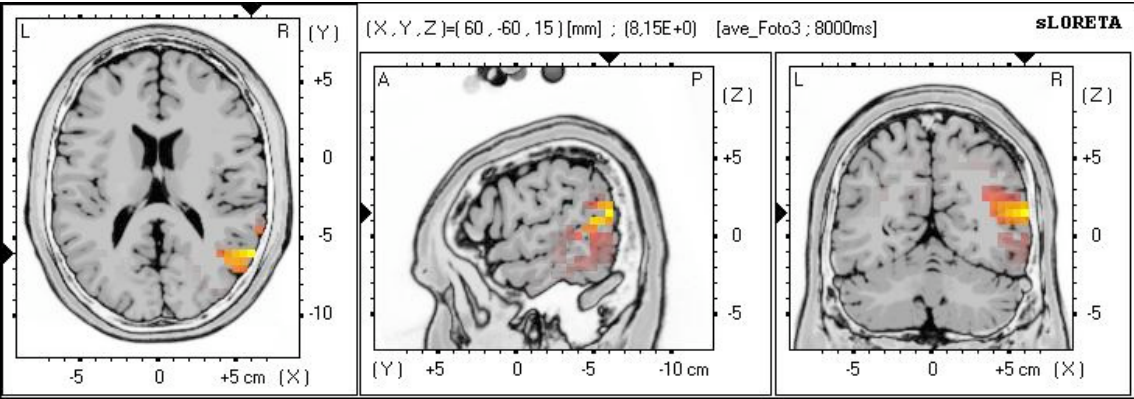
Fair-information



Midfair-information



Unfair-information



C Abstract in German

Die so genannte Feedback Negativity (FN) ist eine Komponente des ereigniskorrelierten Potentials (EKP), die nach Fehlern, negativem Leistungsfeedback und Geldverlusten in Glücksspielen generiert wird. Die kürzlich vorgeschlagene Reinforcement-Learning Theorie der FN nimmt an, die Einschätzung von Ereignissen als „schlechter als erwartet“ werde in der FN reflektiert.

Die vorliegende Studie untersucht die Rolle besagter Komponente im Kontext des Ultimatumspiels. In diesem spieltheoretischen Paradigma erhalten zwei Personen einen bestimmten Geldbetrag (hier 10 Euro), wobei die erste (Proposer) der zweiten (Responder) einen Verteilungsvorschlag unterbreitet, den letztgenannte entweder annehmen oder ablehnen kann. Wir gingen der Frage nach, ob die Wahrnehmung von unterschiedlich fairen Angeboten sich in der Amplitude der FN widerspiegelt. Außerdem versuchten wir den Einfluss sozialer Distanz (manipuliert über das Ausmaß an Information, dass unseren Versuchspersonen über ihre Mitspieler zukam) auf Verhaltens- und neuronaler Ebene zu bestimmen.

Elektroenzephalogramme (EEGs) wurden aufgezeichnet während unsere Probanden in der Rolle des Responders mit fairen (ein Verteilungsvorschlag von 5-5), midfairen (7-3) und unfairen (9-1) Angeboten konfrontiert waren. Wir versuchten, Erwartungen in unseren Versuchspersonen zu wecken über soziale Information, die sie über ihre mutmaßlichen Mitspieler erhielten. Diese Manipulation wurde durchgeführt um das Ausmaß an sozialer Distanz zwischen den Spielern zu reduzieren, was erwiesenermaßen erheblichen Einfluss auf ökonomisches Spielverhalten hat.

Wir konnten beobachten, dass die Wahrnehmung unterschiedlicher Ultimatumspiel-Angebote eine FN generierte, wobei faire Angebote mit den niedrigsten Amplituden assoziiert waren. Der Grad an sozialer Distanz hat die neuronalen Antworten wesentlich beeinflusst: Unterschiede in der Amplitude der FN konnten nur festgestellt werden, wenn zuvor Informationen über den Mitspieler präsentiert wurden.

Wir schlagen vor, dass die FN in dieser Studie die Verletzung von allgemeinen Erwartungen und Fairness-Überlegungen, die durch soziale Information aktiviert werden, darstellt. In diesem Sinne hängt die Amplitude der FN von der Größe des Vorhersagefehlers ab und wächst mit steigender Abweichung vom fairen 50-50 Verteilungsvorschlag.

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