The neural principles of behavior modification using socioemotional facial feedback cues in economic decision-making

Die neuronalen Mechanismen der Verhaltensmodifikation durch sozio-emotionale faziale Feedbackreize bei ökonomischen Entscheidungen

DISSERTATION

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 declaration of Helsinki.

CONFLICT OF INTEREST

The author declares no competing interests.

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ABBREVIATIONS

ACC	anterior cingulate cortex
Ag/AgCl	silver/ silver chloride
cm	centimeters
CSD	current source density
EEG	electroencephalogram
FRN	feedback-related negativity
Hz	Hertz
ICA	independent component analysis
M	mean
ms	milliseconds
RewP	reward positivity
RL	reinforcement learning
SD	standard deviation
SE	standard error
TD	temporal-difference
UG	ultimatum game

SUMMARY

The present dissertation aims to shed light on different mechanisms of socio-emotional feedback in social decision-making situations. The objective is to evaluate emotional facial expressions as feedback stimuli, i.e., responses of interaction partners to certain social decisions. In addition to human faces, artificial emojis are also examined due to their relevance for modern digital communication. Previous research on the influence of emotional feedback suggests that a person's behavior can be effectively reinforced by rewarding stimuli. In the context of this dissertation, the differences in the feedback processing of human photographs and emojis, but also the evaluation of socially expected versus socially unexpected feedback were examined in detail in four studies. In addition to behavioral data, we used the electroencephalogram (EEG) in all studies to investigate neural correlates of social decision-making and emotional feedback.

As the central paradigm, all studies were based on a modified ultimatum game. The game is structured as follows: there is a so-called proposer who holds a specific amount of money (e.g., 10 cents) and offers the responder a certain amount (e.g., 3 cents). The responder then decides whether to accept or reject the offer. In the version of the ultimatum game presented here, different types of proposers are introduced. After the participants have accepted or rejected in the role of the responder, the different proposers react to the participant's decision with specific emotional facial expressions. Different feedback patterns are used for the individual experiments conducted in the course of this dissertation.

In the first study, we investigated the influence of emotional feedback on decision-making in the modified version of the ultimatum game. We were able to show that a proposer who responds to the acceptance of an offer with a smiling face achieves more accepted offers overall than a control proposer who responds to both accepted and rejected offers with a neutral facial expression. Consequently, the smile served as a positive reinforcement. Similarly, a sad

expression in response to a rejected offer also resulted in higher acceptance rates as compared to the control identity, which could be considered an expression of compassion for that proposer. On a neuronal level, we could show that there are differences between simply looking at negative emotional stimuli (i.e., sad and angry faces) and their appearance as feedback stimuli after rejected offers in the modified ultimatum game. The so-called feedback-related negativity was reduced (i.e., more positive) when negative emotions appeared as feedback from the proposers. We argued that these findings might show that the participants wanted to punish the proposers by rejecting an offer for its unfairness and therefore the negative feedback met their expectations. The altered processing of negative emotional facial expressions in the ultimatum game could therefore indicate that the punishment is interpreted as successful. This includes the expectation that the interaction partner will change his behavior in the future and eventually make fairer offers.

In the second study we wanted to show that smiling and sad emojis as feedback stimuli in the modified ultimatum game can also lead to increased acceptance rates. Contrary to our assumptions, this effect could not be observed. At the neural level as well, the findings did not correspond to our assumptions and differed strongly from those of the first study. One finding, however, was that the neural P3 component showed how the use of emojis as feedback stimuli particularly characterizes certain types of proposers. This is supported by the fact that the P3 is increased for the proposer who rewards an acceptance with a smile as well as for the proposer who reacts to rejection with a sad emoji compared to the neutral control proposer.

The third study examined the discrepancy between the findings of the first and second study. Accordingly, both humans and emojis representing the different proposers were presented in the ultimatum game. In addition, emojis were selected that showed a higher similarity to known emojis from common messenger services compared to the second study. We were able to replicate that the proposers in the ultimatum game, who reward an acceptance of the offer with a smile, led to an increased acceptance rate compared to the neutral control proposers. This difference is independent of whether the proposers are represented by emojis or human faces. With regard to the neural correlates, we were able to demonstrate that emojis and human faces differ strongly in their neural processing. Emojis showed stronger activation than human faces in the face-processing N170 component, the feedback-related negativity and the P3 component. We concluded that the results of the N170 and feedback-related negativity could indicate a signal for missing social information of emojis compared to faces. The increased P3 amplitude for emojis might imply that emojis appear unexpectedly as reward stimuli in a social decision task compared to human faces.

The last study of this project dealt with socially unexpected feedback. In comparison to the first three studies, new proposer identities were implemented. In particular, the focus was on a proposer who reacted to the rejection of an offer unexpectedly with a smile and to the acceptance with a neutral facial expression. According to the results, participants approach this unexpected smile through increased rejection, although it is accompanied by financial loss. In addition, as reported in studies one and three, we were able to show that proposers who respond to the acceptance of an offer with a smiling face and thus meet the expectations of the participants have higher offer acceptance rates than the control proposer. At the neuronal level, especially the feedback from the socially unexpected proposer led to an increased P3 amplitude, which indicates that smiling after rejection is attributed a special subjective importance.

The experiments provide new insights into the social influence through emotional feedback and the processing of relevant social cues. Due to the conceptual similarity of the studies, it was possible to differentiate between stable findings and potentially stimulus-dependent deviations, thus creating a well-founded contribution to the current research. Therefore, the novel paradigm presented here, and the knowledge gained from it could also play an important role in the future for clinical questions dealing with limited social competencies.

ZUSAMMENFASSUNG

Die vorliegende Dissertation soll verschiedene Mechanismen des sozio-emotionalen Feedbacks in sozialen Entscheidungssituationen beleuchten. Ziel ist es, emotionale Gesichtsausdrücke als Feedbackreize, d.h. Reaktion des Gegenübers auf bestimmte soziale Entscheidungen, zu evaluieren. Neben menschlichen Gesichtern werden auch künstliche Emojis aufgrund ihrer Relevanz für die moderne digitale Kommunikation untersucht. Bisherige Forschungen zum Einfluss von emotionalem Feedback legen nahe, dass das Verhalten einer Person durch belohnende Hinweisreize erfolgreich verstärkt werden kann. Im Rahmen dieser Dissertation wurden daher vier Studien durchgeführt, die die Unterschiede in der Feedback-Verarbeitung von menschlichen Fotos und Emojis, aber auch die Bewertung von sozial erwartetem gegenüber sozial unerwartetem Feedback eingehend untersuchen. Zusätzlich zu den Verhaltensdaten verwendeten wir in allen Studien das Elektroenzephalogramm (EEG), um neuronale Korrelate sozialer Entscheidungen und emotionalen Feedbacks zu untersuchen.

Als zentrales Paradigma wurde allen Studien ein modifiziertes Ultimatumspiel zugrunde gelegt. Dieses ist so aufgebaut, dass es einen sogenannten Anbieter gibt, der über einen bestimmten Geldbetrag verfügt (z.B. 10 Cent) und dem Empfänger einen gewissen Anteil davon anbietet (z.B. 3 Cent). Der Empfänger entscheidet daraufhin, ob er das Angebot annehmen oder ablehnen möchte. In der hier verwendeten Version des Ultimatumspiels werden dabei verschiedene Typen von Anbietern eingeführt. Nachdem die Versuchspersonen in der Rolle des Empfängers angenommen oder abgelehnt haben, reagieren die verschiedenen Anbieter mit spezifischen emotionalen Gesichtsausdrücken auf die Entscheidung der Versuchsperson. Für die einzelnen Experimente, die im Rahmen dieser Dissertation durchgeführt wurden, werden unterschiedliche Feedbackmuster angewandt.

In der ersten Studie untersuchten wir den Einfluss des emotionalen Feedbacks auf die Entscheidungsfindung in der modifizierten Version des Ultimatumspiels. Wir konnten zeigen, dass im Ultimatumspiel ein Anbieter, der auf die Annahme eines Angebots mit einem lächelnden Gesicht reagiert, insgesamt mehr akzeptierte Angebote erzielt als der Anbieter der Kontrollbedingung, der sowohl auf angenommene als auch auf abgelehnte Angebote mit einem neutralen Gesichtsausdruck reagiert. Folglich wirkte das Lächeln als positive Verstärkung. In ähnlicher Weise führte ein trauriger Gesichtsausdruck als Reaktion auf ein abgelehntes Angebot ebenfalls zu höheren Annahmeraten als die Kontrollperson, was als Ausdruck von Mitgefühl für diesen Anbieter betrachtet werden könnte. Auf neuronaler Ebene konnten wir zeigen, dass es Unterschiede zwischen dem bloßen Betrachten negativer emotionaler Stimuli (d.h. trauriger und wütender Gesichter) und ihrem Auftreten als Feedback-Stimuli nach abgelehnten Angeboten im modifizierten Ultimatumspiel gibt. Die so genannte *feedback-related negativity* wurde reduziert (d.h. positiver), wenn negative Emotionen als Feedback von den Anbietern auftraten. Wir zogen aus den Ergebnissen den Schluss, dass die Versuchsteilnehmer die Anbieter bestrafen wollten, indem sie ein Angebot wegen seiner Unfairness ablehnten, und dass daher das negative Feedback ihren Erwartungen entsprach. Die veränderte Verarbeitung negativer emotionaler Gesichtsausdrücke im Ultimatumspiel könnte daher darauf hinweisen, dass die Bestrafung als erfolgreich interpretiert wird. Dies schließt die Erwartung ein, dass der Interaktionspartner sein Verhalten in Zukunft ändert und schließlich fairere Angebote machen sollte.

In der zweiten Studie war es das Ziel zu zeigen, dass auch lächelnde und traurige Emojis als Feedback-Reize im modifizierten Ultimatumspiel zu erhöhten Annahmeraten führen können. Entgegen unseren Hypothesen konnte dieser Effekt jedoch nicht beobachtet werden. Auch auf der neuronalen Ebene entsprachen die Ergebnisse nicht unseren Annahmen und unterschieden sich stark von denen der ersten Studie. Eine Erkenntnis war jedoch, dass anhand der neuronalen P3-Komponente ersichtlich wurde, dass die Verwendung von Emojis als Feedback-Reize gewisse Typen von Anbietern besonders kennzeichnet. Dies wurde dadurch gezeigt, dass die

P3 sowohl für den Anbieter, der eine Annahme mit einem Lächeln belohnt, als auch für den Anbieter, der auf eine Ablehnung mit einem traurigen Emoji reagiert, im Vergleich zum neutralen Kontrollanbieter erhöht ist.

Die dritte Studie untersuchte die Diskrepanz zwischen den Ergebnissen der ersten und der zweiten Studie. Dementsprechend wurden sowohl Menschen als auch Emojis, die die Identitäten der Anbieter repräsentieren, im Ultimatumspiel präsentiert. Darüber hinaus wurden Emojis ausgewählt, die eine höhere Ähnlichkeit mit bekannten Emojis aus den üblichen Messenger-Diensten zeigten als in der zweiten Studie. Wir konnten replizieren, dass die Anbieter im Ultimatumspiel, die eine Annahme des Angebots mit einem Lächeln belohnen, zu einer höheren Annahmerate im Vergleich zu den neutralen Kontrollanbietern führen. Dieser Unterschied zeigte sich unabhängig davon, ob die Anbieter durch Emojis oder menschliche Gesichter repräsentiert wurden. In Bezug auf die neuronalen Korrelate konnten wir zeigen, dass sich Emojis und menschliche Gesichter in ihrer neuronalen Verarbeitung stark unterscheiden. Emojis zeigten sowohl in der gesichtsverarbeitenden N170-Komponente als auch in der *feedback-related negativity* eine stärkere Aktivierung als menschliche Gesichter. Wir schlussfolgerten daraus, dass die Ergebnisse der N170 und *feedback-related negativity* ein Signal für fehlende soziale Informationen von Emojis im Vergleich zu Gesichtern sein könnten. Die erhöhte P3-Amplitude für Emojis könnte dabei implizieren, dass Emojis im Vergleich zu menschlichen Gesichtern bei einer sozialen Entscheidungsaufgabe unerwartet als Belohnungsreiz erscheinen.

Die letzte Studie dieses Projekts beschäftigte sich mit sozial unerwartetem Feedback. Im Vergleich zu den ersten drei Studien wurden neue Anbieteridentitäten implementiert. Im Mittelpunkt stand insbesondere ein Anbieter, der auf die Ablehnung eines Angebots unerwartet mit einem Lächeln und auf die Annahme mit einem neutralen Gesichtsausdruck reagierte. Den Ergebnissen zufolge nähern sich die Teilnehmer diesem unerwarteten Lächeln durch verstärkte

Ablehnung an, obwohl es mit einem finanziellen Verlust einhergeht. Darüber hinaus konnten wir, wie in den Studien eins und drei berichtet, zeigen, dass Anbieter, die auf die Annahme eines Angebots mit einem lächelnden Gesicht reagieren und damit die Erwartungen der Teilnehmer erfüllen, höhere Angebotsannahmeraten haben als der Kontrollanbieter. Auf neuronaler Ebene führte insbesondere das Feedback des sozial unerwarteten Anbieters zu einer erhöhten P3-Amplitude, was darauf hinweist, dass dem Lächeln nach der Ablehnung eine besondere subjektive Bedeutung beigemessen wird.

In ihrer Gesamtheit liefern die Experimente neue Erkenntnisse über den sozialen Einfluss durch emotionales Feedback und die Verarbeitung relevanter sozialer Signale. Aufgrund der konzeptionellen Ähnlichkeit der Studien ist es möglich, zwischen stabilen Befunden und möglicherweise reizabhängigen Abweichungen zu differenzieren und damit einen fundierten Beitrag zur aktuellen Forschung zu leisten. Das hier vorgestellte neuartige Paradigma und die daraus gewonnenen Erkenntnisse könnten daher in Zukunft auch für klinische Fragestellungen, die sich mit eingeschränkten sozialen Kompetenzen befassen, eine nicht unerhebliche Rolle spielen.

1. INTRODUCTION

"Hence, in order to have anything like a complete theory of human rationality, we have to understand what role emotion plays in it." (Simon, 1983, p. 29)

Herbert Alexander Simon, an American economist and cognitive psychologist, points out the importance of emotions for human decision-making. The development of research on emotions and rationality began after several scientists (e.g., Güth, Schmittberger, & Schwarze, 1982; Hewig et al., 2011; Kahneman & Tversky, 2013; Tversky & Kahneman, 1974, 1981, 2000) showed that the behavior of participants in experiments differs from the theory of rational choice (Von Neumann & Morgenstern, 1944). Unlike the predictions of *rational choice theory*, studies showed that human beings do not always aim at optimizing the expected utility of options when making decisions.

"We can learn different things from looking at a person's face. The face can send messages about such transient and sometimes fleeting events as a feeling or emotion, or the moment-to-moment fluctuations of a conversation. The face can show more enduring moods, perhaps even stable personality characteristics or traits, and such slow progressive changes as age or state of health, and such immutables as sex." (Ekman, Friesen, & Ellsworth, 1972, p. 1)

Anthropologist and psychologist Paul Ekman and his colleagues illustrate the variety of information that can be conveyed by facial expressions. The authors emphasize the importance of facial expressions in transporting emotions to a social interaction partner, although they are not uniquely accountable for the success of nonverbal communication. Since communication and interactions with other people often require simple or complex decisions (e.g., Rilling, King-Casas, & Sanfey, 2008), facial expressions are an important factor in social decision-making. The aim of research on decision-making and social influence is therefore to understand how social actors influence each other and how the brain eventually reacts to such an influence.

The human face is a widespread means of influence, as it conveys a multitude of socially relevant information. Human facial expressions not only express a mere emotional state, they also refer to personality and intentions (Eckel & Wilson, 1998). Therefore, the information transported through facial expressions influence the social interactions themselves (Ekman, Friesen, & Ellsworth, 2013). In order to combine social influence and electrophysiological measures, the researchers began to expand their paradigms by applying electroencephalography to behavioral studies and by using event-related-potentials (ERPs). These stimulus-locked responses are commonly used measures that allow non-invasive access to the processing of certain cognitive events involved in human decision-making.

1.1. DECISION-MAKING

Human beings are social creatures. In the course of our lives we often encounter situations in which we have to make more or less complex decisions. The procedure of making such decisions is often labelled as “social decision-making” and has been studied mainly in the field of experimental and behavioral economics (for a review, see Rilling & Sanfey, 2011). As a starting point for many decision models, the concept of "homo oeconomicus" (Mill, 1836) is used. The idea of homo oeconomicus presupposes an individual who is able to make rational decisions with the goal to maximize the utility for himself. This conceptualization of decision-making is used to mathematically model utility and determine algorithms that maximize utility. However, several aspects of homo oeconomicus limit its application. The concept of bounded rationality (Simon, 1990) contradicts the maximized utility assumption, since social agents do not always have profound economic knowledge to accurately predict relevant behavior. Moreover, social agents do not behave rationally according to the mathematical model all the time. As one of many examples, studies on delay discounting showed the systematic tendency to discount the distant future at a lower rate than the near future (e.g., Chung & Herrnstein, 1967; Kirby & Herrnstein, 1995; Loewenstein & Prelec, 1992; Schmidt, Holroyd, Debener, & Hewig, 2017). This means that faster availability subjectively increased the value of an outcome, although it was objectively smaller, which represents a clear deviation from the assumptions of rational choice. Finally, the homo oeconomicus model assumes that there is no intrinsic motivation of an individual that could lead to deviations from external motivational references. In contrast, however, some people also behave altruistically, which means that they take on costs in order to create an (economic) benefit for other individuals (Fehr & Fischbacher, 2003). The model of homo oeconomicus, on the other hand, would postulate that people act exclusively in a selfish manner with the aim of maximizing their own benefit.

Considering concepts such as bounded rationality, decisions under uncertainty were researched by principles of expected utility. Rational individuals should decide to take an option that maximizes the expected utility. Von Neumann and Morgenstern (1944) showed that social agents have preferences for choices with uncertain outcomes, even if these valuations may differ from the mathematically expected value. Tversky and Kahneman (1974) concluded that people rely on some heuristics to reduce the complexity of probabilistic decision-making and expected utility, which may lead to less accurate predictions and deviations of the mathematically rational behavior. A fundamental aspect of social decision-making is the dependence of an agent's actions on another agent's (re-)actions. Based on this assumption, a potential interference by other agents enhances or diminishes the achievement of a particular goal. Probably the best known concept to address strategic behavior in non-cooperative games is the *Nash equilibrium* (Nash, 1950), which is used in game theory. In such a *Nash equilibrium*, each participant chooses exactly one strategy and is aware of the strategies of the others, whereby it is not worthwhile for any participant to deviate from their strategy. Therefore, the strategies of the individual games are the best possible responses for them and, with the corresponding payouts, represent a *Nash equilibrium*. Nash distinguishes between a deterministic (pure) *Nash equilibrium*, in which each player makes only one particular decision, and a probabilistic (mixed) *Nash equilibrium*, in which each player chooses randomly between several strategies with a given probability (Nash, 1950, 1951).

Game theory focused on a variety of these theoretical and mathematical considerations and used economic, moral, and social games to model such decision-making moments. Due to the ability to control, standardize, adapt and replicate these paradigms, many studies on social interactions were conducted to bridge the gap between the mathematical theory of choice behavior and naturalistic scenarios of decision-making (Zhao & Smillie, 2015).

A special case in the solution of decision problems is *reinforcement learning* (RL; Sutton & Barto, 1998). RL considers how an agent can choose between certain alternatives based on various internal variables and how these variables are learned and moderated through learning experience. The environment in which a decision must be made is unknown to the individual and the learner must develop his or her decision strategy through interactions. Therefore, the learner relies on feedback as no information or instructions about the optimal action are available. In the future, reinforced behavior will occur more frequently than unreinforced behavior and thus, for example in behavioral experiments, forms benefit-maximizing behavior. The RL framework covers a wide range of models and methods, most of which use the basic temporal-difference (TD) algorithm (Sutton & Barto, 1998). In temporal-difference learning, the social agent estimates values of situations or states that can lead to reward or punishment, which includes a learning problem to find a strategy that maximizes the reward. After performing a certain number of actions, the agent receives a reward and based on this, adjusts his strategy to maximize his reward. In TD learning, agents make these strategy adjustments not only when the reward occurs, but use the information gained after each action to better estimate the expected reward. In this case, the so-called prediction error reports the deviation from the expected reward at any given time and the actual reward received. The greater this error term is, the greater the deviation of the received reward from the expected reward. Moreover, this TD error can indicate an expectation about an outcome that is better (positive TD error or positive reward prediction error) or worse (negative TD error or negative reward prediction error) than expected (Rolls, McCabe, & Redoute, 2008). Consequently, if the reward differs from our prediction, we update our prediction and change our behavior. With a positive reward prediction error, we will show more of the behavior that led to the reward, whereas with a negative prediction error we will minimize or avoid the behavior next time. In both cases we learn from our past behavior and adapt it for future predictions and behavior (Schultz, 2016).

Social decision-making is frequently examined with game paradigms, in which participants allocate resources (i.e., money) between themselves and other players based on predefined rules. In this dissertation, we will use a well-known economic game, the ultimatum game (UG), to investigate *reinforcement learning* in a social decision-making task.

1.2. ULTIMATUM GAME

In the UG (Güth et al., 1982), a proposer can divide a fixed amount of money between himself and another player, the responder, into two stacks of any size. The responder then decides to accept or reject the proposed distribution. If he accepts, both players gain the offered money, if he rejects neither player gains anything. A decision tree for an UG with an amount of 10 Cent is shown in Fig 1.

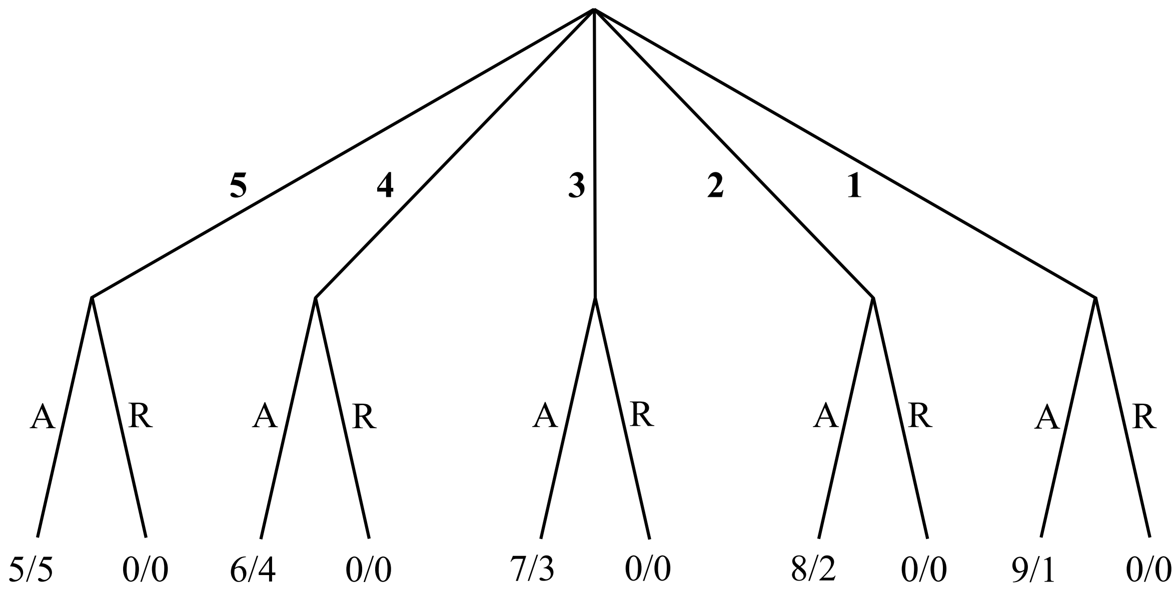

Figure 1. Decision tree for an UG with 10 cents being the total amount and 1 cent being the smallest possible offer. Typically, offers between 10 and 50% of the total amount of money are used in experiments. The proposer chooses his or her strategy first and has five fixed options. The responder reacts to a proposed offer (numbers in bold), with A and R standing for "accept" and "reject", respectively. The numbers at the bottom show the resulting distribution of money (proposer share/ responder share).

According to models of *subgame perfect Nash equilibria* (Gintis, 2000; Vega-Redondo, 2003) and *rational choice theory* (Von Neumann & Morgenstern, 1944), a rational profit-maximizing responder should accept any offer, since a rejection would lead to a smaller profit, in this case winning nothing at all (Güth et al., 1982; Wischniewski, Windmann, Juckel, & Brüne, 2009). Likewise, a rational proposer would offer the smallest possible amount of money to maximize his utility. However, empirical data has shown that this is not how humans usually behave in the UG. For example, in the study conducted by Güth et al. (1982), proposers made 50:50 offers in 33% of all cases. A variety of experimental research showed that proposers typically offer between 40 and 50 percent of the money (for reviews see Camerer (2003) or Güth and Kocher (2014)). From the perspective of the responder, unfair offers, i.e., a 80:20 share in favor of the proposer, are accepted typically in 50% of all cases (e.g., Hewig et al., 2011). However, 50% were still rejected, which does not fit the assumptions of *rational choice theory*. Possible explanations for behavior contrary to the rational choice model vary a lot: Participants may want to punish unfair proposers in repeated games (Fehr & Fischbacher, 2003), even at personal costs (Fehr & Gächter, 2000, 2002). The so-called altruistic punishment of unfair proposers could have a social function, as it would decrease the likelihood of a repetition of such behavior in the future. Consequently, the evolution of cooperation and fairness in social interaction is thought to be a great motivational factor that engages proposers to make fair offers (Abbink, Sadrieh, & Zamir, 2004; Fehr & Fischbacher, 2003; Fehr & Gächter, 2000). Other explanations suggest that responders become angry (Pillutla & Murnighan, 1996) or report feelings of aversion (Osumi & Ohira, 2009) while being offered low amounts of money. The role of anger was further examined by Srivastava, Espinoza, and Fedorikhin (2009) who decoupled anger from unfairness. The authors showed that specifically anger (and not negative affect in general) mediates the evaluation of an offer as unfair and leads to rejection or acceptance of an ultimatum game offer. Other studies considered the ultimatum game from the perspective of the proposer and showed that participants in the role of the proposer may make fair offers out of fear of rejection and loss of money or simply to increase profits (Güth, 1995; Güth & Van Damme, 1998; Haselhuhn & Mellers, 2005; Mellers, Haselhuhn, Tetlock, Silva, & Isen, 2010). Evolution-based approaches to empathy further indicate that proposers make offers that are equal to offers they would accept in the role of the responder themselves (Bellebaum, Kobza, Thiele, & Daum, 2011; Page & Nowak, 2002; Singer et al., 2006).

1.3. EMOTIONAL INFLUENCE

Due to their inherent social nature (for review see Keltner & Lerner, 2010), emotions could provide three basic functions in social decision-making (Lerner, Li, Valdesolo, & Kassam, 2015). First, experiencing personal emotions can facilitate the understanding of emotions, personality and intentions of an interaction partner (Eckel & Wilson, 1998). Second, emotions can be incentives or costs for the behavior of others (Sell, Tooby, & Cosmides, 2009). Third, emotions can trigger mutual or shared emotional responses from others (Keltner & Haidt, 1999). The role of emotions and their possible influence on decision-making has gained importance in the course of the investigation of economic games (e.g., Loewenstein, 2000). Intentions such as cooperation and trust can be derived from the smiling facial expression of an interaction partner (Reed, Zeglen, & Schmidt, 2012; Van't Wout & Sanfey, 2008). Angry facial expressions, on the other hand, can represent malice or threat and therefore lead to rejection tendencies and facilitate avoidance behavior (Hess, Blairy, & Kleck, 2000; Seidel, Habel, Kirschner, Gur, & Derntl, 2010). Moreover, anger might express the desire for concessions from interaction partners (Van Kleef, De Dreu, & Manstead, 2004) or more cooperation in economic games (Van Dijk, Van Kleef, Steinel, & Van Beest, 2008), as anger could signal a desire that the other person should adapt his or her behavior (Fischer & Roseman, 2007). With regard to the ultimatum game, individuals experience negative emotions and an increase in arousal when they receive unfair offers (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; Van't Wout, Kahn, Sanfey, & Aleman, 2006). Experimentally manipulated emotional influence is often operationalized either by confronting the participants with emotion-inducing film clips before the entire game or by presenting affective information (e.g., emotional pictures) directly before the offer is shown in the ultimatum game. Harlé and Sanfey (2007) reported that sadness inducing film clips before the UG provoked lower acceptance rates of unfair offers compared to a neutral control clip. Forgas and Tan (2013) and Andrade and Ariely (2009) reported similar effects for comparing sadness versus happiness and anger versus happiness. Even clinical depression, a mood disorder characterized, among other symptoms, by sad affect, has been found to moderate behavior in the UG. Harlé, Allen, and Sanfey (2010) showed that depressed individuals accepted more unfair offers compared to a healthy control group, although depressed individuals indicated a more negative emotional response to these unfair offers. This contradiction with the findings about healthy people may indicate a specific bias of depression, which may be associated with a higher dependence on the regulation of negative emotions. Finally, Riepl, Mussel, Osinsky, and Hewig (2016) investigated both state and trait affect with induced movie clips and the assessment of trait affect questionnaires. Again, state happiness led to an increase of acceptance rates for unfair offers. Trait-related effects were only found for neural correlates of decision-making, which will be discussed in the next chapter.

With regard to the research reported in this dissertation, the studies by Mussel, Göritz, and Hewig (2013) as well as Mussel, Hewig, Allen, Coles, and Miltner (2014) are of particular interest. Mussel et al. (2013) introduced different proposer identities that were represented by a happy, neutral, or angry looking face prior to the ultimatum offer. In comparison to the neutral control identity, smiling proposers received higher acceptance rates, whereas angry proposers received lower acceptance rates. This effect was further specified by Mussel et al. (2014), who showed that a smiling proposer led to an increase in the acceptance of unfair offers compared to the non-smiling proposer. In contrast to a valence driven influence of emotional faces on acceptance rates, Harlé and Sanfey (2010) argue that the motivational direction of emotional faces (i.e., approach versus avoidance) determines decision-making. In their study, they showed that approach-motivated emotions (i.e., amusement and anger) elicited higher acceptance rates of unfair UG offers compared to withdrawal-motivated emotions (i.e., serenity and disgust). However, they were not able to find a valence-based effect on acceptance rates.

1.4. NEURAL COMPONENTS OF FACE PERCEPTION AND DECISION-MAKING

In the studies outlined in this dissertation, we examined neural correlates in the context of the ultimatum game. We focused mainly on three event-related potentials related to emotion perception, ultimatum game offers and feedback presentation: The N170, the feedback-related negativity (FRN) and the P3. The following sections describe these components and their interpretation in detail.

1.4.1. N170

The N170 brain potential is a negative deflection that reaches its peak between 150 and 200 ms after stimulus onset (Jeffreys, 1989). The strongest activation is usually measured on the mastoids and is greater for the right hemisphere than for the left hemisphere. When human facial expressions are observed, the amplitude of N170 is larger compared to non-facial stimuli, indicating a face-sensitive function of N170. Therefore, N170 is an established correlate of visual processing of human faces (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bentin & Carmel, 2002; Eimer, 2000; Rossion et al., 2000). However, when the brain is confronted with inverted faces, i.e., faces, that are depicted upside-down, the peak latencies increase (Bentin et al., 1996), indicating more difficult and slower processing due to the obfuscation of configural information. These anomalies are particularly visible in the right hemisphere (Rossion et al., 1999). However, when non-facial stimuli were inverted, this increase in N170 amplitudes could not be reported, underlining the specificity of N170 for facial processing (Bentin et al., 1996).

The neural origin of N170, according to its function, lies in the face processing regions, such as the fusiform gyrus (e.g., Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997; Sadeh, Podlipsky, Zhdanov, & Yovel, 2010) and the superior temporal sulcus (e.g., Itier & Taylor, 2004). In summary, it can be stated that the holistic processing of human faces takes place through neural networks in the fusiform gyrus, while individual facial features are recognized and processed in the superior temporal sulcus (Bentin et al., 1996; Carmel & Bentin, 2002).

In addition, not only images of human faces evoke N170 brain potentials. Bentin and Carmel (2002) reported that faces of monkeys produced similar patterns to human faces. Therefore, N170 appears to be caused by facial features, regardless of the expertise of the person processing the stimuli. When the broad concept of a face is represented, schematic images of faces also evoke N170 brain potentials (e.g., realistically painted portraits; Sagiv & Bentin, 2001). Emoticons, i.e., pictographic images composed of symbols resembling facial expressions, also seem to be processed like human faces, when presented upright. Contrary to real human faces, the N170 diminished for emoticons when presented upside-down (Churches, Nicholls, Thiessen, Kohler, & Keage, 2014). Finally, Park (2015) reported that emoticons are processed similarly to human faces, but this processing requires more attentional resources.

Beyond the mere presence of human facial expressions, their emotional valence modulates the deflection of the N170 amplitude. Bruce and Young (1986) very early set up a model that states that human faces and their emotional expressions are encoded in parallel, but independently. Accordingly, a large number of studies reported an influence of emotional expressions on N170 amplitudes (e.g., Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCandliss, 2007; Karl, Hewig, & Osinsky, 2016; Rossignol, Philippot, Douilliez, Crommelinck, & Campanella, 2005; Tortosa, Lupiáñez, & Ruz, 2013), while other studies found no influence of emotions on the deflection of N170 amplitudes (e.g., Eimer & Holmes, 2002; Eimer, Holmes, & McGlone, 2003; Holmes, Winston, & Eimer, 2005; Rellecke, Sommer, & Schacht, 2013; Smith, Weinberg, Moran, & Hajcak, 2013). Among the former studies, the details differ distinctly. For example, fearful expressions evoked more negative amplitudes than surprised or neutral expressions (Batty & Taylor, 2003; Blau et al., 2007). A meta-analysis by Hinojosa, Mercado, and Carretie (2015) reported more negative amplitudes for facial expressions of fear, anger, and happiness than for neutral facial expressions. Furthermore, the minima of N170 for negative emotions peak later compared to the minima for positive emotions (Batty & Taylor, 2003). In summary, the literature suggests that there are emotional influences on the N170 component, but the research results to date are inconsistent. In the studies presented in this dissertation, we focused on the influence of emotional facial expressions and the configural processing of human faces and compared these in one study to artificial emojis.

1.4.2. FEEDBACK-RELATED NEGATIVITY

The feedback-related negativity, also known as feedback negativity or feedback error-related negativity, is a negative deflection in the ERP. Its maximum amplitude is recorded at the scalp over the frontal brain regions at about 250-300 ms after the onset of a feedback stimulus (for review see Folstein & Van Petten, 2008). The FRN detects evaluative signals (Polezzi et al., 2008) such as negative compared to positive performance feedback (e.g., Holroyd & Coles, 2002; Miltner, Braun, & Coles, 1997) or losses compared to gains (e.g., Hewig et al., 2007; Nieuwenhuis, Yeung, Holroyd, Schurger, & Cohen, 2004; Yeung & Sanfey, 2004), which makes it a vital component for *reinforcement learning*. The first study on FRN was conducted by Miltner et al. (1997) with a time-estimation task. Participants were asked to press a specific key as close as possible to a second after a warning tone. During the task, the participants had to estimate a certain duration via key press and received feedback if they were right or wrong. These (visual, auditory or somatosensory) feedback cues were given in such a way that they received positive feedback exactly 50% of the time. As a result, Miltner et al. (1997) reported a negative frontocentral ERP peaking around 230 ms after feedback onset. Negative feedback led to a greater negative deflection compared to positive feedback. Holroyd and Coles (2002) suggested that the underlying evaluative processes of FRN are involved in *reinforcement learning*. They showed that FRN amplitudes were more negative after a loss and indicated a worse result than expected. In contrast, more positive amplitudes after a result better than expected are also associated with a reinforcement response (Holroyd, Pakzad-Vaezi, & Krigolson, 2008). This fits with the assumptions of the RL theory, which states that the change in behavior becomes greater with increasing reward prediction error. Similarly, the FRN increases with the direction of the reward prediction error and indicates a deviation from the expected outcome. The FRN is generated when a negative feedback signal follows a behavior and is transmitted to the ACC via the mesencephalic dopamine signal system (e.g., Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). This neural signal is interpreted by the ACC to modify future behavior and thus task-performance. Negative feedback leads to a lower probability of the behavior occurring in the future, as described by learning after a negative prediction error of RL theory (e.g., Schultz, 2016). The conglomerate of signal processing reflects a general high-level error encoding system as it detects errors to improve performance in a task and influences executive functions mediated by frontal regions of the brain.

The FRN has been studied extensively in gambling tasks with monetary outcomes. For example, Gehring and Willoughby (2002) reported that the FRN amplitude was more negative for gambling losses than for winnings. However, a smaller win compared to a larger win was not detected as an outcome worse than expected, although in some conditions of their experiment it was a relative loss. Thus, the authors concluded that the FRN reflects a sensitivity to gains versus absolute losses but not to error detection (correct versus incorrect decisions). Nieuwenhuis et al. (2004) aimed to distinguish between outcome valence (gain versus loss) and outcome correctness. They disentangled valence and correctness and found that FRN seems to be a binary evaluation of good versus bad outcomes. Therefore, it is primarily sensitive to the valence of an outcome, and not to the magnitude of an outcome (e.g., Hajcak, Moser, Holroyd, & Simons, 2006; Yeung & Sanfey, 2004). However, Holroyd, Larsen, and Cohen (2004) showed that identical outcomes can produce distinct FRN amplitudes, depending on the context of the alternative outcomes. In their study, the FRN amplitudes did not differ for medium-sized and negative outcomes. Similarly, Holroyd, Hajcak, and Larsen (2006) reported that neutral and negative feedback in a gambling task caused greater negativity than positive feedback. In addition, Holroyd, Nieuwenhuis, Yeung, and Cohen (2003) investigated the influence of reward probability on FRN amplitudes in a gambling task. In their study, participants had to choose one of four response options with random reinforcement (positive versus negative feedback). In the condition with a higher frequency of rewarding feedback, the negative feedback generated larger FRN amplitudes. Hence, especially unexpected negative outcomes reflect a feedback evaluation that is worse than expected.

In summary, the FRN is associated with behavioral adaptation and cognitive control reflected in the greater negativity for negative feedback from its source, the ACC (e.g., Holroyd & Yeung, 2012). In terms of RL theory, the results suggest that FRN, as a marker for reward prediction errors, is more sensitive to negative than positive reward prediction errors (e.g., Cohen, 2008).

However, a different interpretation of FRN amplitudes began to develop, as Holroyd et al. (2008) considered the FRN to indicate a lack of positive feedback from rewards. The underlying reward-sensitive component, called reward-positivity (RewP), is caused by the superimposition of RewP on the FRN (Baker & Holroyd, 2011). Functionally, an increased RewP is associated with learning and the increased achievement of task-related goals (Holroyd & Yeung, 2012). Regarding RL, reward positivity reflects a positive rather than a negative reward prediction error (i.e., "better than expected"; Holroyd & Coles, 2002). The concept of RewP is supported by findings on the behavioral and neural activity of problem gamblers in a blackjack gambling task (Hewig et al., 2010). Problem gamblers compared to a neutral control had more reward-related potentials after unexpected but risky wins. Furthermore, Baker, Stockwell, Barnes, and Holroyd (2011) showed that substance-dependent participants with impaired dopaminergic midbrain activity for *reinforcement learning* responded with a smaller RewP in a learning task than healthy individuals. Using principal component analysis, Foti, Weinberg, Dien, and Hajcak (2011) showed that differences in FRN amplitudes after gains and losses were associated with a positivity over frontocentral electrode sites, which is larger for rewards as compared to non-rewards.

In recent decades, the FRN (or RewP) has often been studied in the context of the UG. Unfair offers evoked larger FRN amplitudes compared to fair offers (e.g., Hewig et al., 2011; Polezzi et al., 2008; Wu, Hu, van Dijk, Leliveld, & Zhou, 2012). People with higher fairness concerns (Boksem & De Cremer, 2010) or higher trait or state negative affect (Riepl et al., 2016) showed even greater FRN responses to unfair offers. Furthermore, the influence of facial expressions on FRN amplitudes in the UG was investigated. Ma, Hu, Jiang, and Meng (2015) showed that attractive proposers received higher acceptance rates and evoked smaller FRN responses to unfair offers than less attractive proposers. Apart from this, if the offer was made by a smiling proposer, unfair offers were also accepted more frequently and resulted in smaller FRN responses compared to non-smiling proposers (Mussel et al., 2014). Interestingly, FRN following the face of a proposer who repeatedly makes unfair ultimatum game is similar to the FRN response following the offer itself (Osinsky, Mussel, Ohrlein, & Hewig, 2013). Thus, humans seem to learn about the contingency between a proposer and his or her degree of fairness in proposing money and thus evaluate the fairness of an interaction partner at an early neural stage.

In the studies carried out for this thesis, the FRN is examined both in terms of the presentation of emotional faces in order to define a neural baseline expectation value and in terms of emotional feedback from the proposer in the ultimatum game. In addition, existing findings on the presentation of offers will be re-examined. The specific hypotheses will be presented at the end of the theoretical discourse of each publication.

1.4.3. P3

The P3 is a positive deflection in the EEG signal and shows its peak about 300 ms after stimulus onset (Johnson & Donchin, 1980). Sutton, Braren, Zubin, and John (1965) were the first to report P3 and its relationship to information processing and memory mechanisms. Later, the functional relevance of P3 was divided into two components, the frontocentral P3a (Snyder & Hillyard, 1976) and the classical parietal P3b (Chapman & Bragdon, 1964). Whereas P3a indicates an initial attention orientation (Roth, 1973), P3b is connected with updating processes of working memory and arousal (Houston, Bauer, & Hesselbrock, 2003). It also corresponds to attention and decision-making processes and originates from temporal-parietal brain regions corresponding to norepinephrine pathways (Polich, 2007). In the studies discussed in this dissertation, we will always refer to the P3b component when using the term P3.

In the study that described P3 first by Sutton et al. (1965), either visual or auditory stimuli were presented to the participants. A positive deflection 300 ms after stimulus presentation was observed in the EEG signal, when participants were unsure about the stimulus modality before it occurred. Ritter, Vaughan, and Costa (1968) also associated the P3 component with an orientation response when unpredictable stimuli occurred. Further studies reported that a similar deflection was found for relevant versus irrelevant stimuli in a particular task (Donchin & Cohen, 1967; Johnson & Donchin, 1980). Moreover, several studies (e.g., Courchesne, Hillyard, & Courchesne, 1977; Duncan-Johnson & Donchin, 1977) showed that unexpected stimuli cause increased P3 brain potentials, indicating the relevance of updating the mental context of a particular task (Donchin, 1981). With regard to decision-making, Rohrbaugh, Donchin, and Eriksen (1974) presented two stimuli to their participants that contained relevant information for the task of selecting a correct button press. An adequate response was only possible by knowing the information of the second stimulus. The authors reported an increased P3 amplitude after presentation of the second stimulus compared to the first, suggesting that the P3 is a marker for processing relevant information to make a decision.

Feedback perception plays a crucial role in the studies conducted for this dissertation. Johnson and Donchin (1978) performed a time-estimation task and presented two tones to their subjects that signaled whether the time-estimate was correct or incorrect. During the experiment, the discriminability of the tones was manipulated. As a result, P3 deflections were smaller for both tones when they were difficult to distinguish. The authors concluded that these tones were only useful for the subjects for modifying their behavior if they could be properly discriminated. In a similar study by Campbell, Courchesne, Picton, and Squires (1979), the time-window that determined whether an estimate was correct or incorrect was modified. A larger time window led to more frequent positive feedback and vice versa. The resulting P3 deflections were more positive for the feedback type, which occurred less frequent. The inverse relationship of feedback probability and P3 deflections was also reported by Hajcak, Holroyd, Moser, and Simons (2005), who had participants select one of several stimuli and presented to them positive or negative feedback with different frequency gradients.

With regard to the relevance of the valence of feedback stimuli, the results of P3 deflections are ambiguous. Ito, Larsen, Smith, and Cacioppo (1998) investigated the effects of valence on P3 with an oddball task. Neutral stimuli were presented more frequently than negative and positive ones. The participants were asked to mentally evaluate the valence of each individual stimulus. In conclusion, negative stimuli elicited more positive P3 deflections than positive stimuli. Likewise, Frank, Woroch, and Curran (2005) conducted a task on *reinforcement learning*. The test persons learned which of two different stimuli they had to choose, which led to larger P3 amplitudes for negative compared to positive feedback.

However, several studies showed a greater P3 positivity for positive feedback compared to negative feedback in gambling tasks and a time-estimation task, regardless of feedback probability (e.g., Hajcak et al., 2005; Hajcak, Moser, Holroyd, & Simons, 2007; Johnson & Donchin, 1985). Bellebaum et al. (2011) showed that P3 amplitudes were more pronounced when participants received a reward than when they received nothing at all. The feedback probability only had an influence on P3 deflections after the reward, not on P3 amplitudes after non-reward.

Within the framework of the ultimatum game, several studies have already investigated P3 effects. For instance, Wu et al. (2012) and Riepl et al. (2016) showed that after fair offers P3 amplitudes were greater compared to P3 amplitudes after unfair offers. The authors came to the conclusion that the motivational relevance for a fair offer is higher than for unfair offers. Ma et al. (2015) reported that this effect was even modulated by attractiveness of the proposer. For attractive proposers, no difference was found between the P3, which follows fair and unfair offers. However, the fair offers of unattractive proposers led to a higher P3 amplitude compared to unfair offers of unattractive proposers. On the basis of these findings, P3 will be used as a marker of the subjective relevance of different feedback cues for the studies conducted in this dissertation in order to further investigate the previous, partly contradictory findings.

1.5. OBJECTIVE

The goal of the studies conducted for this dissertation is to investigate basic mechanisms of neural feedback processing with a variety of different emotional expressions and feedback patterns. The findings of Mussel et al. (2013) indicated that the acceptance behavior of responders in the ultimatum game can be manipulated by facial expressions of the proposer preceding the offer. Moreover, Osinsky et al. (2013) and Mussel et al. (2014) showed that human facial expressions before the offer also have an influence on neural components like the FRN. For the present studies we have refined the paradigm of the aforementioned publications. In the standard configuration of our modified ultimatum game, the participants initially see a neutral face of a certain proposer identity. After a participant has accepted or rejected an offer, the proposer uses an emotional expression to tell him how he feels about his decision. We have created different identities (both male and female) that react characteristically to acceptance versus rejection (e.g., one identity smiles upon acceptance and looks neutral upon rejection; another identity looks neutral upon acceptance and sad upon rejection). Regardless of the modifications made in the studies, the emotional response was always communicated after the participant’s decision in order to manipulate future decision behavior specifically for that proposer. Furthermore, we considered differences of physical facial features, i.e., emojis, and real human faces, to be distinguishable aspects of behavioral and neural influence. By implementing human faces and emojis, we wanted to bridge the gap between classic emotion research with images of faces and the rise of artificial emotion expressions in the digital era. In order to make well-grounded statements on the nature of feedback processing during a social decision-making task, we used the same basis for the paradigms implement in all studies that were conducted for this dissertation. The understanding of feedback processing in general may offer useful insight into specifications of social interactions and social learning.

2. PUBLICATIONS

In line with our goals, four different publications are discussed below, each of which is an experiment to investigate the influence of emotional feedback on decision-making and its neural basis. The content of the studies corresponds to the form published in the respective journals, only the format and the captions have been edited for this dissertation.

The studies are presented in the following order:

Study 1: Mussel, P., Hewig, J., & Weiß, M. (2018). The reward-like nature of social cues that indicate successful altruistic punishment. *Psychophysiology*, *55*(9), e13093.

http://dx.doi.org/10.1111/psyp.13093

Study 2: Weiß, M., Gutzeit, J., Rodrigues, J., Mussel, P., & Hewig, J. (2019). Do emojis influence social interactions? Neural and behavioral responses to affective emojis in bargaining situations. *Psychophysiology*, *56*(4), e13321.

http://dx.doi.org/10.1111/psyp.13321

Study 3: Weiß, M., Mussel, P., & Hewig, J. (2019). The value of a real face: Differences between affective faces and emojis in neural processing and their social influence on decision-making. *Social Neuroscience.*

http://dx.doi.org/10.1080/17470919.2019.1675758

Study 4: Weiß, M., Mussel, P., & Hewig, J. (2020). Smiling as negative feedback affects social decision-making and its neural underpinnings. *Cognitive, Affective, & Behavioral Neuroscience, 20*(1), 160-171.

http://dx.doi.org/10.3758/s13415-019-00759-3

After each publication, the relevance of the results is discussed and implications for the introduction of the subsequent research question are drawn.

THE REWARD-LIKE NATURE OF SOCIAL CUES THAT INDICATE SUCCESSFUL ALTRUISTIC PUNISHMENT

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ABSTRACT

Altruistic punishment is the attempt to penalize deviant behavior of another person even though it is accompanied by personal costs. Here, we investigated the influence of the reaction on the socioemotional level of the other person following altruistic punishment behavior on future decision making and neural responses. We used a modified ultimatum game, which included an emotional facial feedback of the proposer following the decision of the participant. We found higher acceptance rates for proposers showing a smile upon acceptance or a sad face upon rejection of an offer, compared to proposers showing a neutral facial expression. On the neural level, we found a reversed N2 effect for negative emotional faces in the context of altruistic punishment, compared to a control condition. Specifically, when following the rejection of an unfair offer, negative emotional faces showed a reward-like positivity that might signal successful altruistic punishment. In addition, differential effects for P3 amplitudes might signal the subjective importance of a desired outcome. Our results are in line with the interpretation that rejection of unfair offers in the ultimatum game is due to intended altruistic punishment. Social cues may exhibit reward-like properties when indicating successful altruistic punishment and can influence subsequent decision making.

INTRODUCTION

In everyday social interaction, individuals influence each other to change the behavior, attitudes, and affective responses of other persons (Argyle, 1969). For example, if a member of a group violates social norms, we might want to punish this person, even if punishment might be accompanied by personal costs—a case that has been termed as altruistic punishment (Bowles & Gintis, 2004; De Quervain, Fischbacher, Treyer, & Schellhammer, 2004; Fehr & Gächter, 2002). The way the other person reacts upon our attempts determines whether our behavior was successful or not, and this might subsequently have an impact on our future behavior. In the present study, we investigate a special kind of reaction of an interaction partner that has been rarely investigated in the literature, namely, the emotional reaction of another person. In the example above, a successful attempt of altruistic punishment might be given if an interaction partner shows an emotional reaction that indicates that our intended influence was understood, and that deviant behavior might be altered in the future.

Altruistic punishment has frequently been examined in bargaining situations like the ultimatum game. In this game, a proposer splits an amount of money and a responder can accept or reject this offer leading to the suggested split of money or a zero outcome for both players (Güth et al., 1982). The latter effect has been seen as an intended negative influence upon the proposer (e.g., Kagel & Roth, 1995), which might include inducing negative emotions in an unfair proposer. Socioaffective variables have been used as performance feedback signals for behavior (Aarts & Pourtois, 2012; Boksem, Ruys, & Aarts, 2011; Pfabigan, Alexopoulos, Bauer, Lamm, & Sailer, 2011; Pfabigan, Zeiler, Lamm, & Sailer, 2014) or brain activity (Mathiak et al., 2010), and have been shown to influence decision making. For example, we showed that negative affective facial expressions increase rejection rate, whereas positive affective facial expressions decrease rejection rate when presented before an offer is made in the ultimatum game (Mussel et al., 2013). However, the effects of social affective cues of an interaction partner as the target of behavior as well as the consequences of these cues on subsequent behavior have not been examined in an interactive bargaining game to date.

In the present study, we extend the interaction process by investigating social affective responses of the proposer that were contingent on the decision of the participant to either accept or reject an offer. We investigate whether variations in social-affective feedback would influence subsequent economic decision making. Therefore, in each ultimatum game, the participants as receivers did see a neutral face indicating the identity of the proposer in the ultimatum game at the beginning of each trial. The identity was defined as the characteristic response pattern to accepted and rejected offers. Particularly, one type of identity smiled upon acceptance of their offers while reacting neutrally to rejection, a second type always reacted neutrally, a third type looked angry upon rejection and neutral upon acceptance, and finally a fourth looked sad upon rejection and neutral upon acceptance. We expected that social-affective feedback following altruistic punishment would influence future decision-making.

Additionally, we examine neural correlates of such behavioral changes due to these different identities. We examined the N170, which primarily reflects face processing (Eimer, 2000; Rossion et al., 2000), the N2, which reflects evaluative feedback processing known as feedback-related negativity (Miltner et al., 1997) and reward positivity (Holroyd & Coles, 2002; Holroyd et al., 2008), and, finally, P3 reflecting attentional processing and subjective importance (Johnson, 1988; Polich, 2007).

We expect that basic face processing in terms of the N170 will be unaffected by the circumstances of the presentation of a face. However, we expected that, in particular, evaluative feedback processing at the N2 latency will reflect a reward-like response—the reward positivity—to emotional facial stimuli, which signal successful altruistic punishment, and that the emotional feedback cues have differential subjective importance, as reflected in P3 amplitudes.

METHOD

PARTICIPANTS

A sample size of *N* = 59 was estimated for a medium effect of partial $\eta^2 = .06$, $\alpha = .05$, and $\beta = .95$ (Mussel et al., 2013; Strobel et al., 2011). Sixty students (44 female; mean age = 22.6 years, *SD* = 3.2) participated for course credit or a monetary compensation of 10 Euro. Additionally, they were told that they could gain more money during the ultimatum game, depending on their task behavior. Since, unknown to them, they played against the computer (see below), at the end they received a fixed additional payout of 5.30 Euro (which was the maximum payout in the ultimatum game) to keep any frustration about the deception as low as possible. All participants gave written informed consent.

EXPERIMENTAL PROCEDURE

After arrival, participants received a general instruction about the experiments. Next, they were given three experimental tasks (see Figure 2.1). The first task was a control condition to examine neural responses to emotional facial expressions. A total of 200 facial stimuli with varying emotional expressions were presented. The task of the participants was to solely look at the stimuli, without providing any reaction. As stimulus material, we used five male and five female characters from the Radboud Faces database (Langner et al., 2010), each with four facial emotional expressions: happy, neutral, angry, and sad. For each participant, one male and one female character was randomly chosen from these five characters, and thus the resulting eight pictures (four facial emotional expressions for each gender) were each presented 25 times in random order.

In the second task, participants played 10 rounds of a modified ultimatum game as a proposer. The purpose of this task was mainly to facilitate understanding and enhance plausibility of the cover story of the third task (see below). In each round, the participants could divide 10 cents into two shares: one for her/himself and one for the other player. They were told that, for each proposal, they would later receive the respective amount of money if the offer is accepted by the other player. There were six predefined proposal options, ranging from 0 to 5 cents for the responder. Irrespective of their choice, they subsequently received the feedback that their offer was either accepted or rejected (in 50% of the cases, respectively). Finally, participants had the opportunity to send a picture to the other player to show how they feel about such a decision. Therefore, the gendermapped four facial emotional pictures from Task 1 were presented such that female participants saw the four facial emotional pictures of the female character and vice versa. Participants picked one of the four pictures by a corresponding button press.

In the third task, participants played eight blocks with 48 trials each of the modified ultimatum game in the role of the responder. Participants were told that the offers they received were made by other participants who took the experiment on an earlier occasion, and that both parties would be paid according to the decisions made by the participant. In truth, the offers were predefined, as outlined below. Each trial began with a picture of either a male or female character with a neutral facial expression representing the proposer of the upcoming offer. The picture was taken from the pool of the eight characters which were not chosen in Task 1. Next, the offer of the proposer was shown, representing a split of 10 cents, ranging from 0 to 5 cents for the responder. The offer was shown as a pie chart (e.g., 3/7 for the responder/ proposer). During each block, each of the eight characters made each of the six possible offers exactly once. The order of the 48 offers was randomized for each participant. Next, participants made a choice to either accept or reject the offer by pressing the left or right arrow button, respectively, on a regular keyboard. Their decision, along with the money that they won, was displayed for 1,200 ms (e.g., “Accept! You get 3 cents”). Next, a picture with varying facial expression of the character who made the offer was shown, representing how the proposer felt according to the decision of the participant. Thereby, each character acted in one of four characteristic ways, which we refer to as the identity of this character. The smiling identity reacted with a smile if an offer was accepted and a neutral expression if the offer was rejected. The neutral identity reacted with a neutral facial expression, irrespective of the decision of the responder. The angry identity reacted with a neutral facial expression if the offer was accepted and an angry facial expression if the offer was rejected. Finally, the sad identity reacted with a neutral facial expression if the offer was accepted and a sad facial expression if the offer was rejected. For each participant, one male and one female character were randomly assigned to one of the four identities from the pool of the eight pictures that were not used for Task 1 and 2. After the experiment, participants completed several questionnaires (not further considered in this article), were informed about the deception, and paid out.

All stimuli were presented on a 17” screen with a black background. Stimulus presentation and response recordings were controlled by PsychoPy 1.83 (Peirce, 2009). During the task, participants were seated in a comfortable chair with a distance 70 cm between the head and the screen. Each of the face pictures was 10 cm high and 6.65 cm wide, resulting in a visual angle of about 14.2° × 9.5°. The pie charts had a diameter of 2.5 cm (3.6° visual angle).

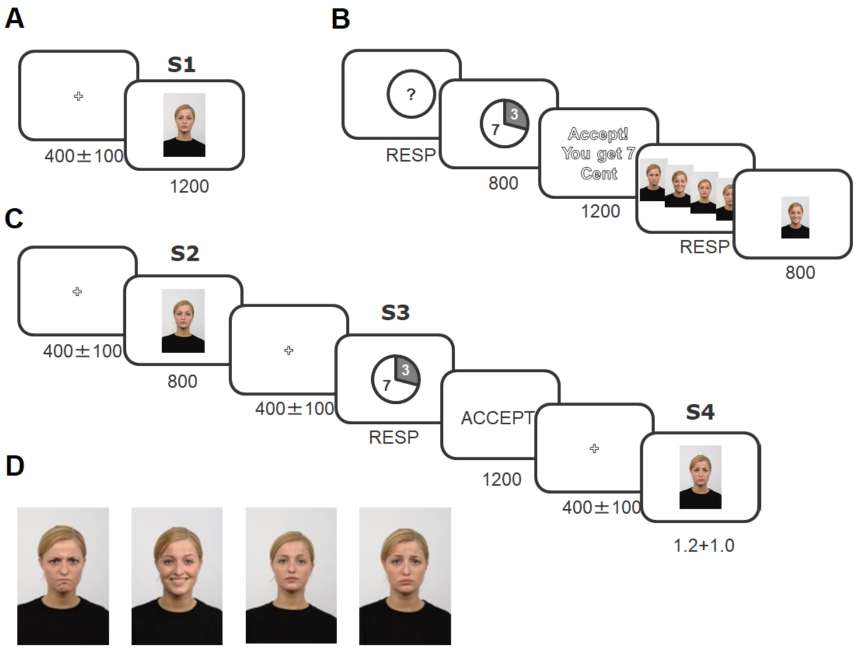

Figure 2.1. (a)–(c) Task time line for the three paradigms. S1 to S4 denote the four stimuli used for the electrophysical analyses, see Figure 2.2. Numbers indicate presentation time in milliseconds. (d) Example pictures for anger, happy, neutral, and sad facial expressions (Langner et al., 2010)

EEG RECORDINGS AND ANALYSES

While subjects performed the ultimatum game, EEG (analog band-pass: 0.1–80 Hz, sampling rate: 250 Hz) was recorded from 31 scalp sites according to the 10–20 system (Fp1, Fp2, F9, F7, F3, Fz, F4, F8, F10, FC5, FC1, FC2, FC6, T7, C3, C4, T8, TP9, CP1, CP2, TP10, P7, P3, Pz, P4, P8, PO9, O1, O2, PO10, Iz), using Ag/AgCl electrodes and a BrainAmp DC amplifier (Brain Products GmbH, Gilching, Germany). During recording, impedances were kept below 5 kΩ and electrodes were referenced to the vertex (Cz). Data were processed offline, using MATLAB R2015b (MathWorks, Natick, MA) and the toolbox EEGLAB 15.0.1 (Delorme & Makeig, 2004). First, data were rereferenced to the average across scalp electrodes and electrode Cz was reinstated. Data were then filtered, using a 25 Hz low-pass filter. Subsequently, the EEG was segmented into epochs of 1,100 ms (-300 to 800 ms relative to the stimulus, see below) and baseline corrected (-300 to 0 ms). For artifact rejection, trials in which the amplitude exceeded the criterion of 4 standard deviations or 300 µV were excluded from further analyses (7.5% of the trials). Next, we used independent component analysis decomposition for the detection of eyeblink and movement artifacts. Components representing artifacts were detected and subsequently removed from the data set using the automatic artifact rejection tool MARA (Multiple Artifact Rejection Algorithm, Winkler et al., 2014), which uses spectral, topographic, temporal, and source features of an independent component for classification as neural or artifact (Smith, Reznik, Stewart, & Allen, 2017). Finally, data were averaged for each participant and each condition.

ERP QUANTIFICATION

We investigated neural processes of the decision-making process according to four different stimuli (S1 to S4, see Figure 2.1). The first stimulus S1 was emotional faces in Task 1, analyzed in a one-factorial design with the factor emotional expression (with four levels: smiling, neutral, angry, sad). The second stimulus S2 was neutral faces in Task 3, analyzed in a one-factorial design with the factor identity (with four levels: smiling/neutral, neutral/neutral, neutral/angry, neutral/sad, according to the emotional reaction following accepted/rejected offers). The third stimulus S3 was the presentation of the offer in Task 3, analyzed in a two-factorial design with the factors offer size (with six levels: 0, 1, 2, 3, 4, 5 cents) and identity (with four levels, see above). Finally, the fourth stimulus S4 was the facial feedback in Task 3, analyzed in a two-factorial design with the factors identity (four levels, see above) and decision (with two levels: accept, reject).

For each of the four stimuli, we quantified the N2 and P3 amplitude for each participant and each condition (see Figure 2.2). The N2 was quantified as the mean amplitude in the interval ±20 ms around the negative peak in time window between 200 and 350 ms at electrode Fz, determined separately for each stimulus (peak latencies for the four stimuli were 248, 248, 328, and 244 ms for S1, S2, S3, and S4, respectively). The P3 was quantified as the mean amplitude in the interval ±20 ms around the positive peak in time window between 400 and 800 ms at electrode Pz, determined separately for each stimulus (peak latencies for the four stimuli were 616, 508, 488, and 588 ms for S1, S2, S3, and S4, respectively).

In addition, we quantified the N170 amplitude for the three facial stimuli S1, S2, and S4, for each participant and each condition. The N170 was quantified as the mean amplitude in the interval ±20 ms around the negative peak in time window between 130 and 210 ms at electrodes TP9 and TP10, determined separately for each stimulus (peak latencies for the four stimuli were 168, 160, and 160 ms for S1, S2, and S4, respectively). The voltage at the two electrodes was subsequently averaged.

The average number of trials per condition for the emotional face in Task 1 (S1) was 46.9 (minimum 36), for the neutral face in Task 3 (S2) 88.5 (minimum 80), and for the presentation of the offer in Task 3 (S3) 14.8 (minimum 10). The situation was more complex for the facial feedback in Task 3 (S4) as the number of trials per condition depended on the decisions made by the participants. Indeed, five participants had fewer than eight trials in at least one of the conditions (because they accepted all or almost all of the offers) and were thus excluded from all analyses involving S4. For the remaining 55 participants, the average number of trials after an offer was accepted was 59.0 (minimum 11), the average number of trials after the rejection of an offer 30.4 (minimum 8). Eight trials have been proposed as the minimum number of trials for quantifying the N2 component, and the same should hold true for larger amplitude components like the N170 and the P3 (Olvet & Hajcak, 2009).

Psychophysiological data were analyzed by repeated measures analyses of variance (ANOVAs) in SPSS software (IBM, Armonk, NY). In case of violation of sphericity-assumption, epsilon (ε; Greenhouse-Geisser correction) and corrected *p* values are reported. For pairwise comparisons, paired *t* tests were conducted. All tests were two-tailed and *p* values $\leq .05$ considered significant. In addition to electrophysiological data, we also analyzed decision making in terms of average acceptance rates using an ANOVA. Brain-behavior relations were analyzed on a trial-by-trial basis using mixed models in SPSS software.

RESULTS

BEHAVIORAL RESULTS

We analyzed decision making with a two-factorial ANOVA with the factors offer size (with six levels, 0 to 5 cents) and identity (with four levels, smiling/neutral, neutral/neutral, neutral/angry, neutral/sad, according to the emotional reaction following accepted/rejected offers). We found a significant effect of offer size (F = 124, p < .001, η_p^2 = .68) indicating that acceptance rates dropped as offers decreased (97%, 95%, 85%, 61%, 40%, and 19%, for offers of 5, 4, 3, 2, 1, and 0 cents, respectively). Additionally, there was a significant effect of identity on acceptance rates (F = 4.7, p = .004, η_p^2 = .07): Offers from smiling identities were accepted more often compared to angry (p = .014) and neutral identities (p = .018, see Figure 2.3). Also, offers from sad identities were accepted more often compared to angry (p = .031) and, tendentially, neutral identities (p = .058). Acceptance rates did not differ significantly between smiling and sad identities as well as between neutral and angry identities (ps > .10).

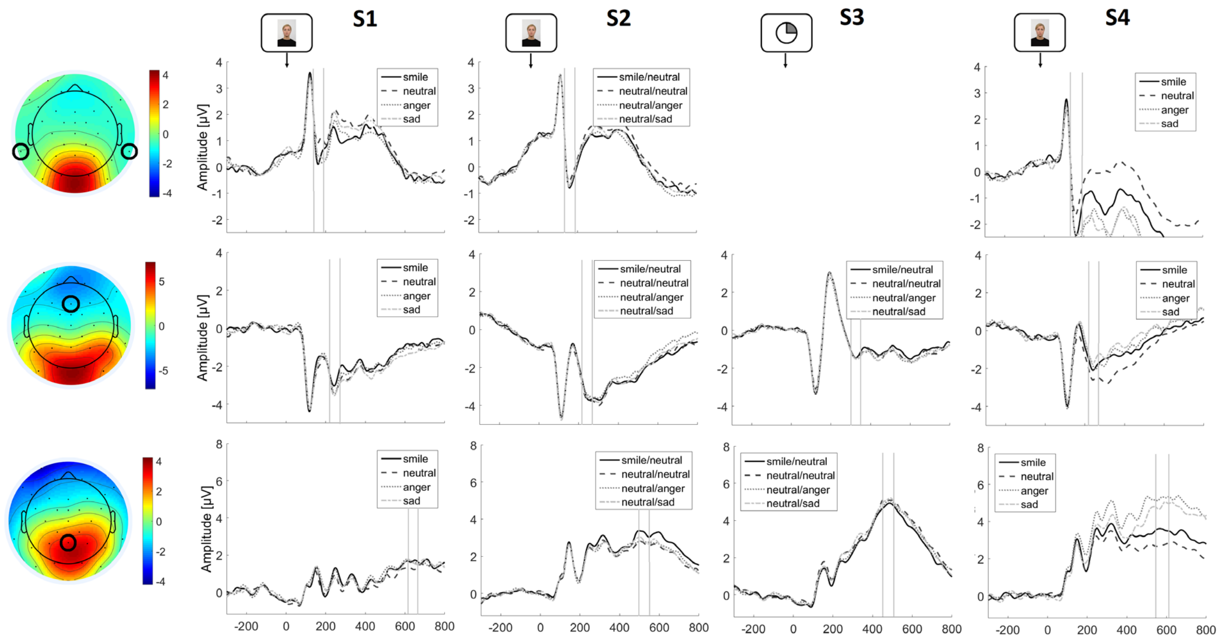

Figure 2.2. Grand averages for the ERPs. The first row contains results averaged across electrodes TP9 and TP10 (relevant for N170), the second row results for electrode Fz (relevant for N2), the third row for electrode Pz (relevant for P3). Each column refers to one of the four stimuli S1 to S4, see Figure 2.1. For S4, the five conditions that present a neutral facial expression were averaged to simplify the presentation. Vertical gray lines indicate the time windows that were quantified for statistical analyses. The topoplots are also based on these time windows, aggregated across stimuli

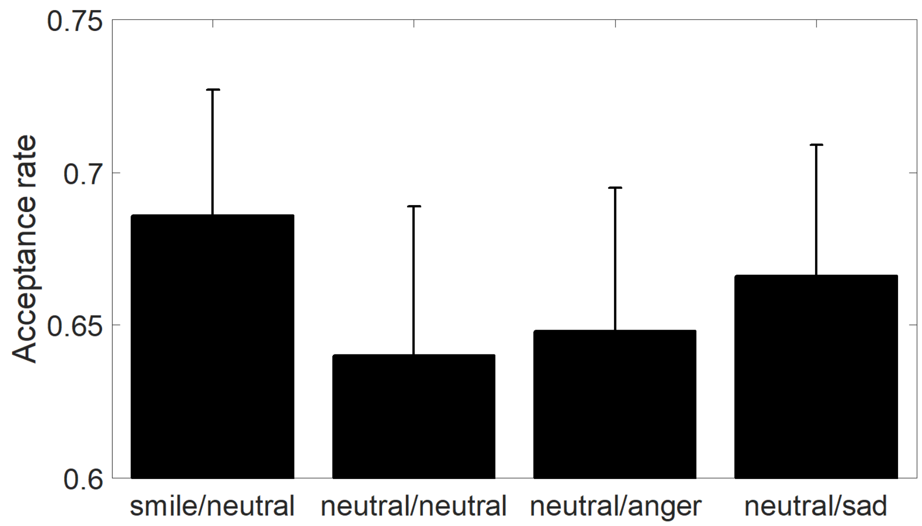

Figure 2.3. Average acceptance rates, depending on the identity of the proposer. Each identity reacted with a characteristic emotional facial expression to accepted versus rejected offers. Error bars indicate standard error of the mean

ELECTROPHYSIOLOGICAL RESULTS

We investigated neural responses following the presentation of stimulus S1 (emotional face in Task 1—mere presentation of the faces) with a one-factorial repeated measures ANOVA with the factor emotional expression (with four levels: smiling, neutral, angry, sad). ERP results can be found in the first column of Figure 2.2. We found a significant effect of emotional expression on N170 amplitude (F = 10.1, p < .001, η_p^2 = .15). Post hoc tests indicated an arousal effect, with lower amplitudes for the neutral compared to all other facial expressions (all ps < .002). No significant differences were found within the three emotional facial expressions of smiling, anger, and sadness (all ps > .17). In addition, results indicated a significant effect of facial expression on N2 amplitudes (F = 4.5, p < .01, η_p^2 = .07). Post hoc tests indicated a valence effect, with more positive (less negative) amplitudes for the smiling compared to all other facial expressions (all ps < .04, see Figure 2.4a). No significant differences were found between the neutral, angry, and sad facial expressions (all ps > .30). Finally, we found no effect of facial expression on P3 amplitudes (F = 1.7, p < .17, η_p^2 = .03).

We investigated neural responses following the presentation of stimulus S2 (neutral face denoting the identity of a proposer in Task 3) with a one-factorial repeated measures ANOVA with the factor identity (with four levels: smiling/ neutral, neutral/neutral, neutral/angry, neutral/sad, according to the emotional reaction following accepted/rejected offers). We found no significant effect of identity of the proposer on N170 amplitude (F = 1.25, p = .294, η_p^2 = .02). As pictures always showed neutral facial expressions, this is in line with results showing that the N170 might reflect stimulus-related processes associated with facial characteristics. There was also no effect of identity on N2 amplitudes (F = 2.5, p = .07, η_p^2 = .04). However, identity had a significant effect on P3 amplitudes (F = 5.1, p < .01, η_p^2 = .08). Post hoc tests indicated that the neutral picture of the smiling identity (proposers reacting with a smile after accepted offers and with a neutral expression after rejected offers) elicited a stronger positive

P3, compared to all other identities (all *p*s < .03, see Figure 2.2, second column, bottom row). None of the other identities differed in P3 amplitude (all *p*s > .13).

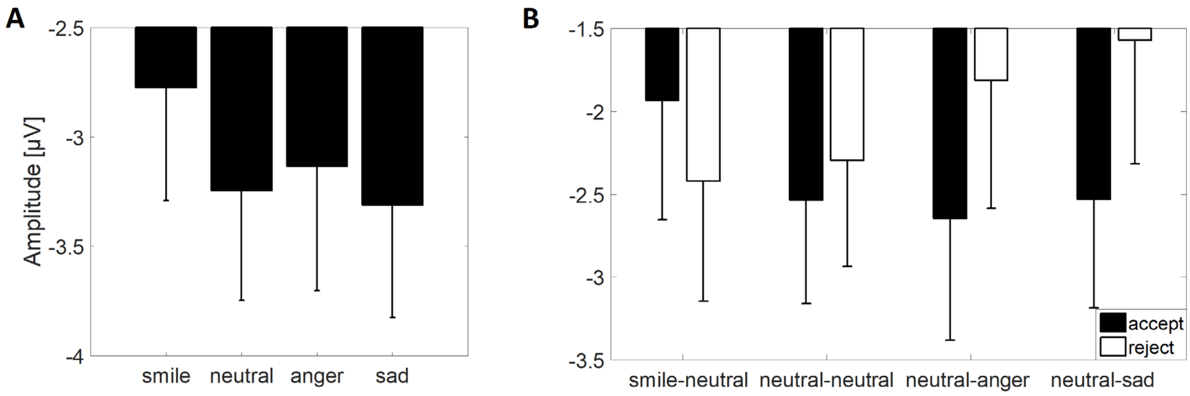

Figure 2.4. (a) Average N2 amplitudes for stimulus S1 (emotional faces in the first task). (b) Average N2 amplitudes for stimulus S4 (according to Task 3, see Figure 2.1). The stimulus consisted of either a neutral or emotional facial expression, depending on the decision of the participant to accept or reject the offer, with each of the four identities reacting with a characteristic pattern (e.g., Identity 1 smiled upon acceptance and reacted neutrally upon rejection). Error bars indicate standard error of the mean

Neural responses following stimulus S3 (presentation of the offer in Task 3) were investigated with a two-factorial repeated measures ANOVA with the factors offer size (with six levels: 0, 1, 2, 3, 4, 5 cents) and identity (with four levels, see above). We found a significant effect of offer size on N2 amplitudes ($F = 4.9, p < .01, \eta_p^2 = .08$). Post hoc tests revealed that unfair offers of 1, 2, and 3 cents elicited a stronger negative deflection, compared to 4, 5, and 0 cents. This might indicate a conflict-related pattern as offers of 4 and 5 cents are virtually always accepted and offers of 0 cents virtually always rejected (see above). Visual inspection of the ERP indicated an additional effect of offer size on the preceding P2 component. Therefore, we also investigated an alternative peak-to-peak measure of the N2 component by subtracting the P2 amplitude (average amplitude ±20 ms around the peak at 200 ms) from N2 amplitudes. We found a large and significant effect of offer size on P2N2 amplitudes ($F = 15.5, p < .001, \eta_p^2 = .20$) reflecting a linear effect of fairness, with the strongest (most negative) P2N2 amplitudes for 0 cents and the weakest (most positive) P2N2 amplitudes for 5 cents. Additionally, we found a large and significant effect of offer size on P3 amplitudes (F = 61.0, p < .001, η_p^2 = .51) indicating a conflict-related process with largest P3 amplitudes for 0 cents and 5 cents and lowest for 3 cents. Importantly, for the three components (N2, P2N2, P3), we found neither a significant main effect of identity nor any interaction between identity and offer size (all ps > .12, see Figure 2.2, third column).

Lastly, we investigated neural responses following stimulus S4 (facial feedback in Task 3) with a two-factorial repeated measures ANOVA with the factors identity (four levels, see above) and decision (with two levels: accept, reject). ERPs can be found in the last column of Figure 2.2. We found a significant effect of identity on N170 amplitudes (F = 6.1, p < .01, η_p^2 = .10) as well as a significant interaction between identity and decision (F = 18.9, p < .001, η_p^2 = .26). Inspection of the means and post hoc tests revealed that emotional facial expressions (the smile of the smiling identity after an offer was accepted as well as the angry and sad facial expression of the angry and sad identities, respectively, after an offer was rejected) elicited a stronger negative deflection compared to neutral facial expressions. Therefore, results for N170 are equivalent to stimulus S1 and reflect the processing of the facial characteristics. For N2 amplitudes, we found a significant main effect of decision (F = 10.8, p < .01, η_p^2 = .17) as well as a significant interaction between identity and decision (F = 9.5, p < .001, η_p^2 = .15). Remarkably, for the N2, results strongly deviated from the emotional facial expressions in Task 1 (S1): For the smiling identity, we found more positive (less negative) N2 amplitudes after accepted (i.e., a smiling facial feedback) compared to rejected (i.e., a neutral facial feedback) offers (p = .05), which is like the results for stimulus S1. However, for the angry and the sad identity, results reversed: In both cases, we found more positive (less negative) N2 amplitudes following rejected (i.e., an angry or sad facial expression) compared to accepted (i.e., a neutral facial expression) offers (ps < .001, see Figure 2.4b). The N2 amplitudes after accepted offers of the smiling identity (i.e., a smiling facial feedback) did not differ significantly from either the N2 amplitudes of rejected offers of the angry identity (i.e., an angry facial expression, p = .60) nor of rejected offers of the sad identity (i.e., a sad facial expression, p = .13). Note that for stimulus S1 (see analysis above), N2 amplitudes for angry and sad facial expressions did not differ from neutral facial expressions and were more negative compared to smiling facial expressions. Finally, we found a significant main effect of identity on P3 amplitudes (F = 23.2, p < .001, η_p^2 = .30), a significant main effect of decision on P3 amplitudes (F = 39.9, p < .001, η_p^2 = .43), as well as a significant interaction between identity and decision (F = 28.7, p < .001, η_p^2 = .35). Post hoc tests revealed that, for the angry and the sad identity, facial feedback after rejected offers (i.e., the emotional face) elicited more positive P3 amplitudes, compared to accepted offers (i.e., the neutral face). No significant differences were found for the smiling and the neutral identity (ps > .34).

BRAIN-BEHAVIOR RELATIONS

We investigated whether the neural response to the neutral picture of the proposer (stimulus S2) would predict subsequent decision making. Therefore, we used a trial-by-trial mixed model for predicting decision making with the two factors offer size (with six levels, 0 cents to 5 cents) and identity (with four levels, as outlined above) and, according to the results reported above, additionally included the z-standardized P3 amplitudes following the presentation of the neutral face of the proposer (stimulus S2). In addition to the main effects for offer size and identity, as reported above, we found a significant interaction between identity and P3 amplitudes. Post hoc tests revealed that stronger P3 amplitudes following the neutral picture of the proposer were associated with larger rejection rates for the neutral identity (coefficient [coef] = -1.2, p < .01), the angry identity (coef = -0.8, p = .03), and the sad identity (coef = -0.8, p = .03), but not for the smiling identity (coef = 0.2, p = .87).

DISCUSSION

Our findings showed that participants will more often accept offers from proposers that smile upon acceptance and less often reject offers from proposers that react sad upon rejection in comparison to a neutral control condition, even though these socio-affective cues are irrelevant for the economic outcome. The rejection of offers has been interpreted as altruistic punishment, that is, an intended negative influence upon the proposer even if it is accompanied by personal costs. The facial emotional feedback stimuli in our experiment allowed us to examine whether altruistic punishment behavior is influenced by the perceived emotional reaction of the partner. Smiling upon acceptance and sadness upon rejection signals successful altruistic punishment and led to higher acceptance rates, compared to neutral facial expressions irrespective of the decision of the participant. For example, the sad face of a partner following rejection might be interpreted as sorrow and thus a signal that the punishment was understood, and future behavior might be adjusted. Interestingly, we found no difference between the angry identity and the neutral identity. It might be speculated that the angry face following rejection of an offer was interpreted as a signal of confrontation and nonapproval in terms of not caring about the punishment and pursuing unfair behavior in the future. Thus, further punishment in upcoming interactions would be necessary and in line with the higher rejection rates.

Concerning the neurophysiological underpinnings of these behavioral effects, our data indicate that early face processing as indicated by N170 is not directly involved. As expected, N170 was unaffected, showing only an arousal effect. In contrast, later processes seem to be rather important. While the P3, signaling the subjective importance and motivational significance of an event, was virtually absent when participants simply viewed emotional stimuli in Task 1, larger P3 amplitudes were observed following the neutral stimuli indicating the identity of the proposer in Task 3, especially for smiling identity, compared to all other identities, which might be interpreted as a motivational indicator to engage in the upcoming bargaining interaction. The pattern was different for the emotional facial expression following the decision in Task 3. The larger P3 amplitudes for the sad and angry identity might indicate the subjective importance of a desired outcome after rejection (i.e., actual punishment). The smiling face, on the other hand, which also signals the desired output (see the N2 effect), follows acceptance of an offer and is, thus, not punishment.

Moreover, our brain-behavior analysis provides a direct link to the neural mechanisms. The degree of subjective awareness and importance as indicated by the P3 in response to the neutral faces of each type of identity seems to play a major role here. The larger P3 may reflect the stronger recognition of an identity (as these identities had to be first learned across the experiment) and may thereby drive the lower acceptance rate for negative and neutral identities. This is in line with the interpretation that participants do reject offers of the negative identities intentionally.

The mere presentation of emotional faces modulated N2 amplitudes, indicating that smiling compared to neutral, sad, and angry faces might be inherently rewarding. Strikingly, in the context of the game, the pattern for angry and sad faces reversed (i.e., elicited more positive ERP response in the N2 range. This may be interpreted as a reward positivity (Holroyd & Coles, 2002; Holroyd et al., 2008) and shows that the negative emotional facial expressions are the desired and intended outcome in terms of successful altruistic punishment (De Quervain et al., 2004; Fehr & Gächter, 2002; Hewig et al., 2007; Strobel et al., 2011). These results are in line with studies showing a reward positivity when another person followed advice (i.e., the social interaction partner showed the intended behavior; Hewig et al., 2008).

We briefly note some of the limitations of the present study. First, a larger sample size would have allowed for investigating smaller population effects. Second, the social affective feedback cues were deterministically connected with the decision of the receiver; thus, effects of the decision and effects of the social affective cues were confounded and could not be investigated separately. Third, we used a repeated measures design to increase statistical power and randomized the order of conditions to account for order effects; spillover effects could be ruled out by repeating the study using a between-subjects design.

In summary, our study extended the bargaining situation in the ultimatum game by adding an additional component of the interaction process, namely, an emotional response of the proposer indicating whether punishment was successful or not. We showed that the pattern of these responses influenced future decisions. Results from electrophysiological measures suggest that altruistic punishment is an intentional behavior that can be rewarding and that can motivate future altruistic punishment behavior.

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IMPLICATIONS FOR STUDY 2

The first study examined the influence of emotional faces on social decision-making in an economic bargaining situation. Emotional feedback changed the acceptance behavior of the participants, although it was irrelevant for the monetary outcome. Therefore, affective responses to monetary decisions influence a person's future behavior. At the neuronal level, successful altruistic punishment was indicated by reward positivity after negative emotional feedback. The second study investigated a similar paradigm with reduced offer sizes and artificial emojis instead of real faces. To reduce the complexity of these novel stimuli in scientific research, we have used very basic emojis. Since emojis are often used in popular mobile messaging services, we wanted to investigate whether these face-like stimuli produce the same behavioral and neuronal responses as human faces. Therefore, we used the same paradigm as in the first study. Since emojis do not differ in gender, we changed the interleaved trial presentation to a block-wise design to create continuous interaction with each identity.

DO EMOJIS INFLUENCE SOCIAL INTERACTIONS? NEURAL AND BEHAVIORAL RESPONSES TO AFFECTIVE EMOJIS IN BARGAINING SITUATIONS

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ABSTRACT

Emojis are nowadays a common substitute for real facial expressions to integrate emotions in social interaction. In certain contexts, emojis possibly could also transport information beyond emotions, reflecting interindividual differences or social aspects. In this study, we investigated the influence of emojis as socioemotional feedback stimuli on behavior and neural responses in a social decision game. We modified the Ultimatum Game by including emotional feedback provided by the proposer as response to the decision of the participant as receiver. Therefore, we generated identities that differed in their feedback behavior to identify differences in the processing of emotional feedback in a positive (acceptance) versus negative (rejection) frame. Regarding offer sizes, we replicated the valence effect of feedback-related negativity for small offer sizes evoking more negative brain potentials compared to larger ones. Further, we found an effect of affective emojis on distinct ERPs: A face-detecting neural component (N170) was examined to be a part of the processing of emojis, which resulted in significantly more negative amplitudes in response to a sad-looking emoji compared to smiling and neutral ones. Furthermore, P3 amplitudes indicate transmission effects from the feedback emoticons to the neural processing of different offer sizes. In contrast to previous findings, P3 responses of our subjects did not depend on the offer size, but rather by which kind of partner they were made. Since some evaluative processes did not reveal any effects, emojis seem to be less effective than real facial expressions, which convey more information that is socially meaningful.

INTRODUCTION

Facial expressions are a relevant aspect of human social interactions since they convey information about one's emotional state (Ekman, 1993). They act as a tool of social signaling, presenting cues about intentions. Subsequently, facial expressions play a fundamental role in building trust and reciprocal behavior (Eckel & Wilson, 1998). In consequence, the information our faces contain affect the social interaction itself (Ekman et al., 2013) and decisions that result from these interactions. Thus, to interact socially with other human beings, it is important to interpret facial expressions correctly (Nachson, 1995), and facial expressions are one among many ways how humans exert social influence upon each other (e.g., Cialdini & Goldstein, 2004; Hareli & Rafaeli, 2008; Muchnik, Aral, & Taylor, 2013; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008).

The current digital era, in which people constantly use messaging services that at least partially replace face-to-face communication, has led to an excessive use of emoticons (Comesaña et al., 2013). Emoticons are the very basic idea of expressing an emotion by simple keyboard characters, whereas emojis are the illustrated version of emoticons. A fundamental function of emoticons is to facilitate nonverbal communication and to put emphasis on one's message (Derks, Bos, & von Grumbkow, 2008). There is evidence that emoticons can activate the face-detective fusiform face area in the brain (Yuasa, Saito, & Mukawa, 2011a). Additionally, it has been shown that pictographic emoticons activate regions of the brain related to affect (i.e., the right inferior frontal gyrus, Nakamura et al., 1999) rather than nonaffective face processing areas (e.g., in the right fusiform gyrus, Kanwisher et al., 1997). Accordingly, the current study used happy, neutral, and sad emojis as substitute for real faces to induce emotional feedback.

To investigate the influence of emojis as socioaffective cues that might influence social interaction and subsequent decision making, we used a modified Ultimatum Game (UG), where emojis served as a feedback stimulus of the proposer similarly to Mussel, Hewig, and Weiß

(2018), who evaluated impacts of photographs of real faces used as feedback. The classic UG (Güth et al., 1982) is a one-shot two-player game measuring economic behavior. In its original setup, one party is acting as a "proposer" and another as a "responder." The proposer must divide a certain amount of money (often operationalized with 10 cents) to share with the responder. It is up to the responder to accept or reject the offered amount of money. If the responder accepts, the money will be split according to the offer; if he or she rejects, then neither will gain anything. Consequently, offering 5 cents out of 10 would be considered as a fair offer, whereas 0 or 1 cent would be unfair. Rational choice theory (Von Neumann & Morgenstern, 1944) suggests that a rational proposer would offer the smallest possible amount to maximize his gains and a rational responder would accept any offer, since obtaining any money is better than gaining no money at all. However, empirical data show that offers below 20% of the money are rejected in 50% of all cases; however, proposers usually offer 40%–45% of the money to the responder (Levine, 1998). Mussel et al. (2018) used a modified UG with different identities who reacted with a distinct pattern toward participants' acceptance and rejection of UG offers. After a participant accepted or rejected an offer, subjects received facial feedback in the form of an emotional facial expression. On a behavioral level, the systematic variation of facial emotional feedback toward acceptance or rejection of an offer influenced decision making in the task. Offers coming from identities that smiled upon acceptance or looked sad upon rejection were accepted more often compared to those showing neutral facial expressions. In addition, the ERPs were examined. In particular, first, to analyze face processing the N170 (Eimer, 2000; Rossion et al., 2000) was examined; second, evaluative processing was investigated using feedback-related negativity (FRN; Miltner et al., 1997) and reward positivity (Holroyd & Coles, 2002; Holroyd et al., 2008); and, finally, P3 reflecting attentional processing and subjective importance (Johnson, 1988; Nieuwenhuis, Aston-Jones, & Cohen, 2005; Polich, 2007) was examined. ERPs to the facial stimuli showed increased N170 for emotional faces and higher P3 amplitudes for angry and sad faces compared to neutral faces, indicating altered face processing. Furthermore, amplitudes in the N2 time range were more negative for acceptance feedback (neutral facial expression) compared to angry and sad expressions that followed the rejection of an offer. This means that people are willing to punish their interaction partners at their own expense, which is called altruistic punishment. In conclusion, P3 was higher for subjectively important emotional expressions, since smiling, sad, and angry facial expressions were presumably intended outcomes. Finally, amplitudes in the N2 time range likely reflect the desired facial feedback outcome since negative emotional faces elicited more positive amplitudes indicating reward positivity during the task in contrast to more negative amplitudes during mere presentation of faces outside the task.

In the current study, we aim to examine the effects of socioaffective feedback on neural processing in that same experimental context, however, using emojis rather than pictures of real facial expressions. To investigate underlying neural processes, we first examined the N170 component, which is known to reflect basic face processing (Eimer, 2000). According to Churches et al. (2014), emoticons equally evoke the N170 as faces do, when they are not inverted or rotated. There is further evidence that emotional facial expressions can modulate the N170 amplitude. For example, fearful faces elicited higher N170 amplitudes than neutral or surprised faces (Batty & Taylor, 2003; Blau et al., 2007). A meta-analysis by Hinojosa et al. (2015) revealed higher N170 amplitudes for facial expressions of fear, anger, and happiness over neutral facial expressions. Next, the N2/reward positivity or FRN as indicator for the processing of evaluative positive and negative feedback (Holroyd et al., 2008; Miltner et al., 1997) was examined. The FRN has already been examined during the UG in several studies. Unfair offers elicited more negative amplitudes at frontocentral sites than fairer offers (e.g., Hewig et al., 2011; Polezzi et al., 2008). This effect was even stronger when participants had higher fairness concerns (Boksem & De Cremer, 2010) or showed higher trait or state negative affect (Riepl et al., 2016). The impact of facial expressions of proposers has also been the objective of some studies. When the offer was made by a proposer with an attractive face, which was shown as a photograph right before the offer, receivers accepted more offers and showed lower FRN amplitudes for unfair offers compared to offers made by unattractive proposers (Ma et al., 2015). When the offer was coupled with a preceding photograph of a smiling face, unfair offers were more often accepted and evoked smaller FRN amplitudes than offers coupled with nonsmiling faces (Mussel et al., 2014). Mussel et al. (2018) showed that emotional faces presented after the bargaining decision had impacts on subjects' behavior and neural activity as well. These stimuli served as feedback for the decision making of the subjects as in the present study.

Recent research considered the FRN to be an absence of a reward positivity (Rew-P), rather than a negative deflection elicited by losses. Holroyd et al. (2008) suspected the FRN to be the same component as the N200, an ERP that is elicited by rare stimuli or visual novelty and attended mismatch from a visual template (for review, see Folstein & Van Petten, 2008). The authors suggested that negative feedback, in fact, elicits a normal N200. According to their theory, FRN modulation is caused by positivity, following positive feedback or events that are better than expected—which is a positive temporal difference error in mathematical descriptions of reinforcement learning theory (Holroyd & Coles, 2002; Holroyd et al., 2008; Miltner et al., 1997; Sutton & Barto, 1998).

Further, P2 amplitudes that precede N200 have also been repeatedly linked to decision making in bargaining contexts as demonstrated by Potts, Martin, Burton, and Montague (2006) and San Martín, Manes, Hurtado, Isla, and Ibañez (2010), who found larger P2 amplitudes for favorable in comparison to unfavorable outcomes. Additionally, Osinsky, Mussel, and Hewig (2012) showed that P2 amplitudes increase with the number of wins and losses in two preceding trials, which was true for current trials with both wins and losses, indicating a role of P2 in the recent local outcome history potentially representing reward expectations for a current trial based on previous trial outcomes. This demonstrates that P2 must be taken into account when analyzing FRN.

Another considerable aspect of P2 amplitudes is their relatedness to attention and attention sensitivity. Whereas Luck and Hillyard (1994) initially found P2 to be sensitive to early attentional and perceptual resources, Peterburs et al. (2017) linked the P2 component to attention toward unexpected or improbable stimuli. Recently, Amodio (2010) associated the P2 component to stimuli that are relevant for the perceiver's current goals. Hence, the motivational salience of a certain stimulus, as a top-down process, indicates potential importance for an individual based on potential rewards, goals, and task demands (Itti & Koch, 2001; Navalpakkam & Itti, 2005).

Finally, the P3 component was analyzed to give additional insight in both attentional processes and subjective importance (Donchin & Cohen, 1967; Ito et al., 1998; Johnson & Donchin, 1985) regarding both offer size and emotional feedback. Concerning UGs, fair offers also elicited higher P3 amplitudes than unfair offers (Qu, Wang, & Huang, 2013; Wu et al., 2012). This effect was modulated by the attractiveness of the proposer: an unfair offer made by an attractive proposer showed no difference regarding the P300 amplitude compared to a fair offer. When the proposer was unattractive, fair offers evoked a higher amplitude than unfair ones (Ma et al., 2015), and thus faces seem to affect P300 in a relevant way in the present study.

We expected that emojis would elicit N170 brain potentials as faces do while being processed. This is essential in order to assume that our emojis worked as an equivalent to real faces in photographs. We anticipated N170 being greater for emotional feedback stimuli compared to neutral ones, since emotional expressions would carry more information. As outlined above, N2 and FRN after both offer and faces should indicate a response worse or better than expected. Hence, the ERP should be more negative after low offer sizes and more positive after higher offers and positive facial feedback (smile). Further, we expected sad faces after low offer sizes and negative facial feedback to elicit more positive amplitudes than neutral faces, indicating some sort of reward of a desired outcome in terms of altruistic punishment. P3 amplitudes should provide insight in differences between positive and negative emotional stimuli as compared to neutral stimuli. Therefore, we expected sad and happy emojis to elicit higher amplitudes than neutral emojis, indicating some sort of subjective importance of a desired outcome in terms of altruistic punishment. To our knowledge, this is the first study in which interactions with emoticons in an economic context were examined on a behavioral and neural level.

METHOD

ETHICAL STATEMENT

The study was carried out in accordance with the recommendations of Ethical Guidelines, The Association of German Professional Psychologists (Berufsethische Richtlinien, Berufsverband Deutscher Psychologinnen und Psychologen). All subjects gave written informed consent in accordance with the Declaration of Helsinki before they participated in the experiment. During the experiment, a cover story was used, but they were told about this deception as soon as the task was over, as is common practice in psychological experiments.

PARTICIPANTS

Sixty subjects (31 psychology students; 34 female; mean age =25.03 years, *SD* =7.59 years, range 18–59 years) participated for monetary compensation and an optional additional course credit. In the beginning, they were told that they would play against human opponents and that they would receive the amount of money that they would have gained from the following game. As they played against the computer (see below), they finally received a fixed payout of 10 Euro (which was slightly more than the highest achievable payout in the UG) with the purpose of keeping frustration about the deception as low as possible. All participants gave written consent after receiving verbal and written instructions.

TASK AND PROCEDURE

Subjects were told that they were randomly assessed as the responder in the UG playing online against five other human participants, acting as proposers who could offer them up to 10 cents in each trial. We designed a mock-up online interaction and told the participants they would be randomly assigned to a bargaining partner. Finally, we implemented a modified UG including different emotional reactions of proposers, which were contingent on the bargaining decision made by the participant. We divided the task into five blocks, in which our subjects faced only one distinct proposer for the whole block. Hence, no indicating stimulus was needed as receivers always saw on the top of the screen against whom they played, indicated by a player number. The proposers, henceforth known as identities, were defined according to their characteristic response pattern to accepted and rejected offers. Identity 1, the smiling identity, gave feedback with a neutral emoji following rejection and a happy emoji following acceptance. Identity 2, as the control identity, sent a neutral emoji following each behavior, and Identity 3, the frowning one, reacted with a neutral emoji following acceptance and a sad emoji following rejection. Importantly, the identities differed only in feedback behavior, not in offer behavior. The identities of the players where unknown to the subjects, and the sequence of the players was counterbalanced. Whereas Player 1, 2, and 3 offered each 1 cent, 3 cents, and 5 cents in randomized order, Player 4 and 5 acted depending on the participant's behavior.

To each participant, the offer of the proposer was presented in the form of a pie chart, with the part they could gain marked in green and the proposer's portion characterized in black. After pressing the left arrow key to accept, participants were shown their earned amount of money. If they pressed the right arrow key to reject the offer, they were shown that no money was split. Subsequently, either the sad, neutral, or the happy feedback emoji was presented. All subjects played the UG repeatedly in a series of 330 single trials (66 for each identity) as a receiver (see Figure 3.1). At the end of the experiment, all participants rated the emojis according to their valence and arousal so that we could check our manipulation.

To enhance the plausibility of the paradigm, we included two additional identities who reacted both with a smiling emoji following acceptance and with a frowning emoji following rejection. We assumed that the random behavior of the first three identities could be suspicious and therefore let these additional identities adapt to the participants' behavior. This was important since there is evidence that participants behave differently when interacting with a computer compared to a human being (Melo, Marsella, & Gratch, 2016). Further, we inserted these filler identities in between the other three identities. Hence, for our analyses, only the first three identities are of interest.

We used a 24" screen for this study. Stimuli were presented, and behavioral data were recorded by PsychoPy 1.84.2 (Peirce, 2007). Subjects were seated in a comfortable chair with a distance of about 70 cm to the screen. The pie charts of the offers and the feedback emojis had a diameter of 7 cm. This resulted in a visual angle of 5.72°.

In this experiment, data regarding personality traits were collected but will not be investigated further in this study.

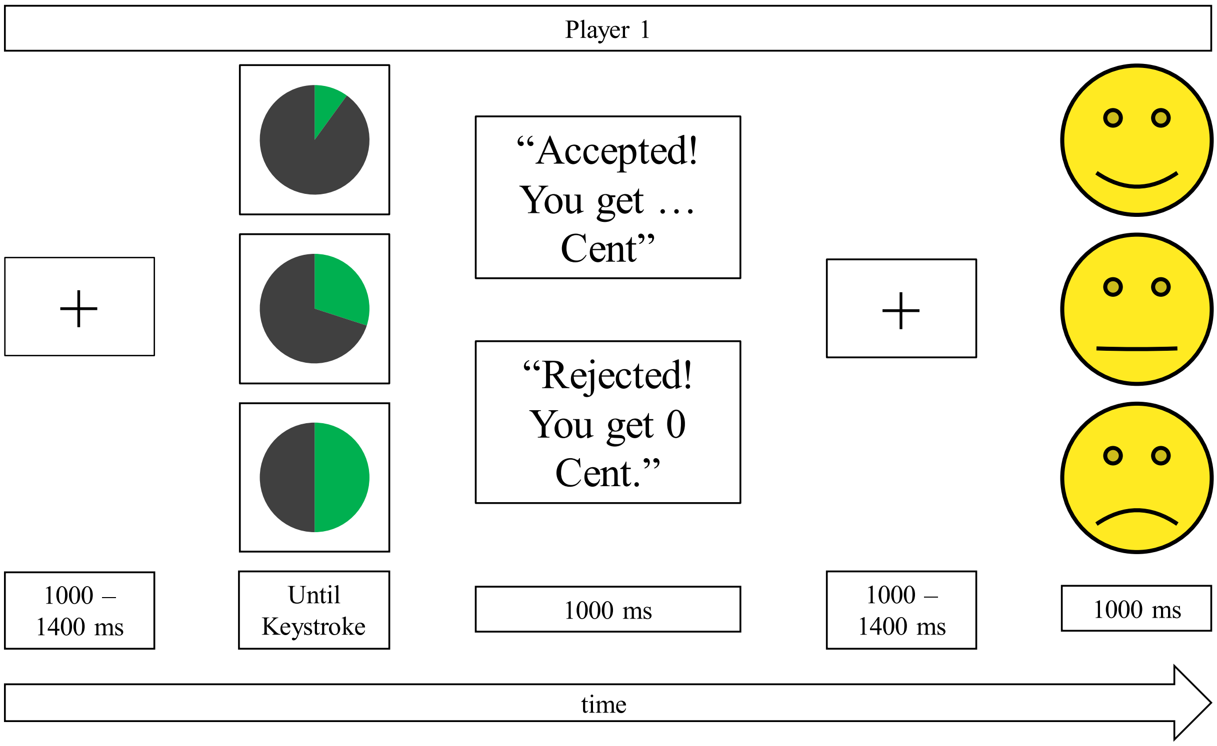

Figure 3.1. Task timeline for this paradigm: Each trial began with a fixation cross (duration 1,000–1,400 ms), followed by the offer (until participants pressed a key). Green part of the pie chart represented the amount of money the receiver could win. Participants had to decide whether to accept or reject the offer while the offer was displayed. Subsequently, a fixation cross was displayed (duration 1,000–1,400 ms). After the decision, feedback was given via emojis regarding the decision made by the responder (1,000 ms). The proposer's identity (Player 1 to 5) was always presented on the top

EEG RECORDING AND QUANTIFICATION

The EEG was measured by Ag/AgCl electrodes located in an electrode cap in 32 scalp positions according to the International 10–20 system: FP1, FP2, Fz, FCz, F3, F4, F7, F8, F9, F10, FC1, FC2, FC5, FC6, CZ, C3, C4, T7, T8, CP1, CP2, TP9, TP10, P3, P4, P7, P8, P09, PO10, O1, O2. An additional electrode to register eye movements and blinks, called electrooculography (EOG), was put below the left eye. All electrode impedances were kept below 5 kOhm for the EEG, and data were referenced online to the vertex (Cz). Data were recorded with a sampling rate of 250 Hz and a high cutoff filter of 80 Hz with BrainVision BrainAMP Standard (Brain Products GmbH, Gilching, Germany) and the respective BrainVision Recorder software. For processing our collected EEG data, we used MATLAB (MathWorks, Natick, MA) and the toolbox EEGLAB (Delorme & Makeig, 2004) version 13.3. Initially, we detected inappropriate channels for each participant and interpolated them. We segmented epochs from −500 ms to 1,000 ms around our target markers (offers and emojis). For baseline correction, we assessed a window of −200 ms to 0 ms. Regarding artifact rejection, we used the criterion of z value>4 for the amplitude and kurtosis of the signal. Before applying independent component analysis (ICA) according to Delorme, Sejnowski, and Makeig (2007), we used a band-pass filter from 0 to 40 Hz. Afterward, we used the EEGLAB extensions ADJUST (Mognon, Jovicich, Bruzzone, & Buiatti, 2011) and MARA (Winkler, Haufe, & Tangermann, 2011), which work with SASICA software (Chaumon, Bishop, & Busch, 2015) to choose ICA components for artifact rejection and handling eye artifacts, loose electrodes, and discontinuities in the signal. Finally, offline reference was transformed to current source density, and data were filtered with a 20 Hz low-pass filter. Statistical calculations were executed individually per stimulus averaged ± 20 ms around the positive respective negative peak in the following time windows. N170 was quantified from 130 to 210 ms pooled at P7 and P8, P2 was calculated from 170 to 230 ms at Fz, and for N2 from 250 to 350 ms at the same electrode position. Furthermore, we also investigated an alternative peak-to-peak measure for the FRN component as in several other studies (Holroyd et al., 2003; Mussel et al., 2018; Osinsky et al., 2012; Yeung & Sanfey, 2004), since a simple amplitude difference between favorable and unfavorable feedback in a certain time window overlaps with both P2 and P3 (Foti et al., 2011; Yeung, Holroyd, & Cohen, 2005). Hence, we quantified FRN in the same manner as the difference between the mean amplitudes around the negative (N2) and preceding positive (P2) peak according to the aforementioned time windows. Finally, a P3 component was calculated between 350 and 500 ms at Pz.

STATISTICAL DESIGN

Data were analyzed using repeated measures analyses of variance (ANOVAs) in SPSS software (IBM, Armonk, NY). For all ANOVAs reported in the following paragraph, we assumed α =

0.05, and for every test, we applied Mauchly's test of sphericity. If this test would yield $p \leq 0.05$, we corrected the degrees of freedom. In these cases, Hyunh-Feldt adjustment factors for degrees of freedom were used, apart from when $\varepsilon < 0.75$. Then, we adjusted the degrees of freedom according to Greenhouse-Geisser. The adjustment factors are reported if sphericity was violated. In case we found a statistically significant result for any ANOVA, we computed Bonferroni - adjusted pairwise comparisons for further investigation of the effect.

The manipulation check was investigated with a one-factorial ANOVA with the factor emoji (smiling, neutral looking, frowning). As the experiment with 330 trials could convey habituation effects, we included the half of the experiment (first vs. second) as a factor in the behavioral and neural analysis. Behavioral results in terms of acceptance rates were analyzed with a three-factorial repeated measures ANOVA with a factor offer size (three levels: 1, 3, 5 cents) and identity (three levels: smiling, control, frowning). To investigate whether our subjects showed effects of exhaustion, taking into account that our design contained many trials (66 per block), we split each block in half and added it as the factor half of the block to our calculations (two levels: first, second half).

Neural responses following the presentation of an offer were investigated with a three-factorial repeated measures ANOVA with the factors offer size (with three levels: 1, 3, 5 cents), identity (three levels: smiling, control, frowning), and half of the block (two levels: first, second half). N170 responses following the presentation of an emoji were investigated with a three-factorial repeated measures ANOVA with the factors emotion (three levels: happy, neutral, sad), hemisphere (two factors: left, right), and half of the block (two factors: first, second half). For the analyses of emotional feedback for components N2, P2, FRN, and P3, we used a three-factorial repeated measures ANOVA with the factors identity (three levels: smiling, control, frowning), decision (two levels: acceptance, rejection) and half of the block (two levels: first, second half).

RESULTS

MANIPULATION CHECK

The happy emoji was rated significantly more positive compared to the neutral or the sad one, and the neutral emoji was rated more positively than the sad emoji, $F(2, 116) = 321.66$, $p < 0.001$, $\eta_p^2 = 0.847$, $\varepsilon = 0.840$; all Bonferroni-corrected pairwise comparisons showed $p < 0.001$. However, participants tended to rate the neutral emoji slightly negative ($M = 3.05$, $SD = 0.88$) compared to the neutral value on our rating scale, which was 4 (on a Likert scale from 1 to 7). This deviation was tested with a *t* test and showed significant results, $t(58) = -8.29$, $p < 0.001$. Ratings regarding arousal depended on the emotional valence of the stimulus as well, $F(2, 118) = 3.58$ $p = 0.031$, $\eta_p^2 = 0.057$. Bonferroni-corrected pairwise comparisons showed that the sad emoji was rated higher in arousal compared to neutral ones ($p = 0.040$). Both happy versus neutral emojis ($p = 0.135$) and happy versus sad ($p = 1$) did not differ significantly from each other.

BEHAVIORAL RESULTS

Results showed that the interaction of half and offer provided a significant result, $F(2, 118) = 4.19$, $p = 0.018$, $\eta_p^2 = 0.066$, $\varepsilon = 0.926$. Post hoc comparisons showed that for 3 cents acceptance rates were higher in the second half of the experiment compared to the first ($p = 0.001$), whereas comparisons of task halves for 1 cent ($p = 0.430$) and 5 cents ($p = 0.126$) were not significant. The main effect regarding acceptance rates for the offers, $F(2, 118) = 225.22$, $p < 0.001$, $\eta_p^2 = 0.792$, indicated that rates decreased from 95.71% (SD =8.91%) for 5 cents to 3 cents with 68.01% (SD =27.88%) to 1 cent with 21.57% (SD 25.66%). The half of the block also had a significant effect, $F(1, 59) = 11.77$, $p = 0.001$, $\eta_p^2 = 0.166$, with offers in the second half being accepted more often than in the first. However, the proposer's identity had no significant effect on the acceptance rates, $F(2, 118) = 0.15$, $p = 0.864$, as displayed in Figure 3.2. All other interactions did not reach significance (all values of $p \geq 0.418$).

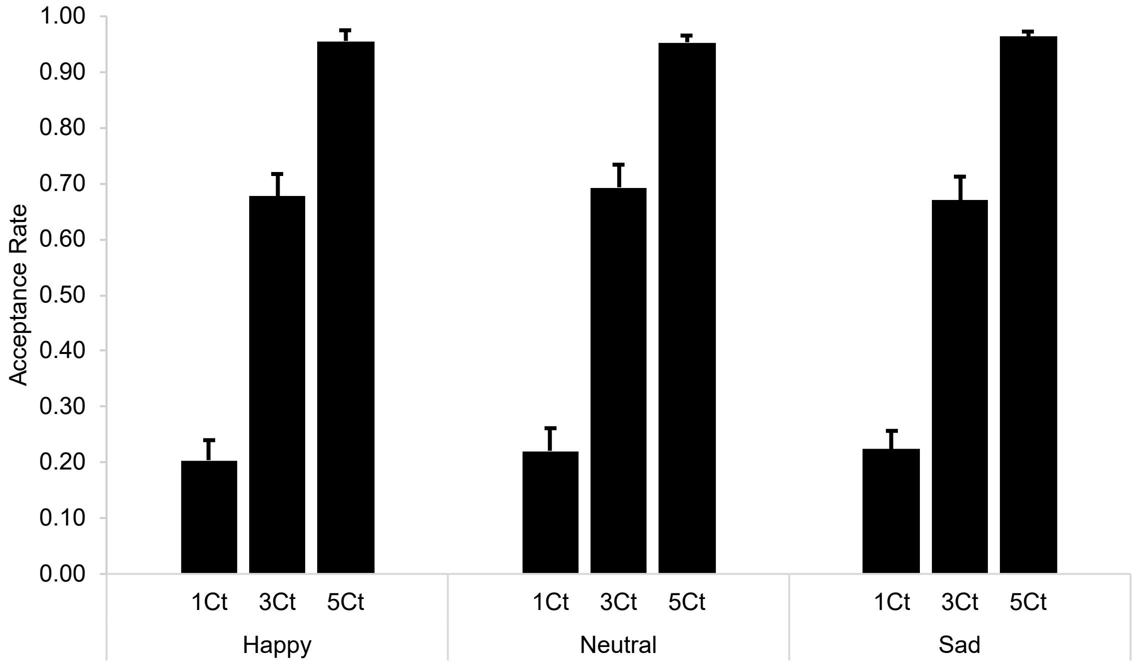

Figure 3.2. Average acceptance rates, depending on the identity of the proposer and the different offer sizes. Each of these identities reacted with a distinct emotional expression to accepted versus rejected offers. Error bars indicate standard error of the mean

ELECTROPHYSIOLOGICAL RESULTS

We investigated neural responses following the presentation of offers and feedback emojis. ERP results for N170 toward feedback emojis for FRN regarding offers and for P3 regarding feedback emojis are displayed as grand averages in Figure 3.3[1].

OFFERS

P2 amplitudes showed only a significant effect for the half of the block, $F(1, 58) = 7.64$, $p = 0.008$, $\eta_p^2 = 0.117$, with amplitudes being more positive in the first half compared to the second.

[1] We also investigated some explorative analyses covering effects of sex and an analysis based on difference signals. These results are outlined in the online supporting information and show slightly different results compared to the three-factorial ANOVA approach.

For identity, $F(2, 116) = 0.63$, $p = 0.531$, offer, $F(2, 116) = 0.60$, $p = 0.548$, and all possible interactions (all values of $p \geq 0.130$), no significant effects occurred.

For N2, the interaction of identity and half of the block showed a significant effect, $F(2, 116) = 8.27$, $p < 0.001$, $\eta_p^2 = 0.125$. Post hoc analyses proved that for the smiling identity N2 amplitudes were more negative in the second half ($p = 0.018$) compared to the first, and for the frowning identity N2 amplitudes were more negative in the first half ($p = 0.012$) compared to the second. For the control identity, no difference could be found ($p = 0.324$). Next, we found a significant difference regarding identity, $F(2, 116) = 4.55$, $p = 0.012$, $\eta_p^2 = 0.073$. Post hoc comparisons showed that the amplitudes were more negative for the control identity compared to the frowning ($p = 0.027$). The smiling identity did not deviate from both the control ($p = 1$) and the frowning one ($p = 0.074$). Further, an unspecific marginally significant effect was found for offer, $F(2, 116) = 3.05$, $p = 0.051$, $\eta_p^2 = 0.050$, where post hoc comparisons did not show any differences (all values of $p \geq 0.106$). Task half, $F(1, 58) = 0.261$, $p = 0.609$, and all other interactions (all values of $p \geq 0.531$) were not significant.

The peak-to-peak calculated FRN amplitudes revealed a significant main effect for identity, $F(2, 116) = 5.26$, $p = 0.006$, $\eta_p^2 = 0.083$. The post hoc comparisons showed that for the frowning identity FRN amplitudes were more positive compared to the control identity ($p = 0.013$), whereas no difference was found for the smiling identity compared to the control ($p = 1$) and the smiling compared to the frowning ($p = 0.078$). Further, there was a significant effect for offer size, $F(2, 116) = 4.02$, $p = 0.020$, $\eta_p^2 = 0.065$. Post hoc comparisons showed that 1 cent elicited more negative amplitudes compared to both 3 cents ($p = 0.048$) and 5 cents ($p = 0.049$), which is displayed in Figure 3.4. In contrast, 3 cents and 5 cents were not different ($p = 1$). However, half of the block, $F(1, 58) = 0.08$, $p = 0.774$, and the interactions did not provide a significant result (all values of $p \geq 0.053$).

P3 amplitudes revealed a significant main effect for identity, $F(2, 116) = 8.12$, $p < 0.001$, $\eta_p^2 = 0.123$, but not for offer, $F(2, 116) = 2.092$, $p = 0.127$, and the half of the experiment, $F(1, 58) = 1.07$, $p = 0.304$. Post hoc comparisons showed that the frowning compared to the smiling identity ($p = 0.001$) elicited larger P3 amplitudes. The frowning identity compared to the control ($p = 0.222$) and the smiling compared to the control ($p = 0.061$) did not differ regarding their P3 amplitudes. Analyzing the interactions again showed no significant results (all values of $p \geq 0.382$).

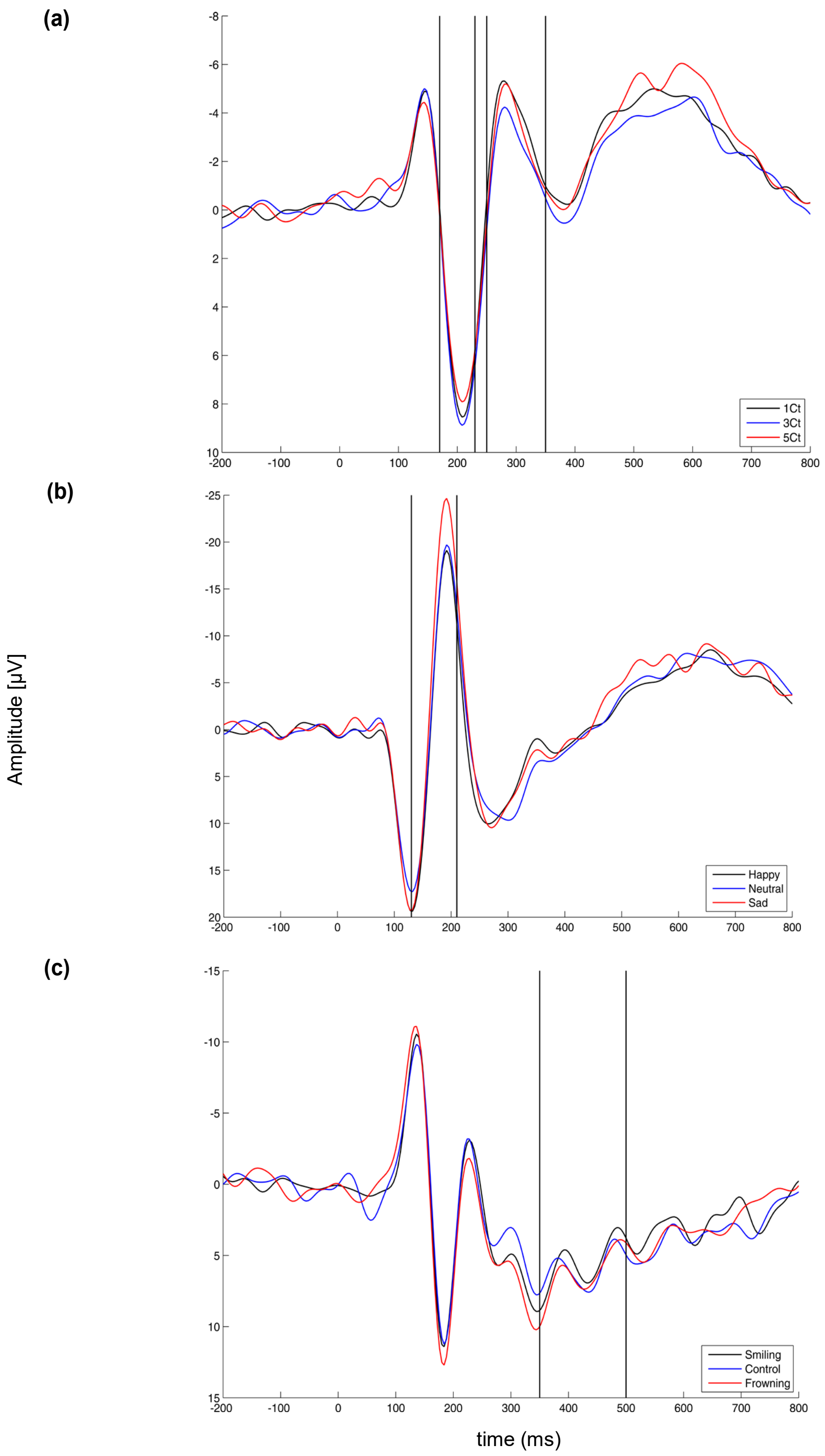

Figure 3.3. (a) Grand averages at electrode Fz for FRN results regarding offers, which are displayed for the three offer sizes: 1 cent, 3 cents, and 5 cents. (b) Grand-averaged amplitudes for the N170 results to emojis pooled at electrodes P7 and P8. We aggregated N170 for happy, neutral, and sad facial expressions. (c) Grand averages of P3 at electrode Pz for the three different identities: smiling, control, and frowning

EMOTIONAL FEEDBACK

The analysis of N170 amplitudes showed a significant main effect for emotion, $F(2, 114) = 7.35$, $p = 0.003$, $\eta_p^2 = 0.114$, $\varepsilon = 0.747$. The sad emoji evoked significantly more negative amplitudes compared to both the happy ($p = 0.026$) and the neutral emoji ($p = 0.009$) whereas happy and neutral emojis did not differ ($p = 1$), as illustrated in Figure 3.5. The interaction of half of the block and hemisphere was also significant, $F(1, 57) = 31.59$, $p < 0.001$, $\eta_p^2 = 0.357$. Post hoc comparisons showed that for both the left hemisphere ($p = 0.007$) and the right hemisphere ($p < 0.001$) the first half evoked more negative amplitudes compared to the second half. The main effect of hemispheric lateralization, $F(1, 57) = 18.11$, $p < 0.001$, $\eta_p^2 = 0.241$, showed amplitudes on the left hemisphere being more negative compared to the right side. Next, amplitudes were more negative in the first half of the experiment compared to the second, $F(1, 57) = 33.77$, $p < 0.001$, $\eta_p^2 = 0.372$. The remaining interactions did not reveal any effect (all values of $p \geq 0.331$).

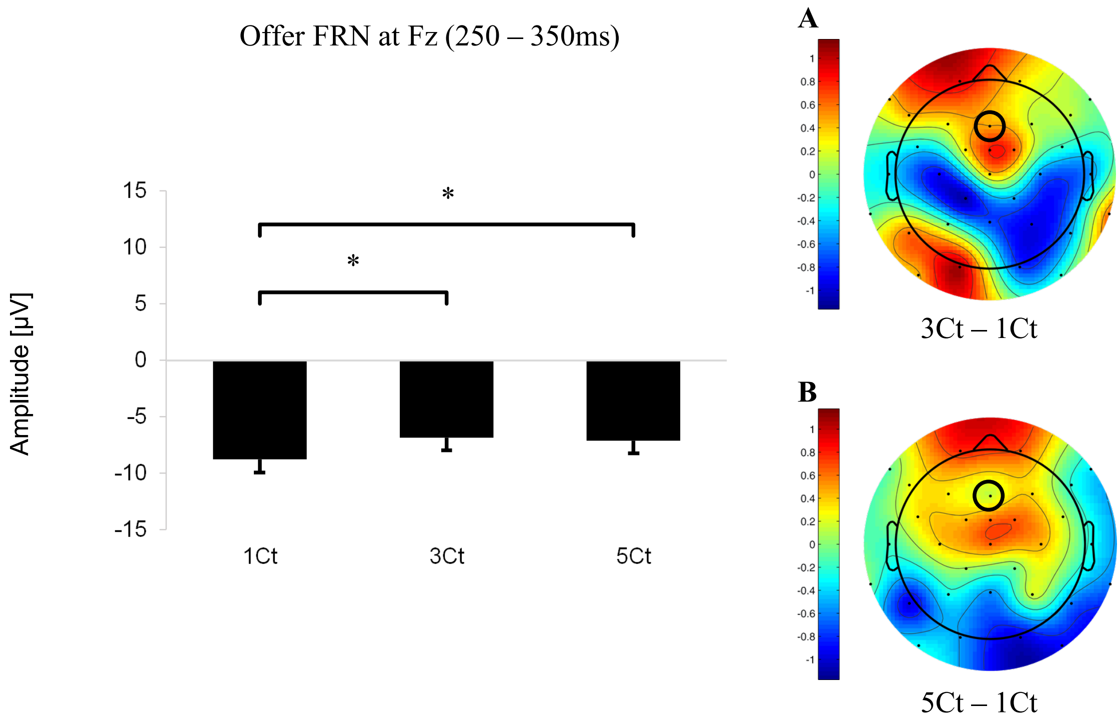

Figure 3.4. FRN results regarding offers. First column shows bar graphs with error bars indicating the standard error of the mean. Second column displays (a) difference topography for 3 cents minus 1 cent, and (b) difference topography for 5 cents minus 1 cent in the complete P2-N2 time window. *$p < 0.05$

Amplitudes for P2 on identity, $F(2, 106) = 0.24$, $p = 0.784$, decision, $F(1, 53) = 0.38$, $p = 0.540$, half of the block, $F(1, 53) = 1.08$, $p = 0.303$, and the interactions (all values of $p \geq 0.434$) revealed no significant effects. N2 amplitudes also did not show a significant effect of identity, $F(2, 106) = 2.50$, $p = 0.086$, decision, $F(1, 53) = 1.14$, $p = 0.291$, half of the block, $F(1, 53) = 1.31$, $p = 0.257$, and the interactions (all values of $p \geq 0.186$). The FRN amplitude for identity showed no significant main effect, $F(2, 106) = 1.09$, $p = 0.340$. Decision, $F(1, 53) = 0.31$, $p = 0.581$, half of the block, $F(1, 53) = 0.24$, $p = 0.621$, and all possible interactions revealed no significant effect (all values of $p \geq 0.436$).

P3 amplitudes showed a significant effect for the identity, $F(2, 106) = 9.28$, $p < 0.001$, $\eta_p^2 = 0.149$. Post hoc comparisons showed that the smiling identity elicited more positive P3 difference amplitudes compared to the control identity ($p = 0.004$) and the frowning compared to the control one ($p = 0.001$). The smiling and the frowning identity did not differ significantly

(p = 0.517); see Figure 3.6. The P3 amplitude for decision showed no significant main effect, $F(1, 53) = 0.42$, $p = 0.518$. However, the first half of the task evoked significantly larger P3 potentials than the second, $F(1, 53) = 35.64$, $p < 0.001$, $\eta_p^2 = 0.402$. Additionally, no interaction showed any effect (all values of $p \geq 0.088$).

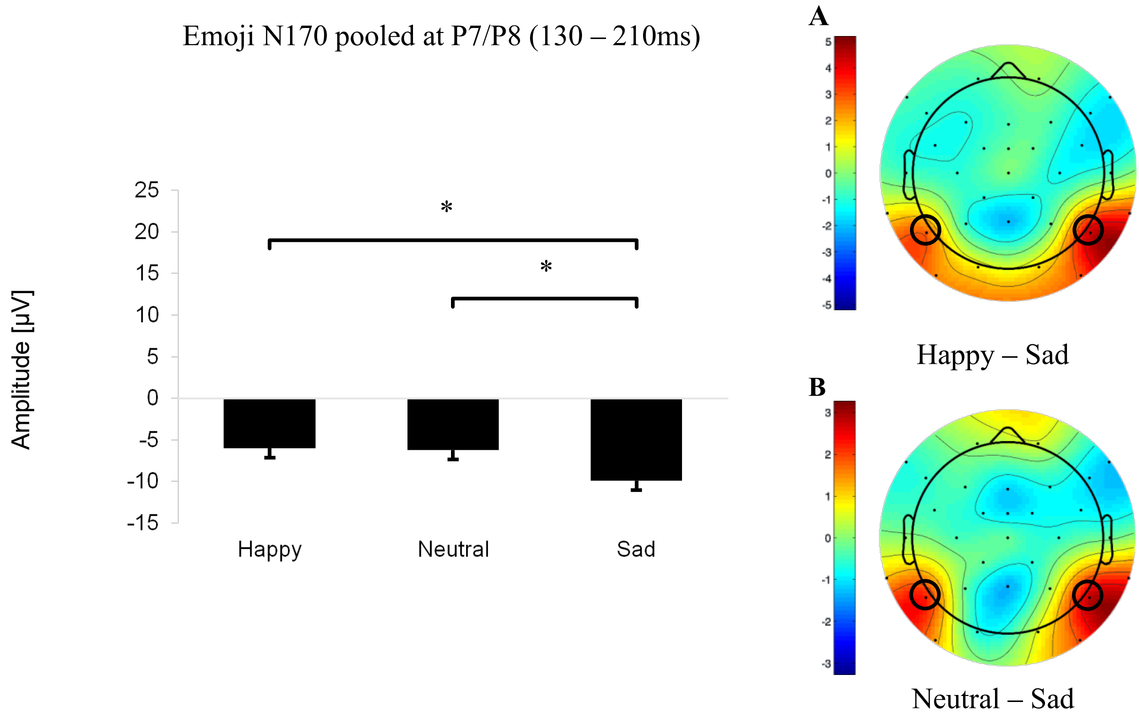

Figure 3.5. N170 results regarding emotional expressions of emojis. First column shows bar graphs for each emoji with error bars indicating the standard error of the mean. Second column displays (a) difference topography for happy minus sad, and (b) difference topography for neutral minus sad in the respective N170 time window. *p < 0.05

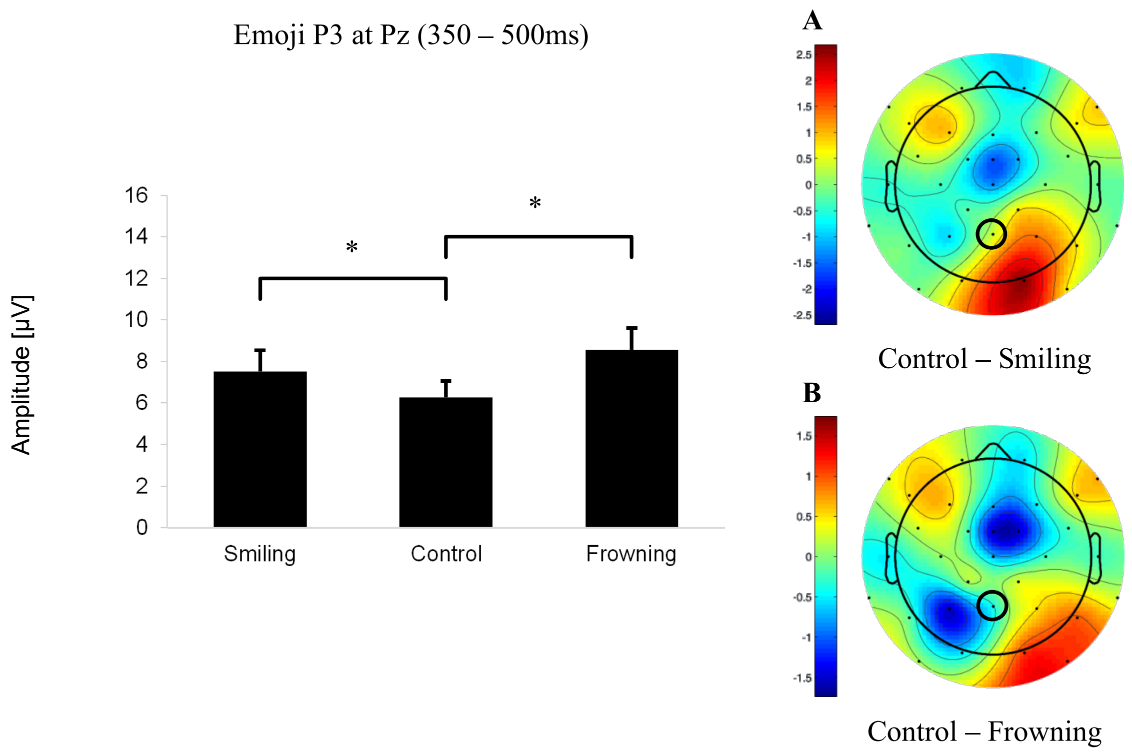

Figure 3.6. P3 results regarding feedback emojis. First column shows the results regarding different identities as bar graphs with error bars indicating the standard error of the mean. Second column shows (a) difference topography for the control minus the smiling identity in the P3 time window, and (b) difference topography for the control minus the frowning identity in the P3 time window. *$p < 0.05$

DISCUSSION

The purpose of the present study was to investigate the influence of affective emojis on social decision making, as they account for a constantly larger aspect within human social interaction. Hence, we included identities reacting differently by means of emojis toward acceptance and rejection in a modified version of the UG. As expected, highly unfair offers (1 cent) were rejected more often than mildly unfair (3-cent) and fair (5-cent) offers. These findings are in line with a great number of studies (Güth et al., 1982; Hewig et al., 2011; Mussel et al., 2014; Osinsky et al., 2013). We aimed to invoke conflict in decision making with our midvalue offer (3 cents). Polezzi et al. (2008) reported acceptance rates close to 50% for the same distribution. With an acceptance rate of almost 70%, our participants accepted notably more offers of 3 cents. Further, acceptance rates increased in the second half of the experiment significantly, which can be a sign of habituation to our task or even of exhaustion. Interestingly, the 3-cent offer provided the greatest discrepancy between the two halves. Possibly our conflict induction actually worked initially, but due to the long task participants solved the conflict quite early toward acceptance and, consequently, overall acceptance rates for 3 cents are very high. If we had chosen an offer that led to more conflict in decision making in our participants, we might have found more effects of the facial feedback after all (e.g., 2:8 cents). Contrary to our predictions and our previous finding with facial expressions (Mussel et al., 2018), the type of facial feedback given after every decision showed no social influence on the behavior of the subjects. Acceptance rates did not differ between the distinct player identities. This could be due to our limited variation of possible offers (1, 3, and 5 cents), possibly indicating a lack of conflict. Further explanations could be our blockwise design, in which the salience of the identity might have suffered due to habituation or the usage of emojis instead of real faces, which might have had a less emotional impact. Potentially emojis were too weak in comparison to real faces to induce behavioral effects. In the current study, monetary feedback seemed to dominate the behavioral responses to offers, whereas the different social identities did not alter decision making. A possible solution for this lack of influence might be to enrich different identities by further information (e.g., by intensifying their social and emotional relevance; Bublatzky, Gerdes, White, Riemer, & Alpers, 2014; Hammerschmidt, Kulke, Broering, & Schacht, 2018). Taken together, our paradigm may be useful to experimentally examine social influence in the sense or context of classic research in social psychology in the future (e.g., Cialdini & Goldstein, 2004), since we at least found effects regarding altered neuronal processing of affective emojis. Although we have no matching behavioral results, this may be achieved in future studies using the mentioned enrichment of the identities.

As in various previous studies (Luo et al., 2014; Mussel et al., 2018; Peterburs et al., 2017), we could replicate the basic valence effects in the FRN, since a greater negativity for unfair offers compared to mildly fair and fair offers is also present in our study. It may be interpreted as a Rew-P in response to the relatively fairer offer categories. Recent research further supports a Rew-P interpretation of FRN (Holroyd et al., 2008). For example, principal component analyses showed that differences in FRN responses to gains and losses are in fact tied to positive deflections over frontocentral recording sites, which are larger for rewards compared to nonrewards (Foti et al., 2011; Proudfit, 2015). In addition, direct coupling of functional magnetic resonance imaging and EEG during a time estimation task showed relatively more negative amplitudes to negative feedback, while BOLD responses suggested higher activation of the ventral striatum, the anterior cingulate cortex, and the medial prefrontal cortex during positive feedback, which are all reward-related brain regions. It has been suggested that FRN differences for positive versus negative feedback are caused by a positive deflection elicited by activity in these regions following positive feedback (Becker, Nitsch, Miltner, & Straube, 2014).

For FRN amplitudes, we further found a meaningful impact of identity on the processing of offers. The fact that offers coming from the frowning identity evoked less negative amplitudes than the control identity might indicate a more positive evaluation of offers from the frowning identity. These findings fit the theory of Rew-P, as one might not expect equally fair offers coming from the frowning compared to the control identity. This would be in line with findings that unexpected positive outcomes might elicit larger Rew-P than expected positive outcomes (e.g., Hewig et al., 2010; Kreussel et al., 2012; Potts et al., 2006). For instance, Hewig et al. (2010), who investigated behavior and neural activity of problem gamblers in a blackjack gambling task, showed that problem gamblers had more rewardrelated positive potentials after unexpected (risky) wins than the control group. This neural response to infrequent success was related to high-risk behavior (Hewig et al., 2010). Taken together, this is in line with reinforcement learning theory of feedback potentials and the idea that Rew-P amplitude is a function of positive temporal difference errors as described in mathematical versions of reinforcement learning theory (Holroyd & Coles, 2002; Holroyd et al., 2008; Miltner et al., 1997; Sutton & Barto, 1998). The latter theory also suggested a link to dopaminergic activity, and recent research supports that notion as substance-dependent individuals with impaired dopamine midbrain activity showed relatively smaller Rew-P in a T-maze learning task than healthy controls (Baker et al., 2011).

The interaction of identity and task half for N2 might indicate that participants over the course of the experiment become frustrated since even the positive counterpart regularly offer unfair shares and therefore fails to fulfill a subjective assumption to be as fair as expected. In contrast, for the frowning identity, people get accustomed to frequently mildly fair and unfair offered shares by a negative framed counterpart. Amplitudes might diminish due to fatigue of playing against such an ungrateful proposer.

Interestingly, we could show that the frowning and the smiling identity did overall evoke higher offer-related P3 than the control identity. Hence, the mere presence of emojis did influence the neural processing of the offers. In our study, subjects seemed to have learned the manner in which their bargaining partner tends to react to their decisions. This internalized information appears to have affected their brain activity during the offer presentation. Thus, we deduced that interindividual differences of proposers influence the processing of a presented offer with a negative identity making offers more subjectively meaningful compared to offers from the smiling identity. This effect could have been enhanced by our blockwise design, in which subjects faced only one distinct opponent over several trials in each block. This shows that the feedback pattern of a bargaining partner who is encountered multiple times influences the way the offers made by him or her are interpreted, even if the emotional interaction takes place after the bargain. We have previously shown a transfer effect from offers to preceding neutral faces for N2/ reward positivity (Osinsky et al., 2013). Yet, to our knowledge, a transfer from faces or emojis to offers in the UG has not been shown previously.

We predicted that emotional (i.e., positive or negative) emojis would evoke more negative N170 amplitudes than neutral emojis. Yet, we found that negative facial expressions elicited the highest amplitudes, while positive and neutral facial expressions did not differ from each other. We are the first to show the emotional enhancement effect of emotions on N170 for emojis, yet only for frownies. This is a finding in contrast to others showing greater N170 amplitudes for emotional facial expressions compared to neutral facial expressions independently of their direction. These findings examined the neural processing of facial stimuli without an economic context. In our study, facial expressions served exclusively for feedback after a bargaining situation. This context may have altered the neural processes occurring after stimulus presentation. The N170 tended to detect negative feedback, although it did not differ between neutral and positive feedback. Once again, the frowning facial expression might have yielded the most important information in the bargaining context, as negative facial expressions indicate that the counterpart understood that a sort of punishment and behavior in future negotiations might thus be altered. This information apparently was processed early on and might have dominated the basic processing of facial stimuli. Regarding the lateralization effect in this study, there is evidence that the right hemisphere is specialized for holistic face processing compared to the left hemisphere, which is specialized in featural processing (Rhodes, Brake, & Atkinson, 1993; Robertson & Delis, 1986). Hence, processing of emojis might be facilitated through a featural processing strategy to encode them similar to real faces. Calvo and Beltran (2014) showed that analytical or part-based processing of facial components (e.g., a smile) is lateralized on the left hemisphere. Since emojis are based on some key features of human faces (eyes, nose, mouth), it seems plausible to argue that a part-based processing feature is used for encoding compared to real faces. Further, the diminishing amplitudes in the second half of the experiment indicate adaption effects due to repeated stimulus presentation. This would be in line with several studies (Grill-Spector, Henson, & Martin, 2006; Grill-Spector & Malach, 2001), which already showed that frequently presented stimuli lead to familiarity and consequently decreasing brain potentials.

We anticipated more positive amplitudes for N2 being present for negative feedback compared to neutral as well as for positive feedback compared to neutral. This should have been a sign of the intention of punishing the proposer for unfair offers, as suggested by our previous study using real facial expressions (Mussel et al., 2018). In general, this was not found here, since there was no significant effect for identity. In our design, feedback valence never was completely surprising, because our identities always reacted repeatedly for multiple trials in a row. Thus, our study participants might have already expected a certain facial expression after their decision, which might have diminished classical N2 effects.

Regarding P3 amplitudes, feedback coming from both the smiling and the frowning identity elicited larger amplitudes compared to feedback coming from the control identity. This may serve as evidence that emotional feedback leads to stronger neural activity and may be more meaningful than neutral feedback in economic and social contexts. One may well argue that this is obvious since in our design a smile was the most positive way to receive feedback and a frowning face the most negative way to do so. While the feedback patterns had no effect on our subjects' behavior, these results show that the feedback arguably had subjective relevance for our participants. In any case, our study shows that the emoji smiles and frowns do affect neural processing and obviously increase subjective importance as compared to a neutral control emoji. Again, an effect of adaption could be found within P3 amplitudes. This serves as further evidence that, over the course of 66 trials in a block, participants become used to the presented stimuli, and therefore neuronal correlates decrease in their activation.

LIMITATIONS

The latter P3 effect may also be explained by the lower frequency of occurrence of the negative emojis as compared to the neutral ones. Since our different proposers always reacted in a fixed pattern to participants' behavior, after some trials the emotionality of the reaction may have been predicted by our receivers, which could have led to smaller ERPs due to low attention. Secondly, feedback was dependent on the responder's decision, which means that the decision itself and the affective feedback were confounded and not fully interpretable independently.

We used only three distinct offer sizes (1 cent, 3 cents, 5 cents), from which most of the 3-cent offers were still accepted (68%). A more conflict-inducing offer might have been 2 cents since it has been shown that offers of 20% of the total lead to an acceptance rate of roughly 50% (Camerer, 2003). In the future, more offer sizes might reveal stronger impacts of facial feedback and personality variables, since more variance in behavior and neural activities can be expected if an offer induces more conflict. We used multiple trials for each condition to gather enough data for ERP calculation, which led to a rather long experiment (330 trials). We found several effects of exhaustion in the second half of the experiment, diminishing some of our effect sizes and which might have increased acceptance rates. The reduction in P2 may indicate a decline in motivational salience accordingly (Amodio, 2010), which is why future research could use fewer conditions to prevent such impacts. For reasons of test economics, time deliberations, and the plausibility of the behavior of the interaction partners, we did not use incongruent feedback in this paradigm. Future investigations should extend their paradigm and include identities with incongruent feedback according to probabilistic feedback learning tasks. Finally, adding an identity that reacts overly altruistic could provide further insights regarding altruistic punishment, since it would be interesting to see whether such an identity would evoke less or more punishing behavior compared to a control identity.

In conclusion, we found that emoticons as feedback stimuli had various impacts on the neural activity during a bargaining situation. Offers from different "unfriendly" bargaining partners were processed differently on a neural level than offers from a "friendly" partner. Furthermore, we were the first to examine differences between negative and other emojis in the early occurring N170. In addition, we found higher P3 amplitudes for emotional versus neutral feedback, suggesting the subjective importance of emotions in economic contexts.

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SUPPLEMENTAL MATERIAL

EXPLORATORY ANALYSIS ON SEX EFFECTS

We performed an exploratory investigation on whether the sex of the participant had an effect on our data since the sample contained 34 females and 26 males. We will briefly report only significant findings on possible effects regarding sex for both behavioral and electrophysiological data.

BEHAVIORAL DATA

There was an interaction of half of the block (first vs. second) and sex (male vs. female): $F(1, 58) = 5.54$, $p = 0.022$, $\eta_p^2 = 0.087$): Men accepted generally more offers in the second half of the experiment than in the first ($p < 0.001$) compared to women who did not differ ($p = 0.263$).

ELECTROPHYSIOLOGICAL DATA

Regarding offer sizes, we found a significant three way interaction for P2 amplitudes between offer, half of the block, and sex $F(2, 114) = 3.59$, $p = 0.031$, $\eta_p^2 = 0.059$). In the first half of the experiment, 1 Cent offers evoked significantly larger P2 brain potentials compared to 3 Cent offers, but only for men ($p = 0.048$). All other comparisons did not yield significance (all values of $p \geq 0.148$).

For emotional feedback, we found a significant three way interaction for FRN amplitudes between decision, half of the block, and sex $F(1, 52) = 7.85$, $p = 0.007$, $\eta_p^2 = 0.131$). In the first half of the experiment, only for male participants feedback upon one's acceptance elicited significantly larger FRN amplitudes as compared to feedback after one's rejection ($p = 0.016$). All other comparisons did not yield significance (all values of $p \geq 0.114$).

DIFFERENCE BASED SIGNAL ANALYSIS

Regarding emotional feedback, we calculated difference waves by subtracting for each identity (i.e. block) the signals upon rejection feedback from those upon acceptance feedback stimuli. This resulted in a 2-factorial ANOVA with the factors "identity" and "half". We briefly want to summarize these results here.

N170. We found a significant main effect of the proposer's identity on N170 amplitudes ($F(2, 106) = 5.13$, $p = 0.007$, $\eta_p^2 = 0.088$): The happy ($p = 0.038$) and the neutral ($p = 0.008$) identity both evoked more negative amplitudes compared to the sad identity. Half of the block ($F(1, 53) = 0.38$, $p = 0.538$) and the interaction between half of the block and identity ($F(2, 106) = 0.07$, $p = 0.930$) did not provide significant results.

P2. There were no significant results for identity ($F(2, 106) = 0.35$, $p = 0.658$, $\varepsilon = 0.818$), half of the block ($F(1, 53) = 0.01$, $p = 0.905$) and the interaction between both ($F(2, 106) = 0.56$, $p = 0.571$).

N2. Again, there were no significant results for identity ($F(2, 106) = 0.41$, $p = 0.666$), half of the block ($F(1, 53) = 0.19$, $p = 0.660$) and the interaction between both ($F(2, 106) = 1.71$, $p = 0.189$, $\varepsilon = 0.902$).

FRN. Regarding FRN potentials, there were no significant results for identity ($F(2, 106) = 0.62$, $p = 0.653$), half of the block ($F(1, 53) = 0.02$, $p = 0.873$) and the interaction between both ($F(2, 106) = 0.83$, $p = 0.426$, $\varepsilon = 0.905$).

P3. There were no significant results for identity ($F(2, 106) = 2.49$, $p = 0.088$), half of the block ($F(1, 53) = 0.29$, $p = 0.592$) and the interaction between both ($F(2, 106) = 1.41$, $p = 0.246$).

IMPLICATIONS FOR STUDY 3

After showing that very simple emojis do not affect behavior like human faces, we wanted to make a direct comparison between human faces and more realistic emojis. To achieve this, we added another four identities to the yet existing eight from Study 1 and conducted a study with twelve blocks. We also retained the block-wise appearance of the identities as in Study 2. Since we were able to show neural framing of certain identities with the very simple emojis in the second study, we expect to find both a neuronal signature of how more realistic emojis differ from real faces, and behavioral similarities or differences between the two stimulus categories by implying both in one task at a time.

THE VALUE OF A REAL FACE: DIFFERENCES BETWEEN AFFECTIVE FACES AND EMOJIS IN NEURAL PROCESSING AND THEIR SOCIAL INFLUENCE ON DECISION-MAKING

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ABSTRACT

Emotional feedback is a crucial part of human social interaction, since it may indicate motivations, intentions, and thus, the future behavior of interaction partners. Nowadays, social interaction has been enriched by artificial emotional feedback provided by emojis, which are the means of transporting emotions in many mobile messengers. In this study, we aimed to examine the influence of emotional feedback by emojis compared to real faces on decision-making and neural processing. We modified the ultimatum game by including several proposers represented both by emojis and human faces who reacted specifically towards acceptance or rejection of an offer. We show that proposers that reward acceptance with a smile cause the highest acceptance rates. Interestingly, acceptance rates did not differ between the proposers represented by human faces compared to emojis.

Regarding electrophysiology, emojis evoked more negative N170 and N2 brain potentials compared to human faces both during a mere presentation and as feedback stimuli within the ultimatum game. Proposers that showed emotional facial expressions evoked larger N170 amplitudes as compared to neutral expressions. Especially the proposers represented by emojis evoked larger P3 amplitudes as feedback stimuli compared to human facial expressions. The comparison of emoji proposers with real-face proposers in this paradigm provides new insight into how relevant social cues influence behavior and its neural underpinnings.

INTRODUCTION

"Until the advent of the smiley, otherwise known as an emoticon, individuals using electronic communication had no way to indicate the subtle mood changes. They couldn't tell jokes, use irony, slip in a pun or become bitingly sarcastic." Godin (1993, p. 4)

As described by Godin (1993), emojis have the fundamental function to facilitate non-face-to-face communication and to emphasize certain aspects of verbal communication (Derks et al., 2008). In general, facial expressions are a crucial aspect of human social interaction, as they do not only convey information about a person's current emotional state but also about personality and intentions (Eckel & Wilson, 1998). In the present study, we wanted to investigate, whether emojis can capture comparable social information as real faces do and if they influence behavior and underlying neural processes similarly.

A few studies have compared neural responses between emojis and real faces. For instance, Kim, Lee, Choi, Kim, and Jeong (2016) reported that the brain recognizes text-based emoticons as facial stimuli (i.e., using colons, hyphens, and parentheses), but their emotional intent or content did not activate the amygdala, a fundamental part of the brain for emotion processing. Additionally, a study using electroencephalography (EEG) by Churches et al. (2014) showed that text-based emoticons could evoke an N170 brain potential similar to real faces. Moreover, there is some evidence that sentences enriched with emoticons activate brain regions associated with verbal and nonverbal information more strongly compared to plain text (Yuasa, Saito, & Mukawa, 2011b). While these previous studies focused on neural correlates of the mere presentation of emoticons, emojis, and faces, we aimed to extend research onto the task-specific influence. Therefore, we included both a mere presentation phase and a social interaction task in this study to cover the passive and interactive processing of emotional facial expressions.

Over the years, scientists have investigated effects evoked by different emotional feedback stimuli. For example, Mehu, Grammer, and Dunbar (2007) and Brown, Palameta, and Moore

(2003) argue that cooperative individuals in comparison to non-cooperative individuals frequently express positive emotions and tend to show more commitment. Eckel and Wilson (2003) added further evidence in this direction, as they found that participants are more likely to interact with persons represented by smiling icons than with those represented by frowning icons. Reed et al. (2012) showed that participants used smiling feedback as an accurate predictor for cooperative intentions, whereas negative facial-feedback worked as a warning signal for defection in a social decision game.

A commonly used social and economic game for investigating various aspects of human decision-making is the ultimatum game (UG). The original UG (Güth et al., 1982) is a one-shot two-player game measuring economic behavior. In its original set up, one party is acting as a "proposer" and another as a "responder." The proposer must divide a certain amount of money (often operationalized with 10 Cent) to share with the responder. It is up to the responder to accept or reject the offered amount of money. In case the responder accepts, the money will be split according to the offer. If he or she rejects, neither of them will gain anything. Consequently, offering 5 Cent out of 10 would be considered as a fair offer, whereas 1 Cent would be very unfair. According to rational choice theory (Morgenstern & Von Neumann, 1953), a rational proposer would offer the smallest amount to maximize his gains, and a rational responder would accept any offer, since receiving any money is better than gaining nothing. Contrary to this theory, empirical data show that offers below 20% of the money are rejected in 50% of all cases; and on the other hand, proposers on average offer 40-45% of the money to the responder (Levine, 1998).

Recent evidence shows that a smiling proposer gets more offers accepted as compared to a proposer with neutral or negative facial expression (Csukly, Polgar, Tombor, Rethelyi, & Keri, 2011; Mussel et al., 2013). Since these and similar studies mostly worked with photographs as feedback stimuli, questions about sex, race, and attractiveness effects may arise. For example, a study on facial attractiveness conducted by Ma et al. (2015) confirmed that responders in ultimatum games had longer reaction times when an attractive proposer in comparison to a rather unattractive proposer made unfair offers. Additionally, male responders were more likely to accept unfair offers if they received them from an attractive female proposer. Previously, Solnick and Schweitzer (1999) had already observed attractive females being offered more money than ordinary-looking people. Another study, reported by Eckel and Grossman (2001), describes overall sex effects on acceptance rates. Offers made by female proposers were accepted more often than offers from male proposers. Also, Kubota, Li, Bar-David, Banaji, and Phelps (2013) found differences in the acceptance rates depending on the skin color of the proposer. Offers made by white proposers were accepted more frequently compared to offers made by black proposers. Furthermore, low offers were more likely to be accepted when coming from white proposers. Based on these arguments, it may first be experimentally interesting to use emojis as an equivalent to transport emotions without possible gender, attractiveness, and race biases.

Mussel et al. (2018) extended the use of a mere presence of facial expressions in economic games and used a modified UG with different proposers who reacted with a distinct pattern towards participants' acceptance and rejection of UG offers. After a participant accepted or rejected an offer, he or she received an emotional facial expression from the proposer. On a behavioral level, the facial emotional feedback influenced decision-making in the task. Participants showed higher acceptance rates if the co-player either consistently smiled upon acceptance, or looked sad upon rejection, compared to proposers showing a neutral facial expression. Regarding event-related potentials (ERPs), they examined the N170 to analyze face processing. In order to investigate the evaluative processing of facial stimuli, feedback-related negativity (Miltner et al., 1997) and reward-positivity (Baker & Holroyd, 2011; Holroyd & Coles, 2002; Holroyd et al., 2008) were discussed. Finally, the P3 component was examined as a neural sign for attentional processing and subjective importance (Johnson, 1988; Polich, 2007). ERPs regarding facial stimuli showed greater N170 amplitudes for emotional faces and increased P3 amplitudes for angry and sad faces compared to neutral faces indicating altered face processing. Furthermore, angry and sad expressions elicited more negative amplitudes in the N2 time range upon mere presentation and evoked a reward positivity if they were the consequence of the rejection of an unfair offer. These results indicate that people are willing to punish their interaction partners on their own expenses, a behavior which is known as altruistic punishment (Fehr & Gächter, 2002). Amplitudes in the N2 time window likely reflected the desired facial feedback outcome, since negative emotional faces elicited more positive amplitudes indicating reward positivity, in contrast to more negative amplitudes during the mere presentation of faces. In an article by Weiß, Gutzeit, Rodrigues, Mussel, and Hewig (2019a), the authors already used very basic emojis to test whether they were able to influence behavior and neural correlates. On a behavioral level, no effects of emojis on behavior in an ultimatum game could be shown. However, emojis affected N170 and P3 brain potentials and thus provided a social frame for a particular situation. Accordingly, emojis did influence neural processing but did not influence behavior as compared to real faces in the preceding study. Yet, a direct comparison of the effects of faces versus emojis on decision-making in a social bargaining situation has not been done. As the emojis used in the aforementioned emoji study differed from emojis known from popular messaging services, we used emojis that are closer to reality for the present study.

To sum up, the aim of the current study is to directly compare the influence of emotional facial feedback to the effects of emojis on decision-making and its neural correlates. Therefore, we included both real faces and artificial emojis into one task, in order to provide a deeper insight into the influence of emojis compared to faces on social decision-making and its neural underpinnings. In contrast to the study conducted by Mussel et al. (2018), we presented each proposer repeatedly in a block of trials (block-wise) compared to an interleaved presentation. We deduced the following hypotheses:

H1: The proposer with the smiling attitude will obtain higher acceptance rates compared to the neutral control.

H2: Emotional facial expressions will evoke higher task-independent N170 amplitudes compared to neutral faces. The second and primary goal of this study was to enlarge the paradigm of Mussel et al. (2018) by equivalent emoji identities.

H3: Real faces evoke higher P3, N2, and P2 brain potentials since they cover more relevant social information compared to emojis.

H4: Emojis elicit more negative N170 brain potentials compared to human photographs, which is expected to be true for both task-independent and task-relevant stimuli.

H5: We expect similar behavioral patterns for the corresponding attitudes of male, female, and emoji proposers.

METHODS

PARTICIPANTS

A sample size of $N = 51$ was estimated for a medium effect of $\eta_p^2 = .06$, $\alpha = .05$, and $\beta = .95$ using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). Finally, fifty-eight subjects were recruited. Two participants accepted more than 90% of all offers and thus were excluded from all analyses since they would not produce enough trials for decision-dependent EEG analyses. Moreover, one participant interrupted the experiment and was excluded from analyses. Thus, the final sample consists of 55 individuals (39 female; mean age 28.55 years, $SD = 11.56$, range 18 to 66), who participated for course credit or monetary compensation. All participants were informed, gave their written consent, and were debriefed after the end of the experiment.

EXPERIMENTAL PROCEDURE

After arriving in the lab, participants received general instructions about the experiment. Next, they completed two experimental tasks, as displayed in Figure 4.1. Concerning stimulus material, we used five male and five female identities from the Radboud Faces database (Langner et al., 2010). Each of the ten identities was available in four emotional expressions: happy, neutral, angry, and sad. Additionally, we used one set of emojis which also consisted of the four emotional expressions happy, neutral, angry, and sad. The emojis used in the experiment came from joypixels (https://joypixels.com).

The first task was a control task to examine context-free neural responses to emotional faces and emojis. In addition to the emojis, for each participant, one male and one female identity was randomly chosen from the five male and female identities, respectively. For each of these, we presented the four emotional expressions 20 times, resulting in (3*4*20=) 240 trials. The participants were asked to look at the stimuli without providing any action.

The second task was an ultimatum game in the role of the responder with emotional feedback by the proposer towards accepted and rejected offers. Thereby, one male, one female, and one emoji identity reacted equally in one of four particular ways, which we call the attitude of a proposer. The smiling attitude is assigned to a proposer who responded with a smile if an offer was accepted and a neutral expression if the offer was rejected. The neutral attitude refers to a proposer with a neutral facial expression, irrespective of the decision of the responder. The angry attitude is assigned to a proposer who responded with a neutral facial expression if the offer was accepted and an angry facial expression if the offer was rejected. Finally, the sad attitude refers to a proposer who reacted with a neutral facial expression if the offer was accepted and a sad facial expression if the offer was rejected. Each of these proposers with a distinct attitude pattern existed three times (i.e., one male representative, one female representative, and one emoji representative). Each of the resulting 12 proposers was presented in a separate block. The sequence of blocks was randomized between participants.

The participants conducted 48 trials within each block. At the beginning of each trial, the offer of the proposer was shown, representing a split of 10 cents. The split indicated six different offer sizes for the responder: 0, 1, 2, 3, 4, or 5 Cent. The offers were predefined (8 trials per offer size) and presented as a pie chart (e.g., 2/8 for the responder/proposer). For each block, the order of the 48 offers was randomized. As a cover story, all participants were instructed that the offers they received had been made by other participants who had taken part in the experiment on an earlier occasion and that both parties would be paid according to the decisions made by the participant. After the presentation of the offer, participants decided to either accept or reject the offer by pressing the left (acceptance) or right (rejection) arrow button. Their decision was shown on the screen for 1,200 ms along with the money that they won (e.g., “Accept! You get 2 Cents!”). Finally, a picture with varying facial expressions of the proposer who made the offer was shown, representing how the proposer felt concerning the decision of the participant.

The twelve blocks with the associated 48 randomized trials per block resulted in a total of 576 trials. The chosen identities for the four male and the four female proposers were the remaining identities that were not used for Task 1. The cover story implied that we took a picture of each participant for the following participant. For the emoji condition, we stated that some participants did not want to provide a picture of themselves. We indicated that we would use emojis as representatives instead.

After completing the two tasks, we conducted a manipulation check on the stimuli. For each of the twelve pictures used in task 1, participants rated valence and arousal on a 7-point scale. Then, participants were informed about the deception and paid out.

All stimuli were presented on a 17" screen with a black background. Stimulus presentation and response recordings were controlled by PsychoPy 1.83 (Peirce, 2008). During the task, participants sat in a comfortable chair, with a distance of 70 cm between the head and the screen. Each of the face and emoji pictures was 10 cm high and 6.65 cm wide, resulting in a visual angle of about 14.2° x 9.5°. The pie charts had a diameter of 2.5 cm (3.6° visual angle).

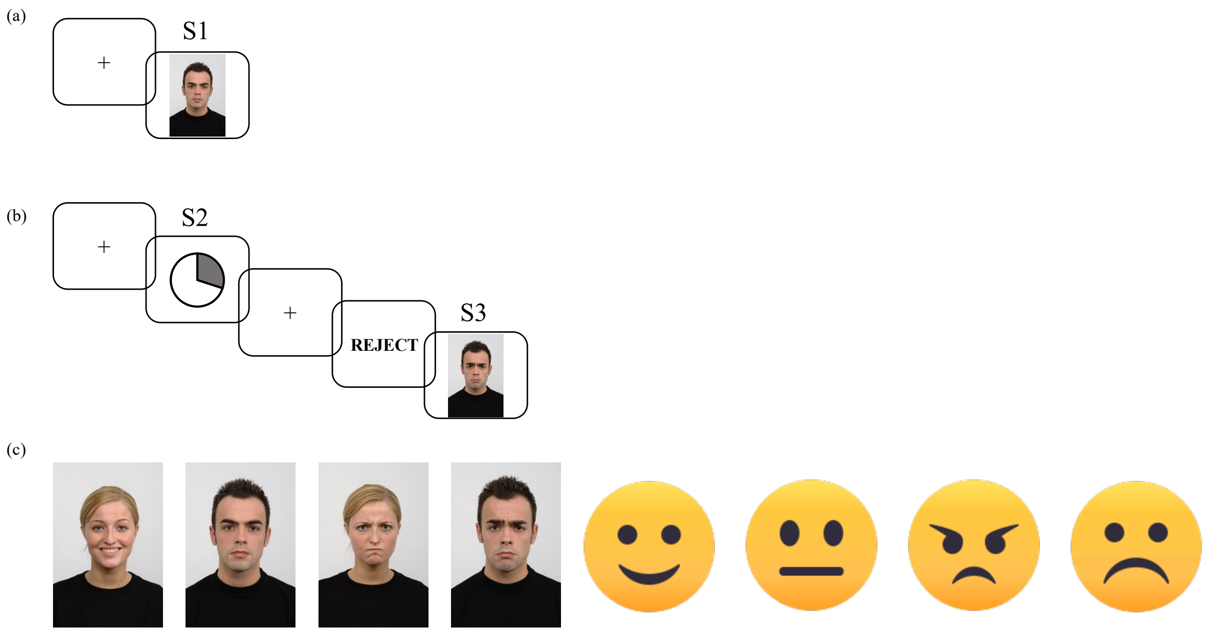

Figure 4.1. Task time line for the two paradigms: Each trial began with a fixation cross followed by a picture (S1) in the first task (a) and the offer (S2) in the second (b). Participants had to decide whether to accept or reject the offer while the offer was displayed. After the decision, feedback (S3) was given regarding the decision made by the responder. (c) Example pictures of happy, neutral, angry, and sad facial expressions for both humans (Langner et al., 2010) and emojis.

EEG RECORDING AND ANALYSES

The EEG was measured by Ag/AgCl-electrodes located in an electrode cap in 32 scalp positions according to the international 10-20 system: FP1, FP2, Fz, FCz, F3, F4, F7, F8, F9, F10, FC1, FC2, FC5, FC6, CZ, C3, C4, T7, T8, CP1, CP2, TP9, TP10, P3, P4, P7, P8, P09, PO10, O1, O2. An additional electrode to register eye movements and blinks, called electrooculography (EOG), was put below the left eye. All electrode impedances were kept below 5 kOhm for the EEG, and data were referenced online to the vertex (Cz). Data were recorded with a sampling rate of 250 Hz and a high cutoff filter of 80 Hz with BrainVision BrainAMP Standard (Brain Products GmbH, Gilching, Germany) and the respective BrainVision Recorder software. For processing our collected EEG data, we used MATLAB (MathWorks, Natick, MA) and the toolbox EEGLAB (Delorme & Makeig, 2004) version 13.3. Initially, we detected inappropriate channels for each participant and interpolated them. We segmented epochs from -500ms to 1000ms around our target markers and assessed a window of -200ms to 0ms for baseline correction. Regarding artifact rejection, we used the criterion of z-value > 4 for the amplitude and kurtosis of the signal. Before applying independent component analysis (ICA) according to Delorme et al. (2007), we used a band-pass filter from 1 to 40 Hz. Afterward, we used the EEGLAB extensions ADJUST (Mognon et al., 2011) and MARA (Winkler et al., 2011), which work with SASICA software (Chaumon et al., 2015) to choose ICA components for artifact rejection and handling eye artifacts and discontinuities in the signal. Finally, offline reference was transformed to current source density, and data were filtered with a 20Hz low pass filter.

ERP QUANTIFICATION

We investigated the neural processes of the decision-making tasks according to three different stimuli (S1 to S3, see Figure 4.1). The first stimulus S1 contained facial expressions in Task 1. The second stimulus S2 was the presentation of the offer in Task 2. Finally, the third stimulus S3 was the emotional feedback in Task 2. For each of the three stimuli, we quantified the N2, P2, and P3 amplitude for each participant and each condition (see Figure 4.2).

The P2 and N2 components were analyzed at electrode site FCz, where their maxima would typically occur (Burle, Roger, Allain, Vidal, & Hasbroucq, 2008; Gehring & Willoughby, 2002; Holroyd & Coles, 2002). P2 was quantified as the mean amplitude in the interval ± 12 ms around the positive peak in the time window between 150 and 250 ms, determined separately for each stimulus (peak latencies for the three stimuli were 208, 203, and 213 ms for S1, S2, and S3, respectively). N2 was quantified as the mean amplitude in the interval ± 12 ms around the negative peak in the time window between 200 and 400 ms determined separately for each stimulus (peak latencies for the three stimuli were 317, 311, and 319 ms for S1, S2, and S3, respectively). Further, for S2 and S3 the FRN component was also quantified as an alternative peak-to-peak measure as reported in several other studies (Holroyd et al., 2003; Mussel et al., 2018; Osinsky et al., 2012; Yeung & Sanfey, 2004), since a simple amplitude difference between favorable and unfavorable feedback in a specific time window overlaps with both P2 and P3 (Foti et al., 2011; Yeung et al., 2005). Therefore, we quantified FRN as the difference between the mean amplitudes around the negative (N2) and the preceding positive (P2) peak, according to the time windows mentioned above; results are provided in the supplement. Finally, P3 was quantified as the mean amplitude in the interval ± 12ms around the positive peak in time window between 400 and 800 ms at electrode Pz, determined separately for each stimulus (peak latencies for the three stimuli were 629, 548, and 643 ms for S1, S2, and S3, respectively).

Besides, we quantified the N170 amplitude for the facial stimuli S1, and S3, for each participant and each condition. The N170 was quantified as the mean amplitude in the interval ± 12 ms around the negative peak in the time window between 130 and 210 ms at electrodes P7 and P8, determined separately for each stimulus (peak latencies for the two stimuli were 170, and 168 ms for S1, and S3).

Data were analyzed using repeated-measures analyses of variance (ANOVA) in SPSS software (IBM, Armonk, NY, USA). For all ANOVA reported in the following paragraph, we assumed $\alpha = .05$, and for every test, we applied Mauchly's test of sphericity. If this test would yield $p \leq .05$, we corrected the degrees of freedom. In these cases, Hyunh-Feldt adjustment factors for degrees of freedom were used, apart from when $\varepsilon < .75$. Then we adjusted the degrees of freedom according to Greenhouse-Geisser. The adjustment factors are reported if sphericity was violated. In case we found a statistically significant result for any ANOVA, we computed

Bonferroni-adjusted pairwise comparisons for further investigation of the effect.

RESULTS

In order to investigate significant interactions in detail, we analyzed simple contrasts as post-hoc tests. As the reference category, we used emojis within the factor *category*, neutral within emotion and the neutral one within *attitude*. When analyzing ultimatum game offers, we used 0 cents as reference. For ease of understanding, we talk about an affective difference score, when referring to the comparison of affective categories to the neutral reference for the factor emotion within both the manipulation checks and the control presentation task.

(a)

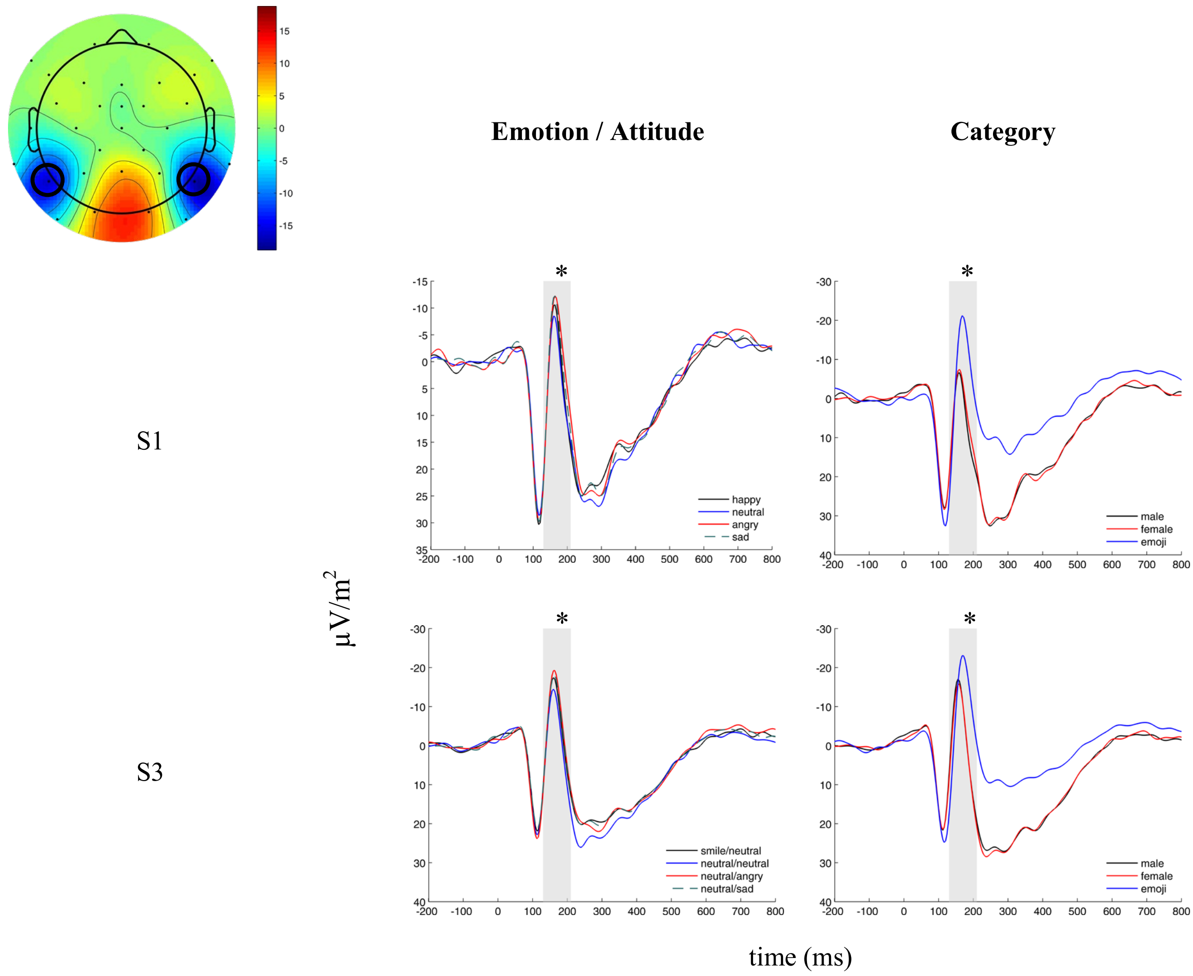

Figure 4.2. (a) Grand average ERP waveforms from P7 and P8 electrode sites. The gray areas highlight the time window of the N170 (130–210 ms) used for searching the negative peak. In the first column,

grand averages are shown regarding emotional content for S1 (first row) and S3 (second row). In the second column, grand averages regarding the category (male vs. female vs. emoji) are depicted for S1 (first row) and S3 (second row). (b) Grand average ERP waveforms from the FCz electrode site. The gray areas highlight the search window of the P2 peak (150–250 ms) and the blues area the search window of the N2 peak (200–400 ms). The first row shows grand averages of each category regarding S1. In the second row grand averages of each category regarding S3 are indicated. (c) Grand average ERP waveforms from the Pz electrode site. The gray areas highlight the time window of the P3 (400–800 ms) used for searching the positive peak. The first row indicates P3 amplitudes according to their category for S1, and the second row for S3. Topographic maps show averaged voltage across all conditions in the respective time window for each component. * $p \leq .05$.

MANIPULATION CHECK

The manipulation check regarding the valence and arousal of S1 was analyzed with a two-factorial ANOVA with the factors category (three levels: male, female, emoji) and emotion (four levels: happy, neutral, angry, sad). Valence ratings differed significantly according to emotion ($F(3, 162) = 477.04$, $p < .001$, $\eta_p^2 = .898$, $\varepsilon = .718$). The happy expressions were rated more positively compared to the neutral looking, the angry, and the sad-looking ones. Further, the neutral-looking facial expression was rated more positively than both the angry and the frowning facial expressions. Finally, the sad facial expression was rated more positively compared to the angry one. All Bonferroni corrected pairwise comparisons showed $p < .001$. There was no significant effect of category ($F(2, 108) = 2.01$, $p = .078$, $\varepsilon = .927$), but a significant interaction of emotion and category ($F(6, 324) = 4.78$, $p < .001$, $\eta_p^2 = .088$, $\varepsilon = .755$). The contrasts showed that for emojis compared to male faces, the affective difference score for frowning emojis was significantly greater ($p = <.001$). Females versus emojis and the other emotions versus neutral did not differ (all values of $p \geq .092$).

Arousal ratings also showed an effect of emotion ($F(3, 162) = 48.81$, $p < .001$, , $\eta_p^2 = .475$, $\varepsilon = .814$). Bonferroni corrected pairwise comparisons revealed that the sad expression was rated higher in arousal compared to neutral-looking, angry, and happy expressions (all values of $p < .001$). Both happy and angry faces were rated more arousing compared to neutral ones (all values of $p < .001$), but did not differ from each other ($p = 1$). Again, there was no significant effect of category ($F(2, 108) = .95$, $p = .391$), but a significant interaction between category and emotion ($F(6, 324) = 5.48$, $p < .001$, $\eta_p^2 = .092$, $\varepsilon = .887$). Males opposed to emojis revealed a greater affective difference score regarding happy ($p = .001$) and angry ($p = .006$) faces, but not for sad ones ($p = .529$). Females opposed to emojis showed a greater affective difference score referring to happy ($p < .001$), angry ($p < .001$), and sad ($p = .019$) facial expressions.

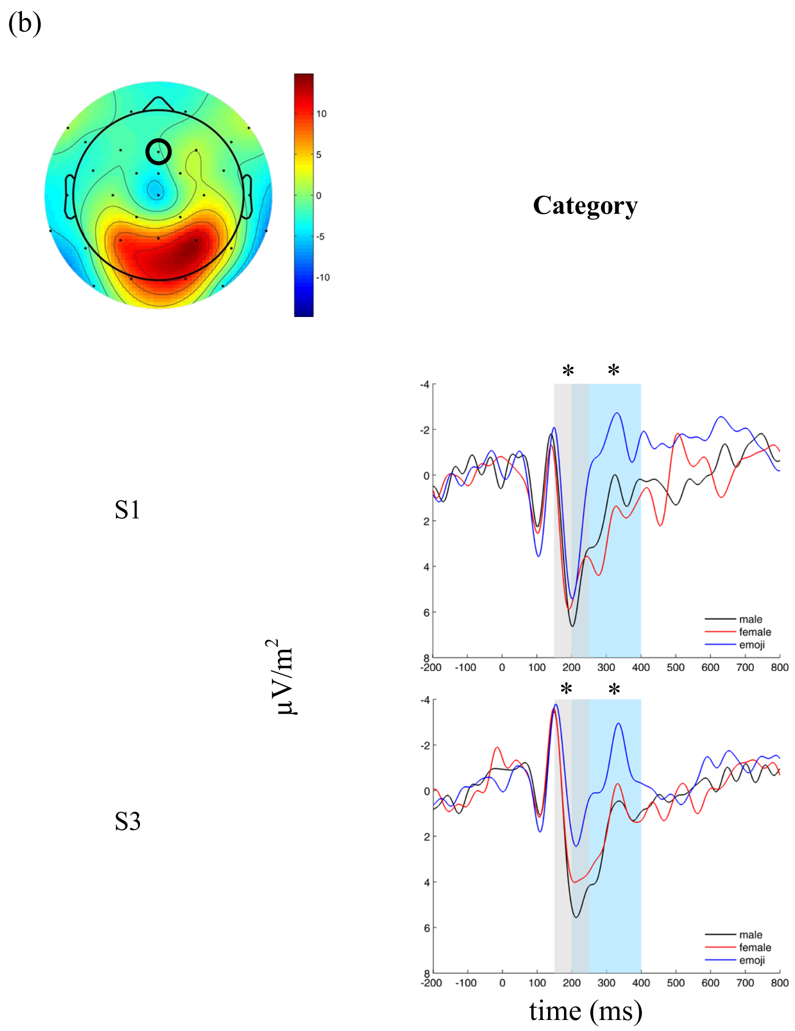

Figure 4.2. (Continued).

BEHAVIORAL RESULTS

We analyzed decision-making with a two-factorial ANOVA with the factors category (three levels: male, female, emoji), attitude (four levels: smiling/neutral, neutral/ neutral, neutral/angry, neutral/sad, according to the emotional reaction following accepted/rejected offers), and offer (six levels: 0–5 Cents). There was a significant effect of attitude on acceptance rates ($F(3, 162) = 6.37$, $p = .001$, $\eta_p^2 = .106$, $\varepsilon = .799$), as displayed in Figure 4.3. Further, we found a significant interaction between category and attitude ($F(6, 324) = 2.31$, $p = .042$, $\eta_p^2 = .041$, $\varepsilon = .867$). Offers coming from proposers with a smiling attitude (proposers reacting with a smile after accepted offers and with a neutral expression after rejected offers) were accepted more often compared to proposers with neutral (p = .015) and angry attitude (p = .020), but not compared to proposers with sad attitude (p = .144). Acceptance rates did neither differ between proposers with neutral and angry attitude (p = 1) nor between proposers with neutral and sad attitude (p = .757). Likewise, proposers with sad and angry attitude did not differ (p = .211). The follow-up contrasts for the interaction revealed that for both males compared to emojis (p = .028) and females compared to emojis (p = .006), offers from proposers with sad attitude were accepted more often than offers from proposers with neutral attitude. The remaining contrasts did not differ significantly (all values of $p \geq .209$).

Further, we found a significant effect of offer ($F(5, 270) = 123.29$, $p < .001$, $\eta_p^2 = .695$, $\varepsilon = .594$) indicating that acceptance rates dropped according to decreasing offer sizes (93%, 77%, 59%, 36%, 30%, and 13%, for offers of 5, 4, 3, 2, 1, and 0 cents, respectively). For the difference between males, females and emojis ($F(2, 108) = 1.15$, $p = .321$) and the remaining interactions (all values of $p \geq .051$) we did not find any significant results.

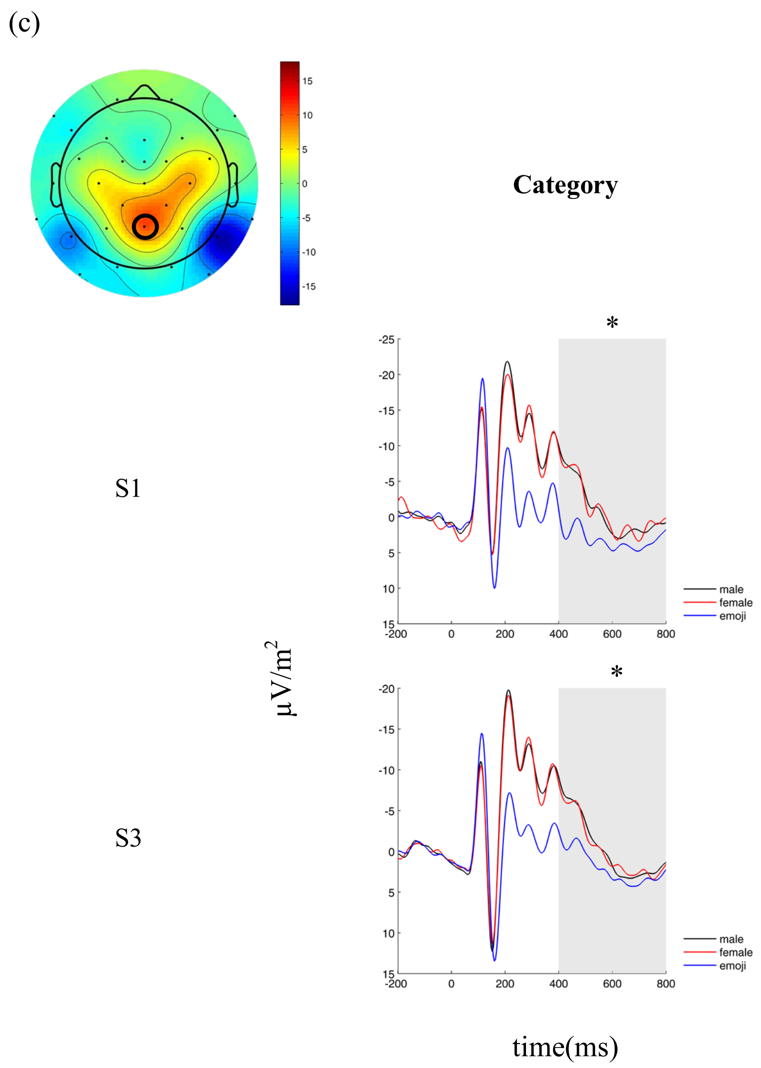

Figure 4.2. (Continued).

ELECTROPHYSIOLOGICAL RESULTS

PRESENTATION TASK

S1 (see Figure 4.1) was analyzed with a two-factorial design with the factors category (three levels: male, female, emoji) and emotion (four levels: happy, neutral, angry, sad). N170 amplitudes showed an effect for category ($F(2, 108) = 45.75$, $p < .001$, $\eta_p^2 = .459$, $\varepsilon = .625$), emotion ($F(3, 162) = 5.76$, $p = .001$, $\eta_p^2 = .096$) and a significant interaction of category and emotion ($F(6, 324) = 6.45$, $p < .001$, $\eta_p^2 = .107$, $\varepsilon = .925$). Emojis evoked more negative amplitudes compared to both males and females (*p*s < .001), whereas these two did not differ from each other (p = .340). Neutral expressions evoked significantly less negative N170 amplitudes compared to both angry (p = .008) and sad (p = .008) expressions. However, none of the other comparisons yielded significance (all values of $p \geq .268$). Regarding the interaction, the contrasts revealed that for emojis compared to both males ($p < .001$) and females (p = .012) the affective difference score was greater (i.e. more negative) for angry faces. The remaining contrasts did not show significant effects (all values of $p \geq .052$).

For P2 amplitudes, an unspecific significant effect was detected for category ($F(2, 108) = 3.46$, $p = .040$, $\varepsilon = .894$), as no post-hoc comparisons were significant (all values of $p \geq .111$). Neither emotion ($F(3, 162) = 0.23$, $p = .791$, $\varepsilon = .675$) nor the interaction between category and emotion ($F(6, 324) = 0.83$, $p = .501$, $\varepsilon = .645$) revealed significant effects. Concerning N2 amplitudes, a significant effect was found for category ($F(2, 108) = 13.58$, $p < .001$, $\eta_p^2 = .201$), showing that emojis evoked more negative amplitudes compared to males (p = .002) and females ($p < .001$). The humans, on the other hand, did not differ (p = .548). The interaction between category and emotion also yielded significance ($F(6, 324) = 2.95$, $p = .012$, $\eta_p^2 = .052$, $\varepsilon = .852$). Within females compared to emojis, the affective score was greater (i.e. more negative) for angry faces (p = .006), whereas all other contrasts were not significant (all values of $p \geq .515$). However, for emotion itself no effect was found ($F(3, 162) = 1.30$, $p = .276$, $\eta_p^2 = .060$, $\varepsilon = .790$). Regarding P3 amplitudes neither emotion ($F(3, 162) = 1.79$, $p = .149$), nor the interaction ($F(6, 324) = 0.52$, $p = .758$, $\varepsilon = .842$) yielded significance. In contrast, the main effect of category ($F(2, 108) = 8.58$, $p < .001$, $\eta_p^2 = .137$) indicated that emojis elicited significantly larger P3 brain potentials compared to male (p = .008) and female faces (p = .001).

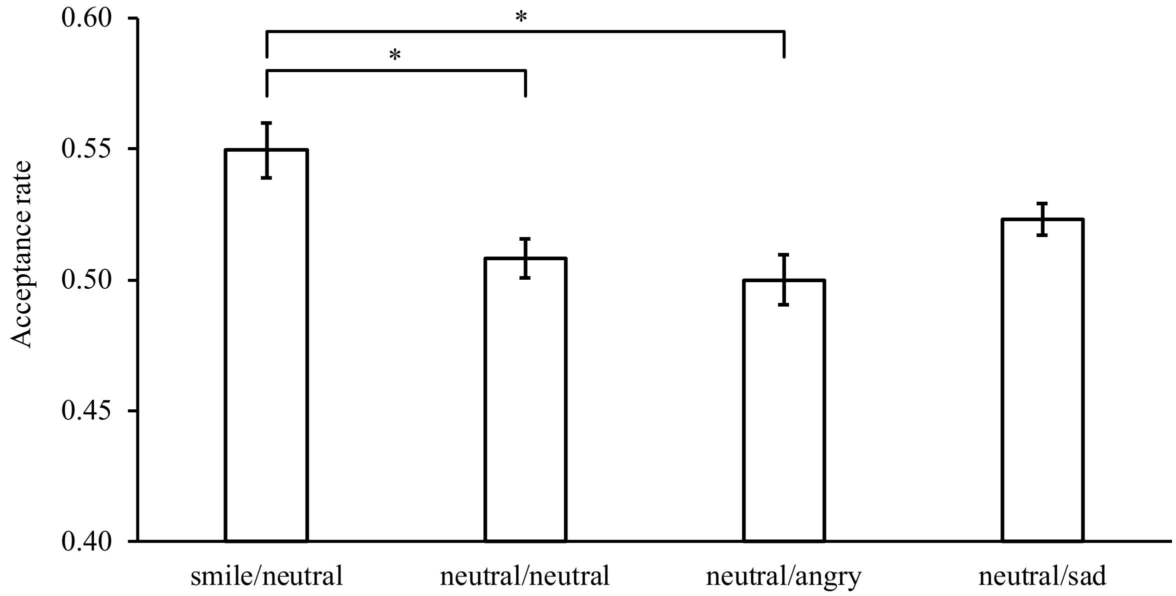

Figure 4.3. Average acceptance rates, depending on the attitude of the proposer. Each attitude reflected a characteristic emotional facial expression to accepted versus rejected offers. A male, female and emoji proposer represented each attitude. Error bars indicate standard error of the mean. * $p \leq .05$.

ULTIMATUM GAME OFFERS

S2, the presentation of the offer, was analyzed in a three-factorial design with the factors category (three levels: male, female, emoji), attitude (four levels: smiling/neutral, neutral/neutral, neutral/angry, neutral/sad), and offer (six levels: 0 - 5 Cents). P2 amplitudes showed no effects for category ($F(2, 108) = .59$, $p = .554$), attitude ($F(3, 162) = .32$, $p = .771$, $\varepsilon = .842$), and the interactions (all values of $p \geq .329$). However, we found a significant effect for offer ($F(2, 108) = 5.88$, $p < .001$, $\eta_p^2 = .098$, $\varepsilon = .851$). 5 Cent offers evoked more positive P2 amplitudes compared to 0 Cent ($p < .001$). Similarly, 4 Cent ($p = .024$) and 3 Cent ($p = .005$) evoked larger P2 amplitudes compared to 0 Cent. No further comparisons yielded significance (all values of $p \geq .065$). Concerning the N2 component, there were no effects of category ($F(2, 108) = 0.72$, $p = .884$, $\varepsilon = .762$), attitude ($F(3, 162) = 1.16$, $p = .323$, $\varepsilon = .896$), offer ($F(2, 108) = 1.57$, $p = .183$, $\varepsilon = .798$), and the interactions (all values of $p \geq .105$). Regarding P3 amplitudes, we examined a significant effect for offer ($F(5, 270) = 8.65$, $p < .001$, $\eta_p^2 = .138$, $\varepsilon = .816$). Cero cent offers elicited more positive amplitudes compared to 2 Cent ($p < .001$), 3 Cent ($p < .001$), and 4 Cent (p = .009). One cent evoked more positive amplitudes compared to 2 Cent (p = .001) and 3 Cent (p = .023). Category (F(2, 108) = 1.10, p = .336), attitude (F(3, 162) = 1.57, p = .693), and the interactions (all values of $p \geq .166$) were not significantly different.

EMOTIONAL FEEDBACK

We analyzed emotional feedback in a three-factorial design with the factors category (three levels: male, female, emoji), attitude (four levels: smiling/neutral, neutral/neutral, neutral/angry, neutral/sad), and decision (two levels: acceptance, rejection). Regarding N170 amplitudes following S3, the main effect of decision (F(1, 54) = 5.65, p = .021, η_p^2 = .095) showed that acceptance feedback evoked more negative amplitudes compared to rejection feedback. Attitude also provided a significant result (F(3, 162) = 11.34, p < .001, η_p^2 = .174). Post-hoc comparisons showed that proposers with neutral attitude evoked less negative N170 brain potentials compared to proposers with smiling, angry, and sad attitude (all ps < .006), whereas the other comparisons were not significant (all values of $p \geq .290$). We also found a significant interaction between attitude and decision (F(6, 324) = 18.02, p < .001, η_p^2 = .250). Proposers with angry attitude compared to neutral elicited more negative amplitudes for acceptance compared to rejection (p = .007). The same pattern was found for proposers with sad attitude (p < .001). Further, we found a significant effect of category (F(2, 108) = 15.05, p < .001, η_p^2 = .218, ε = .588). Feedback provided via emoji elicited more negative N170 amplitudes compared to male and female (ps ≤ .001) photographs. The remaining interactions did not yield significance (all values of $p \geq .060$).

Regarding P2 positivity, we found a significant effect of category (F(2, 108) = 8.37, p < .001, η_p^2 = .134). Both males (p = .002) and females (p = .009) elicited more positive amplitudes compared to emojis. Again, males and females did not differ (p = .680). However, P2 amplitudes revealed no effects for attitude (F(3, 162) = 1.92, p = .136, ε = .874), decision (F(1,

54) = .54, p = .462) and the interactions (all values of $p \geq .167$). N2 amplitudes showed a significant result for category ($F(2, 108) = 20.28$, $p < .001$, $\eta_p^2 = .273$), showing that feedback provided by emojis elicited more negative amplitudes compared to both males and females (ps < .001). Male and females did not differ ($p = .630$). Further, we found a significant interaction of category and decision ($F(2, 108) = 3.28$, $p = .046$, $\eta_p^2 = .057$, $\varepsilon = .909$). For emojis compared to males, acceptance feedback elicited more negative amplitudes than rejection feedback (p = .007). However, there were no significant effects of attitude ($F(3, 162) = 2.12$, $p = .099$), decision ($F(1, 55) = .03$, $p = .855$), and the remaining possible interactions (all values of $p \geq$ .132). P3 amplitudes also showed a significant effect of category ($F(2, 108) = 4.18$, $p = .018$, $\eta_p^2 = .072$) indicating that particularly emojis evoke significantly more positive P3 brain potentials compared to males ($p = .015$), but not compared to females ($p = .164$). We also found a significant, but unspecific effect of attitude ($F(3, 165) = 2.69$, $p = .048$, $\eta_p^2 = .047$). Decision ($F(1, 54) =.89$, $p = .348$), and possible interactions (all values of $p \geq .126$) did not yield significance.

DISCUSSION

The study aimed to compare behavioral and neural differences of emojis and real faces in a modified ultimatum game with emotional feedback. We presented proposers that reacted with distinct attitudes towards acceptance and rejection in a block-wise task. Each of these proposers was represented by emojis, males, and females. To the best of our knowledge, this is the first study to investigate the differences between real faces and emojis in a social interaction task.

We were able to replicate the influence of emotional feedback towards behavior in an ultimatum game, although some of our results differ slightly from Mussel et al. (2018). In the present study, participants more often accepted offers from proposers that smile after accepting an offer compared to proposers with other attitudes. When a human face represented the proposer, interaction with the sad attitude led to less often-rejected offers compared to the neutral control condition. However, when the proposer with the sad attitude was represented by emojis, acceptance rates did not differ from the neutral attitude. Since Derks et al. (2008) reported that emoticons are mostly used in positive contexts, the absence of higher acceptance rates with the sad emoji attitude might support this finding. To sum up, we found behavioral differences for the distinct attitudes, although these cues were irrelevant for the monetary outcome. In the present study, offers coming from female proposers did not deviate from male ones, which has been shown in previous research (Eckel & Grossman, 2001; Ma et al., 2015). Interestingly, emojis were capable of influencing behavior in a very similar way like photographs of males and females. The manipulation check strengthens this result as no main difference was found in valence between male, female, and emoji expressions. In contrast, we found that human faces convey more information that arouses people.

Regarding neurophysiological foundations of the reported behavioral effects, the results differ at some crucial points from the original study. Throughout the mere presentation, especially the emoji representing anger seems to enhance facial processing of N170. We could replicate the arousal effect for emotional expressions reported by Mussel et al. (2018). However, we only detected the effect for negative emotional expressions and not for positive ones. Generally, larger N170 amplitudes for negative facial expressions are in line with prior research (Batty & Taylor, 2003; Blau et al., 2007). Itier, Alain, Sedore, and McIntosh (2007) reported that the mere presence of eyes without a whole face led to a dramatic increase in N170 amplitude compared to inverted faces or faces without eyes. In contrast to complex faces, emojis might reveal core information more concisely and thus evoke larger N170 brain potentials. Finally, Summerfield and Egner (2009) showed that visual processing provided by areas of the sensory cortex becomes more efficient when stimuli are learned or expected and thereby lead to less pronounced N170 amplitudes. In contrast, novel stimuli require more processes of updating.

Until now, emojis are novel in scientific studies, and the neural activity might be enhanced due to the unfamiliarity compared to facial expressions that are frequently used.

Alternatively, the results can be interpreted according to research on the analytic and holistic perception of facial emotional expressions. Some studies have shown that the neural processing of facial expressions should be seen neither as strictly analytic nor holistic. Bombari et al. (2013) and Tanaka, Kaiser, Butler, and Le Grand (2012) proposed a dual-code view indicating that each specific task and the particular expression are crucial for underlying analytic and holistic processes. A processing step, where emojis might deviate from faces, lies within the grouping of emotional facial features based on their spatial configuration. This configuration results in a template of a holistic facial expression based on stored knowledge (Meaux & Vuilleumier, 2016). Probably, emojis fail to match the generic face template by content features (not by configural ones) and thus elicit more pronounced N170 brain potentials as the encoding requires more effort compared to the encoding of real faces.

Moreover, the deviance of emojis from human facial expressions continues at the N2 component. Maybe emojis might not provide sufficient social information to satisfy the individual need of gathering cues within a facial expression at early processing stages and thus produce errors. This assumption is supported by findings of social versus nonsocial stimulus material. According to Sakaki, Niki, and Mather (2012), nonsocial emotions are detected automatically, whereas socio-emotional stimuli require a more profound neural processing to be interpreted accurately. Further, basic perceptional (e.g., recognition of facial emotions) and high-order Theory of Mind processes need to be conducted, to attribute the emotional meaning to ambiguous social stimuli (Billeke & Aboitiz, 2013).

Concerning the processing of the different offer sizes, our results may indicate a linear effect of reward-positivity since more substantial amounts of money evoked larger P2 brain potentials. In contrast, we did not find the hypothesized u-shaped and linear pattern for N2 amplitudes.

Instead, we found a decreasing linear pattern for FRN amplitudes, as outlined in the supplement, which was calculated as a difference-measure of P2 and N2 brain potentials. Overall the finding is in line with reinforcement learning theory of feedback potentials (Baker & Holroyd, 2011; Hewig et al., 2010; Holroyd & Coles, 2002; Holroyd et al., 2008; Proudfit, 2015), although typically, reward positivity will have a longer latency and will overlay N2. However, reward positivity can vary sometimes in latency (Baker & Holroyd, 2011; Potts et al., 2006), and early effects of current trial outcomes at P2 have been found previously in an analysis of sequential effects of wins and losses (see Osinsky et al., 2012). Finally, we found offer-related effects in the following P3 component (Nieuwenhuis et al., 2004; Polich, 2007). Particularly extremely unfair (i.e., 0 Cent) offers elicited larger amplitudes compared to mid-value (i.e., 2-4 Cents) offers. Thus, unfair offers compared to mid-value offers are highly salient to individuals since they provide the most distinguishable information about a dovish versus reckless negotiation partner.

Concerning emotional feedback, we could show that emotional expressions provided by emojis elicit more negative N170 amplitudes compared to human identities. Furthermore, emotional proposers (i.e., smiling, angry, sad) evoke more negative amplitudes compared to a neutral control. Possibly, the neutral faces lack information and thus are more complicated to encode compared to unambiguous emotional expressions (see discussion on N170 above). Regarding N2, we could replicate the effect of the presentation task. Again, emojis elicited more negative amplitudes compared to male and female proposers. In consequence, emojis as feedback stimuli seem to be processed differently compared to human faces. One possible reason might be that they occurred more seldom compared to real faces as only 4 out of 12 identities provided feedback by emojis. Another explanation could be that emojis lack the necessary social information that we might expect to find within an ordinary facial expression. Unawareness about the gender and the countenance of an interaction partner might lead to unfulfilled expectations regarding valuable information. Further, emojis used for acceptance feedback (i.e., neutral and smiling) evoked more negative N2 amplitudes compared to negative emojis. We expected the rejection feedback (i.e., a sad facial expression) to produce no expectation mismatch since it reflects an intended reaction as reported in Mussel et al. (2018). As there were no effects for human faces, we could not find a neural signature for altruistic punishment.

We found that P2 amplitudes are heightened only for human proposers. Therefore, we suggest that they may be inherently more rewarding or salient compared to emoji proposers. Finally, we found heightened P3 amplitudes, especially for proposers represented by emojis. Previous research on P3 brain potentials linked enhanced amplitudes to unexpected stimuli (Courchesne et al., 1977; Duncan-Johnson & Donchin, 1977). Possibly, emojis are not that prominent within their use as a direct reward or punishment stimulus in the natural environment as they usually emphasize verbal content. As a remarkable difference to Mussel et al. (2018), we want to mention the absence of P3 effects regarding the different attitudes of the proposers and their facial expressions. Hence, motivational salience towards feedback might not be indicated.

We briefly want to mention some possible limitations in our study. Eventually, we have lost some behavioral and neural effects due to the constant interaction with one partner. As a consequence of the block-wise design, feedback might have been predictable, and thus diminishing the importance of the partner's behavior. However, a repeated interaction might appear more natural compared to trial-by-trial changing partners. In contrast, interleaved designs allow for unexpected occurrences and thus enhance deliberation, whether prior behavior (i.e., acceptance/rejection) might have influenced the proposer's behavior. Future studies might test both versions with a within-subjects two-day study or a between-subject design. Further, predetermined offer sizes might limit the subjective feeling of being able to punish the counterpart from the participants' perspective. Hence, a probabilistic study design would yield benefit towards behavioral results. In contrast, unequal distributions of feedback stimuli are yet a problem and might even be enlarged by this approach, which would make subsequent ERP quantifications less reliable.

To sum up, this study investigated the influence of real faces as opposed to emoji when used as emotional feedback stimuli in the ultimatum game. These stimuli reflect a response provided by the proposer indicating whether a possible punishment was successful. We could replicate the finding that the pattern of these responses influenced future decisions independent of the proposer's category. Electrophysiological results suggest that emojis and real faces convey different aspects of social relevance and cannot be exchanged without losing information.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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IMPLICATIONS FOR STUDY 4

So far, we have shown that both human faces and artificial emojis known from messengers can influence human decision making. In the first and third studies, both faces and emojis rewarding acceptance in the ultimatum game with a smile achieved a higher acceptance rate than a control identity. At the neuronal level, however, the representation of the emojis has differed greatly from face representation. In the last study of this dissertation, we wanted to address another aspect of social influence, namely that of socially unexpected feedback. For this purpose, we have again used exclusively human faces and removed all negative emotions from the study design in order to avoid generating too many implausible combinations of conditions. Consequently, we have assumed that socially unexpected feedback (i.e., smiling after an offer has been rejected) will lead to lower acceptance rates than control identity and create a specific neuronal pattern.

SMILING AS NEGATIVE FEEDBACK AFFECTS SOCIAL DECISION-MAKING AND ITS NEURAL UNDERPINNINGS

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ABSTRACT

A crucial aspect of social decision-making is the ability to learn from the outcomes of preceding decisions. In particular, learning might be influenced by the expectedness of feedback and its valence. Expectedness has largely been operationalized as the frequency of stimulus occurrence and not in terms of its social context. Therefore, we investigated the influence of socially unexpected feedback, i.e., smiling upon adverse events, on behavioral and neural responses. We used a modified version of the ultimatum game, a commonly used paradigm for economic decision-making, by implementing different proposer identities with a distinct reaction pattern towards accepted and rejected monetary offers. We could show that an identity, who reacted with a smile towards rejected offers, evoked lower acceptance rates compared to identities, who reward acceptance with a smile. Electrophysiological correlates indicate N170 effects for emotional identities compared to a neutral control identity. Regarding FRN and P3 brain potentials, we detected a particular function of the smiling face when used as a socially unexpected, negative feedback stimulus. Hence, individuals seek an unexpected smile despite the associated monetary loss, which is accompanied by distinct neural patterns.

INTRODUCTION

Humans often learn from their experience when it comes to social decision-making. There is a consensus that we learn and then adjust future action selection based on the evaluation of consequences and influences of our own behavior toward others (Huang & Yu, 2014; Maier & Steinhauser, 2013). However, the behavioral and neural correlates of unexpected positive feedback toward punishing behavior have not been in the focus of research yet.

The neural underpinnings of feedback evaluation have gained increasing attention in the past. Research using event-related potentials (ERPs) has identified a brain component, the feedback-related negativity (FRN; Miltner et al., 1997), which is sensitive to the valence of feedback. Holroyd and Coles (2002) and Holroyd et al. (2008) stated that the FRN indicates activation of a reinforcement learning system, which evaluates the outcome of a distinct decision to direct reward-oriented behavior. The FRN is generated when a negative signal for reinforcement learning is conveyed to the anterior cingulate cortex (ACC) via the mesencephalic dopamine learning system. Holroyd and Coles (2002) suggest that the system classifies feedback into events that are better or worse than expected and computes the difference between outcome and expectation as a reward prediction error (Holroyd et al., 2008). Alternatively, Alexander and Brown (2011) stated in their theory on the prediction of response-outcome that the ACC prognoses possible outcomes of behavior and indicates unexpected nonoccurrence of these outcomes. Thereby, the unexpectedness relates to both negative and positive outcomes. In the present study, we used positive feedback (i.e., a smiling facial expression) toward an adverse event (i.e., rejection of an ultimatum game offer, which means monetary nonreward). Hence, we investigated neural responses of feedback that in terms of frequency is fully expectable but in terms of social behavior might be unexpected.

In order to study (socially) unexpected facial expressions, we needed a controllable social environment, as in the ultimatum game (UG; Güth et al., 1982), which is a commonly used economic game for investigating human decision-making. In this task, one party is acting as a "proposer" and must divide a certain amount of money to share with the "responder." The responder subsequently accepts or rejects the offered amount of money. If the responder accepts an offer, the money is divided as proposed. Otherwise, no money will be distributed. For most people, offering 5 cents out of 10 would be considered a fair offer, whereas 1 cent would be considered unfair. According to rational choice theory (Morgenstern & Von Neumann, 1953), a rational proposer would offer the smallest possible amount to maximize his gains, and a rational responder would accept any offer, because receiving any money is better than gaining nothing. In contrast to rational choice theory, empirical findings show that offers below 20% of the money are rejected in 50% of all cases; and proposers offer approximately 40-45% of the money to the responder (Levine, 1998).

Recently, Mussel et al. (2018) and Weiß, Mussel, and Hewig (2019b) modified the UG by implementing different proposer identities, who reacted with distinct patterns of socioemotional feedback after participants accepted or rejected UG offers. On a behavioral level, systematic emotional feedback influenced decision-making in the task. Participants showed higher acceptance rates if the co-player consistently smiled upon acceptance compared to proposers showing neutral facial expressions. Building upon Mussel et al. (2018), we developed an additional modification of the UG, which allowed us to investigate the behavioral and neural consequences of socially unexpected positive feedback. A particular social framing could turn a stimulus that is usually associated with reward (i.e., a smile) into a stimulus covering negative content and thus lead to increased rejection rates. As an example of positive facial expressions as compensation for negative emotions, Ansfield (2007) showed that smiling when feeling distressed may serve a function in self-regulation. Otherwise, these smiles go along with negative social consequences.

In the present study, by realizing the socially unexpected smile, we also wanted to solve a methodological issue concerning unequally distributed feedback stimuli in preceding studies. Previous publications on emotional feedback (Mussel et al., 2018; Weiß et al., 2019a; Weiß et al., 2019b) worked with different identities, who reacted with emotional expressions to accepted and rejected UG offers. However, among these identities the neutral facial expression was overrepresented (Mussel et al., 2018: in 62.5% of the conditions, feedback was neutral). The actual frequencies depend on the decisions of the participants, which we cannot control. Only under the assumption of equally frequent acceptance and rejection is the probability now equally distributed for the different emotional facial expressions (50% neutral, 50% smiling). This is an advantage over previous studies. Regarding electrophysiology, we wanted to address the effects of social decision-making and emotional faces on N170, FRN, and P3 brain potentials. When watching human facial expressions compared with nonfacial stimuli, the N170 brain potential is larger, indicating a face-sensitive function of N170. Therefore, N170 is an established correlate of the visual processing of human faces (Bentin et al., 1996; Eimer, 2000; Rossion et al., 2000). Mussel et al. (2018) reported that the N170 reflected the processing of basic facial features since emotional faces elicited larger amplitudes for the presentation of faces without context and as feedback stimuli in the UG. In conclusion, we predict a valence effect of smiling faces over neutral faces both when presented context-free and as feedback stimulus toward the acceptance or rejection of an UG offer. Next, we addressed the FRN as an indicator for positive and negative feedback processing (Miltner et al., 1997). In order to investigate the neural underpinnings of social feedback, facial expressions have been linked to FRN brain responses in several studies. Pfabigan et al. (2011) reported that FRN was particularly large after negative and unexpected social feedback in a gambling task. With regard to the ultimatum game, Mussel et al. (2014) showed that a smiling compared with a neutral face preceding the offer not only led to higher acceptance rates but also to smaller FRN amplitudes. In contrast, Schreiner, Alexopoulos, Pfabigan, and Sailer (2010) showed that the FRN would be more pronounced for smiling proposers offering an unfair amount of money than for angry proposers making the same unfair offer. Osinsky et al. (2013) found that the face of a proposer who always makes unfair offers provokes a similar FRN brain response as to the offer itself. In addition, Mussel et al. (2018) found that the desired feedback expressions of an interaction partner (i.e., anger feedback after rejection of an unfair offer) led to a decrease in FRN amplitudes compared with looking at the anger face without context. Accordingly, some studies showed increased FRN for unexpected and/or negative social feedback, whereas others showed decreased FRN for positive and/or expected social feedback. Thus, we investigated the FRN in the context of socially unexpected positive feedback in the present study. We hypothesized that FRN amplitudes are smaller for unexpected positive feedback (i.e., following the rejection of an offer) in terms of social content compared with neutral feedback following the acceptance of an offer. This hypothesis is based on a valence account of FRN (Holroyd et al., 2008) rather than on an unexpectedness account of FRN (Alexander & Brown, 2011). Finally, the P3 component was analyzed to investigate attentional processing and subjective importance (Ito et al., 1998; Johnson, 1988; Polich, 2007) of UG offers and emotional feedback. Several studies (Hajcak et al., 2005; Hajcak et al., 2007; Johnson & Donchin, 1985) reported a valence-related modulation of P3 in decision tasks, indicating a larger positivity for positive compared with negative feedback. In the context of the UG, the P3 component was pronounced for fair compared with unfair offers (Qu et al., 2013; Wu et al., 2012). Ma et al. (2015) further indicated that this P3 effect was modulated by a proposer’s attractiveness. Whereas for attractive proposers no P3 difference regarding the fairness of an offer could be reported, unattractive proposers evoked larger P3 brain potentials for fair compared with unfair offers. In conclusion, Ma et al. (2015) showed that faces could have a meaningful impact on P3 amplitudes in the context of the UG. Moreover, Bellebaum et al. (2011) reported that P3 amplitudes were more prominent when participants gained a reward compared with gaining nothing at all. Regarding emotional feedback, we assume that P3 amplitudes will be heightened especially for the unexpected smile following the rejection of an offer. Although implemented as negative feedback, we believe that its positive valence might elicit larger P3 amplitudes compared with neutral feedback following accepted offers.

On the behavioral level, we expect that the identity who unexpectedly reacts with a smile toward the rejection of an offer will elicit lower acceptance rates compared with identities that reward acceptance with a smile.

The present study was designed to clarify whether unexpected content-related feedback would affect human decision-making. Therefore, we used a modified version of the ultimatum game with different proposers, who provide emotional feedback toward acceptance or rejection of an offer. Considering that in previous research expectedness was operationalized by the frequency of stimulus occurrence, the social context was used to investigate the influence of unexpected feedback. ERPs were recorded to analyze the effects of smiling versus neutral faces across a mere presentation task and when used as feedback stimuli within different proposer identities. To the best of our knowledge, this is the first study to investigate the social influence of unexpected positive feedback in a decision-making task.

METHODS

ETHICAL STATEMENT

The study was performed in accordance with the recommendations of Ethical Guidelines, The Association of German Professional Psychologists (Berufsethische Richtlinien, Berufsverband Deutscher Psychologinnen und Psychologen). All subjects gave written, informed consent in accordance with the Declaration of Helsinki before they participated in the experiment. During the experiment, a cover story was used, but they were told about this deception as soon as the task was over, which is common practice in psychological experiments.

PARTICIPANTS

A sample size of 51 was estimated for a medium effect of $\eta_p^2 = 0.06$, $\alpha = 0.05$, and $\beta = 0.95$ using G*Power (Faul et al., 2007). The determination was a based on a conservative estimation of the behavioral influence of different proposer identities on acceptance rates in the ultimatum game (Mussel et al., 2018; Weiß et al., 2019b). Finally, 56 subjects were recruited (37 females; mean age 28.53 years, $SD = 9.96$, range 19-62), who participated for monetary compensation of 15€. All participants gave written, informed consent and were debriefed after the end of the experiment.

EXPERIMENTAL PROCEDURE

For the present study, we selected five male and five female persons from the Radboud Faces database (Langner et al., 2010), each with two facial emotional expressions: happy and neutral. The first task (Figure 5.1) was a control task to examine context-free neural responses to emotional facial expressions. Thus, the participants were asked to look at the pictures without providing any action. For each participant, one male and one female person were randomly chosen and subsequently presented 25 times in random order (100 trials in total). Additionally, we conducted a manipulation check on the selected stimuli to evaluate their arousal and valence on a seven-point scale. In the second task, participants played ten rounds of a modified ultimatum game in the role of the proposer. Primarily, the purpose of this task was to facilitate understanding and enhance the plausibility of the cover story for the third task (see below). In each round, the participants could divide 10 cents into two shares: one for her/himself and one for the responder. There were six predefined shares, ranging from 0 to 5 cents. Irrespective of their choice, the participants subsequently received feedback that their offer was either accepted or rejected (in 50% of the cases). Finally, participants had the opportunity to send a picture to the other player to express how they felt about his or her decision. For this purpose, the two emotional pictures from Task 1 were presented, and female participants could select a happy or a neutral picture of the female person and vice versa.

In the third task, participants played eight blocks (with 48 trials each) of the modified ultimatum game in the role of the responder. All participants were informed that the offers were made by other participants who conducted the experiment on an earlier occasion and that both parties would be paid depending on the decisions made by the participant. Furthermore, we stated that we took a picture of each participant for the subsequent participant. In truth, the UG offers were predefined, as outlined below. Each trial began with a picture of either a male or female person with a neutral facial expression representing the proposer of the upcoming offer. The picture was taken from the pool of the eight persons who were not chosen in Task 1. Next, the offer made by this proposer was shown, representing a split of 10 cents, ranging from 0 to 5 cents for the responder. The offer was presented as a pie chart (e.g., 2/8 for the responder/proposer). During a block, each of the eight persons proposed each of the six possible offers exactly once. The order of the 48 offers was randomized for each participant. Afterward, the participants decided to either accept or reject the offer by pressing the left (acceptance) or right (rejection) arrow button. Their decision was shown for 1,200 ms along with the gained money (e.g., “Accept! You get 3 Cents!”). Finally, a picture with varying facial expression of the proposer was shown, indicating how he or she felt in answer to the decision of the participant. Thereby, each of the eight persons behaved in one of four particular ways, which we call the identity of this person. The happy identity reacted with a smile if an offer was accepted and a neutral expression if the offer was rejected. The neutral identity reacted with a neutral facial expression, irrespective of the decision of the responder. The content identity reacted with a smile, irrespective of the decision of the responder. Finally, the unexpected identity reacted with a neutral facial expression if the offer was accepted and a smile if the offer was rejected. For each participant, one male and one female person was randomly assigned to one of the four feedback patterns resulting in eight different identities (4 identities represented each by males and females). All stimuli were presented on a 17” screen with a grey background. Stimulus presentation and response recordings were controlled by PsychoPy 1.83 (Peirce, 2008). During the task, participants were seated in a comfortable chair with a distance of 70 cm between the head and the screen. Each of the pictures was 10-cm high and 6.65-cm wide, resulting in a visual angle of about 14.2° x 9.5°. The pie charts had a diameter of 2.5 cm (3.6° visual angle).

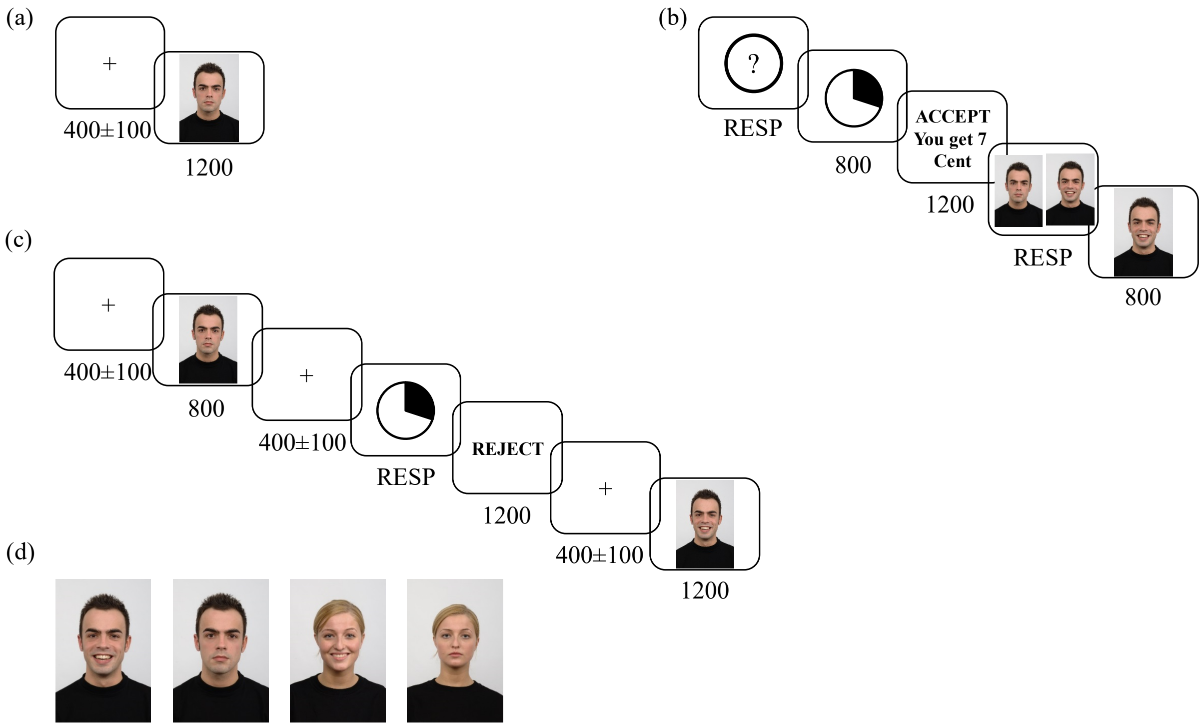

Figure 5.1. (a-c) Task timeline for the three paradigms. The numbers indicate presentation time in milliseconds. **(d)** Example pictures for smiling and neutral facial expressions (Langner et al., 2010).

EEG RECORDING AND QUANTIFICATION

The EEG was measured by Ag/AgCl-electrodes located in an electrode cap in 32 scalp positions according to the international 10-20 system: FP1, FP2, Fz, FCz, F3, F4, F7, F8, F9, F10, FC1, FC2, FC5, FC6, CZ, C3, C4, T7, T8, CP1, CP2, TP9, TP10, P3, P4, P7, P8, P09, PO10, O1, and O2. An additional electrode to register eye movements and blinks, called electrooculography (EOG), was put below the left eye. All electrode impedances were kept below 5 kOhm for the EEG, and data were referenced online to the vertex (Cz). Data were recorded with a sampling rate of 500 Hz and a high cutoff filter of 80 Hz with BrainVision BrainAMP Standard (Brain Products GmbH, Gilching, Germany) and the respective BrainVision Recorder software. For the processing of the collected EEG data, we used MATLAB (MathWorks, Natick, MA) and EEGLAB (Delorme & Makeig, 2004). Initially, we detected inappropriate channels for each participant and interpolated them. We segmented epochs from −500 ms to 1,000 ms around the target markers. For baseline correction, we assessed a window of −200 ms to 0 ms. Regarding artifact rejection, we used the criterion of z-value >4 for the amplitude and kurtosis of the signal. Before applying independent component analysis (ICA) according to Delorme et al. (2007), we used a band-pass filter from 1 to 40 Hz. Afterward, we applied the extensions ADJUST (Mognon et al., 2011) and MARA (Winkler et al., 2011), which operate with SASICA software (Chaumon et al., 2015) to choose ICA components for artifact rejection. Offline reference was transformed to current source density like in other ERP studies before (Kayser et al., 2010; Milne, 2011; Weiß et al., 2019a), and data were filtered with a 20-Hz low pass filter. Statistical calculations were conducted for each participant for each condition ±20 ms around the positive or negative peak, respectively. N170 latency was quantified as the negative peak between 130 and 210 ms (Johnston, Molyneux, & Young, 2014; Mussel et al., 2018; Weiß et al., 2019a) pooled at electrodes P7 and P8. Latencies for FRN were calculated as the negative peak between 200 and 400 ms at electrode site FCz, where their maxima would typically occur (Burle et al., 2008; Gehring & Willoughby, 2002; Holroyd & Coles, 2002). The P3 component was calculated as the positive peak between 250 and 400 ms at Pz electrode site, as illustrated in Figure 5.2.

STATISTICAL ANALYSES

Data were analyzed using repeated-measures analyses of variance (ANOVA) in SPSS software (IBM, Armonk, NY). For all ANOVA reported in the following paragraph, we assumed α = 0.05. In case of violation of sphericity assumption, epsilon (ε) and corrected *p* values are reported. We used Hyunh-Feldt adjustment factors for degrees of freedom, apart from when $\varepsilon < 0.75$. In this case, we adjusted the degrees of freedom, according to Greenhouse-Geisser. When we found a statistically significant result for any ANOVA, we computed Bonferroni-adjusted pairwise comparisons for further investigation of the effects.

The manipulation check regarding the valence and arousal of the stimuli was analyzed with a one-factorial repeated-measures ANOVA with the factor emotion (two levels: smiling and neutral). In the mere presentation task, N170, FRN, and P3 brain potentials were investigated with a one-factorial ANOVA with the factor emotion (2 levels: smiling, neutral). Behavioral results regarding acceptance rates were obtained by investigating the factors identity (4 levels: happy, neutral, content, unexpected), block (8 levels: 1-8), and offer (6 levels: 0–5 cents). Emotional feedback was investigated with a two-factorial, repeated-measure ANOVA with the factors identity (4 levels: happy, neutral, content, unexpected) and decision (2 levels: acceptance, rejection).

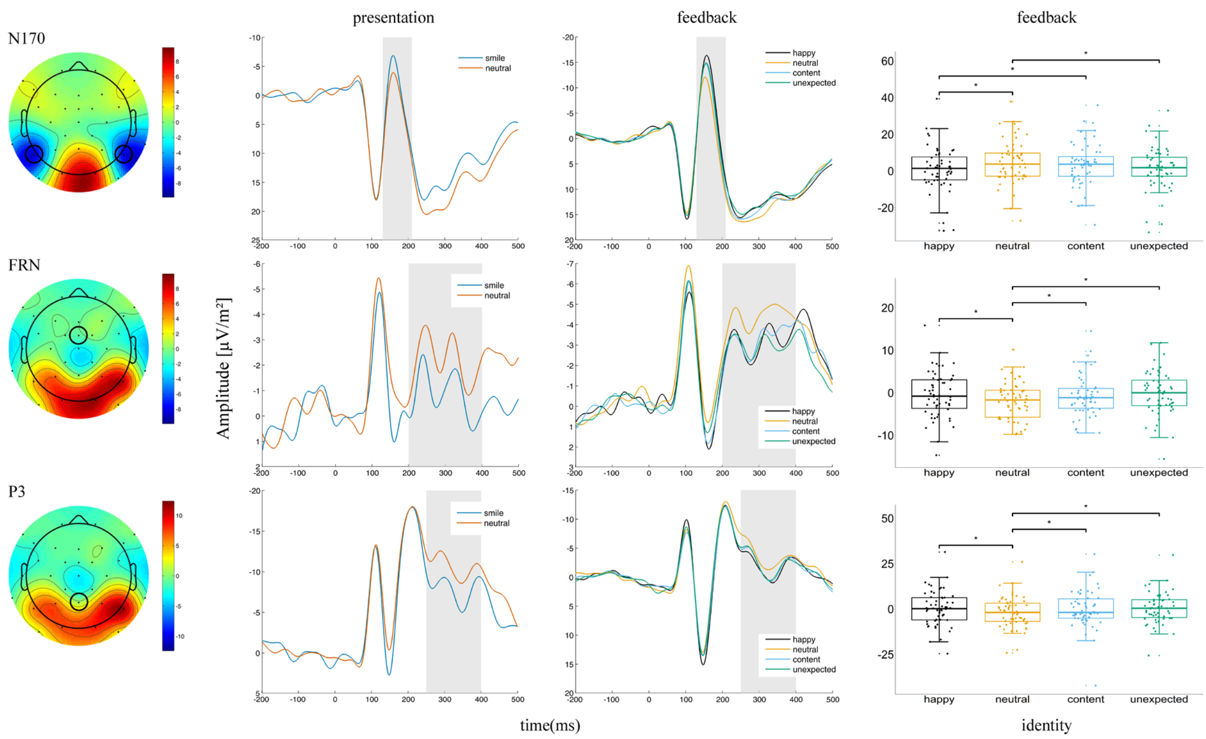

Figure 5.2. Grand averages according to the presentation task and emotional feedback. The first row contains results averaged across electrodes P7 and P8 (relevant for N170), the second row results for electrode FCz (relevant for FRN), and the third row for electrode site Pz (relevant for P3). In the first column, grand averages regarding the presentation task are displayed. In the second column, grand averages for the main effect of identity in the feedback condition are depicted. Finally, in the third column, individual data for the main effect of identity are displayed with boxplots. The whiskers have the length of 1.5 times the interquartile range. The grey areas highlight the search windows for peak detection. The topographic maps are also based on these time windows and aggregated across stimuli. $^*p \leq 0.05$

RESULTS

MANIPULATION CHECK

Smiling facial expressions obtained higher valence ratings compared with neutral ones, $F(1,53) = 359.01$, $p < 0.001$, $\omega_p^2 = 0.866$. Ratings regarding arousal also depended on the emotional valence of the stimulus, $F(1,53) = 38.60$, $p < 0.001$, $\omega_p^2 = 0.406$, because smiling faces were rated higher in arousal compared with neutral facial expressions.

Furthermore, we conducted an explorative analysis on the feedback selection in task 2, where participants acted as proposers 10 round to validate the concept of unexpected positive social feedback. A chi-square test of independence was performed to examine the relationship between acceptance/rejection and feedback selection. The relation between these variables was significant, X^2 (1, N = 56) = 374.9, p < 0.001. Positive feedback was selected significantly more often than neutral feedback after acceptance, and neutral feedback was selected significantly more often than positive feedback after rejection.

BEHAVIORAL RESULTS

Regarding behavior, we found a significant effect of identity, F(3,165) = 7.69, p < 0.001, ω_p^2 = 0.106, ε = 0.546, and offer, F(5,275) = 151.80, p < 0.001, ω_p^2 = 0.728, ε = 0.545. Furthermore, there was a significant interaction of identity and block, F(21,1155) = 2.37, p = 0.014, ω_p^2 = 0.023, ε = 0.407. The unexpected identity obtained significantly less accepted offers compared with the happy identity (p = 0.014) and the content one (p = 0.045) but not compared with the neutral identity (p = 0.666). Furthermore, the acceptance rates for the happy (p = 0.002) and the content identity (p = 0.031) were significantly higher compared with the neutral identity, whereas happy and content identities did not differ (p = 1; Figure 5.3). The comparison of the six offer sizes indicated higher acceptance rates for higher offers. All offers differed significantly (all values of p < 0.001), apart from 4 cents and 5 cents (p = 0.240). The significant interaction of identity and block is displayed in Figure 5.4. In the first two blocks, acceptance rates did not differ significantly (all values of $p \geq 0.715$). Beginning in the third block, the main effect of identity was mostly stable across the remaining five blocks corroborating the above findings. We found no significant effect for block, F(7,385) = 0.73, p = 0.572, ε = 0.585; the interaction between identity and offer, F(15,825) = 1.59, p = 0.124, ε = 0.534; the interaction between block and offer, F(35,1925) = 1.09, p = 0.354, ε = 0.419; and the three-way interaction of identity, block and offer, F(105,5775) = 0.82, p = 0.718, ε = 0.239.

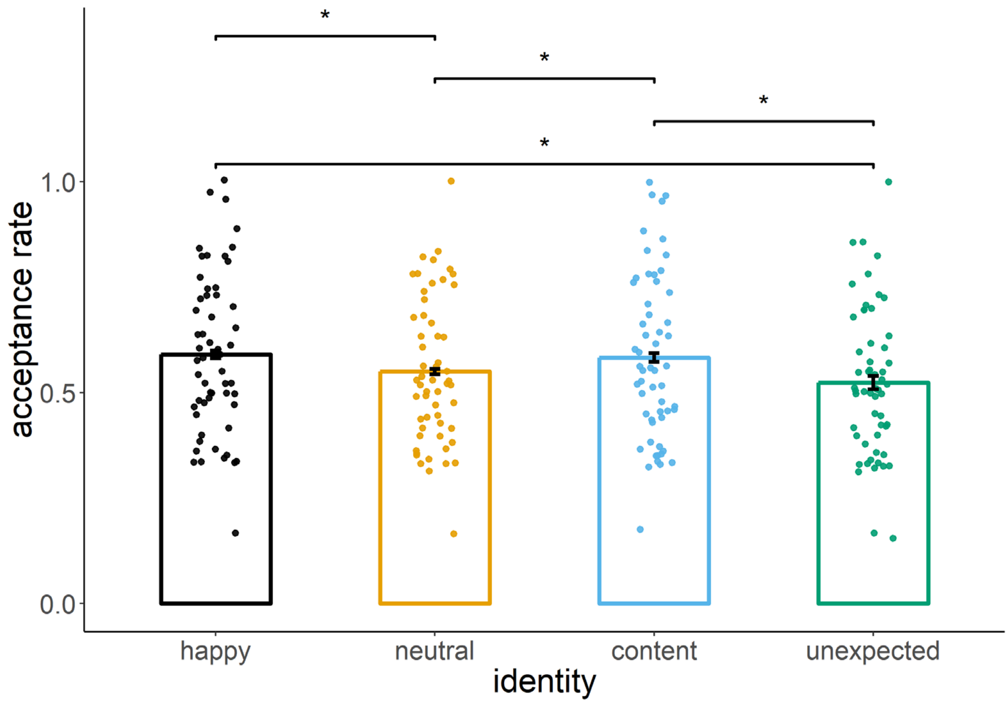

Figure 5.3. Average acceptance rates, depending on the identity of the proposer. Each identity reacted with a characteristic pattern of emotional facial expressions towards accepted and rejected offers. Data points represent the mean acceptance rate of each subject per identity. Error bars indicate standard error of the mean. *$p \leq 0.05$

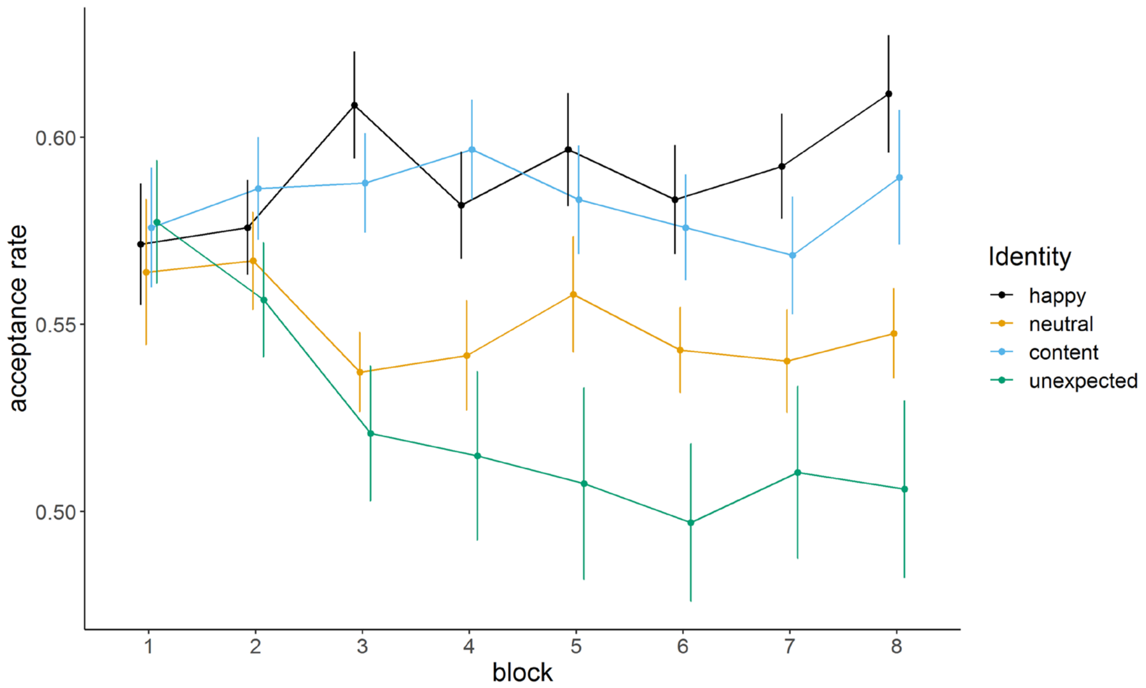

Figure 5.4. Average acceptance rates, depending on the block in the task and the identity of the proposer. The plot indicates learning curves as a significant interaction of block and identity. Error bars indicate standard error of the mean.

ELECTROPHYSIOLOGICAL RESULTS[2]

In the presentation task, we detected a significant effect of emotion on N170 brain potentials, $F(1,55) = 13.08$, $p = 0.001$, $\omega_p^2 = 0.174$, indicating that smiling faces evoked larger N170 amplitudes compared with neutral faces. FRN amplitudes[3] also showed a main effect of emotion, $F(1,55) = 9.31$, $p = 0.003$, $\omega_p^2 = 0.127$. The neutral facial expression elicited larger FRN brain potentials compared to the smiling face. Likewise, the main effect of emotion on P3 brain potentials indicated larger amplitudes when a smiling compared with a neutral face was presented, $F(1,55) = 9.31$, $p = 0.003$, $\omega_p^2 = 0.127$.

[2] We also analyzed the effects of the presented offers in the ultimatum game. These results and a short discussion are outlined in the online supporting information.
[3] We observed two peaks in the FRN time-window (Figure 5.2), and therefore ran separate analyses on the two peaks (time-windows: 200-300 ms and 300-400 ms). The results were almost identical to the analyses presented in the *Results* section. Only within the second time-window, the interaction of identity and decision regarding emotional feedback was significant and not marginally significant, as reported in the *Results*. The direction of all effects did not deviate from the analyses on the general time-window.

Regarding emotional feedback and N170 brain potentials, the main effect of identity, $F(3,162) = 21.35$, $p < 0.001$, $\omega_p^2 = 0.268$, was qualified by a significant interaction with decision, $F(3,162) = 21.40$, $p < 0.001$, $\omega_p^2 = 0.269$, $\varepsilon = 0.873$. The neutral identity evoked significantly less negative amplitudes compared with the happy and the unexpected identity (all values of $p \leq 0.045$). Furthermore, the happy compared to the content identity evoked more negative amplitudes ($p < 0.001$). No further comparisons yielded significance (all values of $p \geq 0.054$). Within the happy identity, the neutral face following rejection evoked more negative amplitudes compared with the smile following acceptance ($p = 0.003$). The neutral identity's facial expressions did not differ ($p = 0.335$). In contrast, the content identity's smile following acceptance evoked significantly more negative N170 brain potentials compared with the smile after rejection ($p < 0.001$). Regarding the unexpected identity, the smile following rejection evoked more negative amplitudes ($p < 0.001$) compared to the neutral face after acceptance. For the factor decision no effect could be reported, $F(1,54) = 1.72$, $p = 0.194$.

Next, we found a significant effect of identity on FRN brain potentials, $F(3,162) = 4.62$, $p = 0.004$, $\omega_p^2 = 0.061$. The neutral identity evoked significantly more negative amplitudes compared to all other identities (all values of $p \leq 0.039$). We examined a marginally significant interaction between identity and decision, $F(3,162) = 2.59$, $p = 0.055$, $\omega_p^2 = 0.027$. Within the unexpected identity, the neutral face following acceptance elicited more negative FRN brain potentials than the smiling towards rejection ($p = 0.013$), as illustrated in Figure 5.5. No further comparisons yielded significance (all values of $p \geq 0.271$). Concerning the factor decision, no effect was found, $F(1,54) = 1.66$, $p = 0.203$.

Finally, the main effect of identity on P3 brain potentials, $F(3,162) = 5.39$, $p = 0.001$, $\omega_p^2 = 0.073$, $\varepsilon = 0.896$, was qualified by a significant interaction between identity and decision, $F(3,162) = 5.39$, $p = 0.001$, $\omega_p^2 = 0.073$. The neutral control identity elicited significantly less positive P3 amplitudes compared with all other identities (all values of $p \geq 0.021$). Within the unexpected identity, rejection (i.e., a smile) evoked more positive P3 amplitudes compared with acceptance ($p = 0.001$; Figure 5.5). For the content identity, the smile toward acceptance elicited more positive P3 amplitudes compared with the smile following rejection ($p = 0.032$), whereas all other identities showed no significant differences (all values of $p \geq 0.278$). Decision did not show any effect, $F(1,54) = 0.93$, $p = 0.339$.

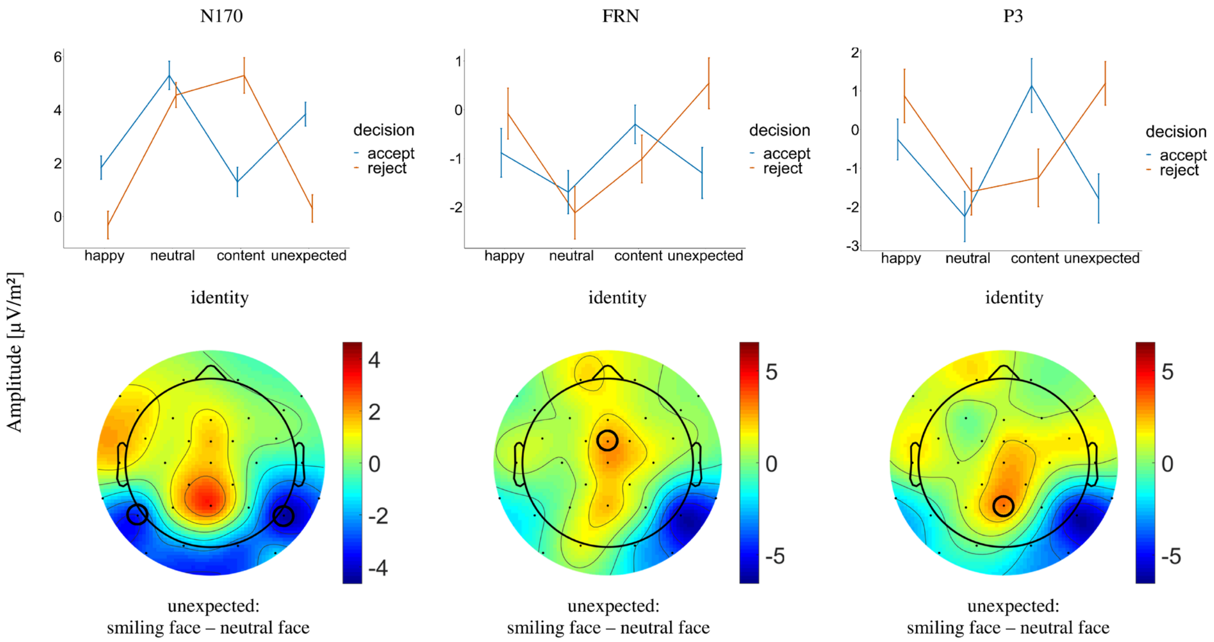

Figure 5.5. Interaction of identity and decision in the feedback task. The first row indicates the two-way interaction of identity and decision for N170, FRN, and P3 brain potentials, respectively. The second row shows difference topographic maps for the unexpected identity. The unexpected identity reacted with a smile toward rejection and a neutral face toward acceptance. In the first column, rejection-acceptance at the minima for the N170 component (160ms) at the P7 and P8 electrode sites is indicated. In the second column, rejection-acceptance at the minima for the FRN (300 ms) at the FCz electrode site is indicated, and in the third column rejection-acceptance at the maxima for P3 (333 ms) at the Pz electrode site, respectively.

DISCUSSION

We investigated behavioral and neural responses to different proposer identities in a modified ultimatum game with emotional feedback. As a novel contribution, the present study focused on how socially unexpected feedback alters acceptance rates and underlying neurophysiological correlates. Thereby, we were able to show the influence of emotional feedback toward behavior in the ultimatum game, as initially reported by Mussel et al. (2018). In the present study, participants more often accepted offers coming from proposers who smile toward accepted offers and who smile independent of the responder's decision. In contrast, acceptance rates were lower for the neutral identity and the unexpected identity who smiled upon rejection.

Descriptively, the unexpected identity reached the lowest acceptance rate (52%) followed by the neutral (55%), the content (58%), and the happy identity (59%). According to our assumptions, we were able to create an identity that altered behavior, although by positive feedback toward rejection. The unexpected feedback may be linked conceptually to personality traits, such as cynicism. Selfish and reckless attributes of cynics (Dean, Brandes, & Dharwadkar, 1998; Graham & Graham, 1990) could facilitate anger, sadness, and withdrawal from social interactions (Greenglass & Julkunen, 1989). Consequently, lower acceptance rates for the unexpected identity mirrored findings reported by Demerouti, Xanthopoulou, and Bakker (2018), who investigated cynical behavior in an employee-customer relation. The authors reported that cynical employees showed more negative actions and reactions toward customers, which subsequently led to less satisfied customers. A second interpretation might be that a smile after the rejection of an offer merely evokes aggression, which could be intended to signal dominance, or that it might appear simply odd or irritating. Furthermore, for individuals who strive for the reward of a smiling face, the rejection of offers coming from the unexpected identity yielded immediate positive feedback in terms of reinforcement learning. However, seeking reward would lead to a loss of money, which would yield a strong conflict as the reward of the smile goes along with the absence of a monetary reward and vice versa. Finally, the meaning of the smile could vary as a function of offer. As Niedenthal, Mermillod, Maringer, and Hess (2010) state, a human face expressing a smile is the most complex facial expression and therefore may transport very complex messages. Possibly, positive feedback following the rejection of an unfair offer might be interpreted as some sort of apology by the proposer.

People encounter and learn from dyadic social interactions over time. Therefore, we investigated learning curves across the blocks for the proposer identities in the ultimatum game. As the interleaved design in the present task was rather complex, the participants needed the first two blocks of trials to get to know the distinct feedback patterns of the proposers. However, after these two initial blocks, the acceptance rates began to diverge. In the intermediate blocks, the identity with the highest acceptance rate switched between the happy and the content identity, both rewarding acceptance with a smile. The neutral and the unexpected identity, both responding with a neutral face to acceptance, steadily received the lowest acceptance rates. Interestingly, the unexpected identity obtained continuously lower acceptance rates over the course of time. Hence, social learning might imply that individuals use (un-)successful interactions to reevaluate the meaning of social cues (Zaki, Kallman, Wimmer, Ochsner, & Shohamy, 2016).

In the mere presentation task, we found a frequently reported effect of emotional valence on N170 brain potentials (Almeida et al., 2014; Blau et al., 2007; Blechert, Sheppes, Di Tella, Williams, & Gross, 2012; Hinojosa et al., 2015), as smiling faces elicited more pronounced N170 amplitudes compared with neutral ones. Regarding FRN, we observed that neutral facial expressions compared to smiling ones elicited more negative brain potentials. In line with the results reported by Mussel et al. (2018), the FRN might signal the conflict processing toward neutral faces, because they do not indicate a negative or positive emotion. Furthermore, smiling faces are inherently rewarding as compared to neutral facial expressions. They can be interpreted as feedback stimuli, which are better than expected and thus elicit a reduced FRN or a feedback positivity (Holroyd et al., 2008). Pronounced P3 amplitudes for smiling faces might further indicate the benefits of a smile, because it inherently might be more salient to an individual compared with a possibly unimportant neutral facial expression. At this point, we want to mention that the FRN in both presentation and feedback task is somewhat noisy, which might have occurred due to our relatively short interstimulus interval (for discussion on the influence of inter-stimulus intervals on P3 amplitudes see Sambeth, Maes, & Brankačk, 2004). We therefore point to evaluate the FRN results with caution.

Concerning emotional feedback, we reported an effect of valence on N170 brain potentials. Both the content and the unexpected identity evoked more negative deflections compared with the neutral control. However, the interaction revealed that for the happy identity, the neutral face following rejection elicited more negative amplitudes than the smile following acceptance. In contrast, within the unexpected identity, the smile upon rejection compared with the neutral face upon acceptance evoked greater N170 amplitudes. Calvo and Nummenmaa (2016) presume that the differentiation between emotional and nonemotional affective faces is based on arousal. Thus, the N170 component might have indicated arousal toward feedback after a subject rejected an offer preceding the valuation of its emotional valence. Positive and neutral feedback after a monetary reward might not be that arousing as the reward per se. However, feedback after nonreward might add arousal to the monetary nonreward. Because this effect only occurred when stimuli differed within an identity, the relativity of rejection versus acceptance feedback might play a key role in this arousal component. Next, the FRN results followed our predictions. We expected the smallest FRN for unexpected positive feedback after rejecting an (unfair) offer. Two different explanatory approaches are discussed below. First, we will focus on the similarity between the mere presentation task and the feedback effects. Second, we will provide possible interpretations for the expected FRN effect for unexpected positive feedback. The FRN results of social feedback mirrored the findings of the presentation task, because the control identity compared with the other identities evoked more negative FRN brain potentials. In consequence, the absence of emotional feedback seemed to evoke greater conflict or a more negative evaluation compared with the other feedback patterns used in this study, which is in line with previous research reporting enhanced FRN for conflict monitoring (Donkers & Van Boxtel, 2004). Moreover, the absence of reward within the control identity might have caused pronounced negativity compared with identities that reward either acceptance or rejection with a smile. Bellebaum and Daum (2008) showed that the FRN for expected nonreward in a learning paradigm was significantly larger compared with expected reward. Accepting an offer from the unexpected identity did not lead to a rewarding stimulus compared with rejecting an offer from this proposer (neutral face vs. smiling face). Therefore, the larger FRN amplitudes for acceptance feedback might reflect a conflict about the absence of expected positive feedback. Similar to the N170 results, the relativity of acceptance versus rejection feedback might drive this effect. Whereas for the happy identity the positive feedback upon acceptance and the neutral feedback upon rejection coincide with expectable behavior, the feedback pattern of the unexpected identity contradicts expectations. Alternatively, the smile invited subjects to reject offers, thus leading to a decrease in FRN. Hence, participants could have aimed to provoke the positive feedback of the unexpected identity, which could be the reason for less negative brain potentials toward the intended reaction (Mussel et al., 2018). Furthermore, individuals underlie an optimism bias (Sharot, 2011). A misprediction of future occurrences (i.e., the assumption that the unexpected identity would sometime also smile upon acceptance) might lead to a reduced processing of the feedback towards an adverse event (i.e., loss of money), as the social feedback was rewarding. Decreased FRN amplitudes for the feedback smile might further indicate that the smile was perceived as a polite apology of the proposer for his or her unfair offer or an acknowledgement of having done something wrong. The reward-like neural response to the smile might thus be interpreted as successful costly punishment, i.e., the receiver renounced a financial benefit in order to penalize the proposer for his or her unfair offer, and the emotional facial expression of the proposer signals that the action was successful.

Regarding P3 brain potentials, we found the expected larger amplitudes for rejection feedback (i.e., a smiling face) of the unexpected identity. Similar to the results of the FRN, P3 results are first discussed in relation to the presentation task and then in relation to the feedback evaluation. As in the presentation task, smiling faces as feedback after accepted offers and the smiling face after rejected offers of the unexpected identity showed larger P3 amplitudes than the neutral faces. However, the smiling face after rejection from the content identity deviated from this pattern and showed P3 amplitudes of similar magnitude as the neutral feedback faces. Hence, the context of feedback valence between and within identities seems to alter its neural representation. The increased P3 brain potentials for proposers who reacted emotional with a smile to either acceptance or the smile after rejection from the unexpected identity might indicate a particular strong recognition of these identities. For instance, Calvo and Beltrán (2013) showed that P3 amplitudes for loved faces were larger compared with babies, neutral, famous, and unknown faces. Although not necessarily loved, the affective proposers might be more likeable than the neutral control. Furthermore, the unexpected identity's smile upon rejection compared with the neutral face following acceptance might reflect an even stronger recognition as the smile was socially unexpected.

We briefly address some of the limitations of the present study. First, we did not assess the concrete meaning of the feedback smile following the rejection of an offer. We could have asked the participants to rate each of the identities according to social affective dimensions such as likeability and trustworthiness. Second, a probably confounding factor when interpreting the findings of the present study is that, according to our manipulation check, smiling faces were rated as more arousing, compared to neutral facial expressions. According to Schupp, Markus, Weike, and Hamm (2003), ERPs are sensitive to the arousal of a stimulus, independent of its valence. Furthermore, Bradley, Greenwald, Petry, and Lang (1992) reported that viewing time and the memorization of pictures is also related to higher arousal, indicating enhanced attention and encoding. Hence, an elevated level of motivational and affective attraction by the smiling faces might have produced some artificial effects, because they were physiologically more relevant than the lower arousing neutral faces.

CONCLUSIONS

In the present study, we focused on the emotional influence of an unexpected acting identity who reacted with positive feedback (i.e., a smile) toward an adverse event, i.e., the rejection of an offer in the ultimatum game. The distinctive character of this kind of interaction partner is accentuated by obtaining lower acceptance rates compared with identities that reward acceptance with a smile. Further evidence stems from neural components, as FRN brain potentials indicate heightened negativity for the acceptance feedback coming from the unexpected identity (a neutral face). Additionally, larger P3 brain potentials for the smile provided by the unexpected identity compared to the neutral face following acceptance indicated subjective relevance. To sum up, we were able to show that positive feedback does not necessarily have to be interpreted as such, and by social framing, it could have different meanings, such as a friendly apology.

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SUPPLEMENT

In this supplement, we report results concerning electrophysiological responses (FRN and P3) following an additional stimulus: the presentation of the offer.

HYPOTHESES

Regarding FRN, we expect offers of medium size (2 and 3 cents) to elicit more negative FRN amplitudes (Mussel et al., 2014). Furthermore, we predict that P3 brain potentials will be more positive for fair as compared to unfair offers (e.g., Qu et al., 2013; Wu et al., 2012).

OFFER PRESENTATION

The neural analyses concerning offers presented in the ultimatum game included the factors identity (four levels: happy, neutral, content, cynical), and offer (six levels: 0 – 5 cents). The analysis revealed a significant effect of offer on FRN, $F(5,275) = 12.15$, $p < 0.001$, $\omega_p^2 = 0.165$, $\varepsilon = 0.871$. Post-hoc comparisons indicated a u-shaped form with 0 Cent evoking less negative amplitudes compared to 1 cent ($p < 0.001$), 2 cents ($p = 0.002$), and 3 cents ($p = 0.033$). 5 cents elicited more positive amplitudes compared to 1 cent, 2 cents, and 3 cents (all values of $p < 0.001$). Further, 4 cents elicited more positive FRN amplitudes compared to 1 cent ($p = 0.013$), whereas all other comparisons were not significantly different (all values of $p > 0.100$). Regarding identity, $F(3,165) = 0.64$, $p = 0.589$, and the interaction between emotion and identity no effects could be reported, $F(15,825) = 1.11$, $p = 0.341$, $\varepsilon = 0.944$. Concerning P3 positivity, we examined no main effect of offer, $F(5,275) = 1.59$, $p = 0.177$, $\varepsilon = 0.787$. Again, identity, $F(3,165) = 0.86$, $p = 0.463$, and the interaction of identity and offer did not show any effect, $F(15,825) = 1.18$, $p = 0.278$, $\varepsilon = 0.840$.

DISCUSSION

Regarding ultimatum game offers, we found larger FRN amplitudes in conditions of low to medium-sized offers (i.e., 1 or 3 cents). In these conditions, it is not easy to decide whether to accept or reject, compared to unfair (i.e., 0 cents) and fair (5 cents) conditions, as reported by Mussel et al. (2014). Therefore, we were able to show that the FRN would indicate conflict in the subjects. In the later P3 component (Nieuwenhuis et al., 2005; Polich, 2007), particularly unfair (i.e., 0 cents) offers elicited larger amplitudes compared to lower mid-value (i.e., 2 cents) offers. Hence, unfair offers are more salient to individuals compared to mid-value offers, since they would be less expected from an interaction partner. Probably stacks of 20% of the total amount would be considered as socially minimally fair and therefore elicit less pronounced P3 amplitudes.

3. GENERAL DISCUSSION

3.1. SUMMARY

This dissertation intended to shed more light on the influence of socioemotional feedback in economic decision-making situations at both the behavioral and neural levels. The experiments were aimed at investigating the mechanisms of emotional feedback with classical human faces as well as new ways of digital communication using emojis. The degree of complexity of the artificial emojis was adapted successively to current messenger services across the studies in order to be able to measure the influence of these stimuli on everyday life as closely as possible. The results could show that, except for abstract emojis, rewarding feedback in all scenarios led to increased acceptance rates in the ultimatum game and therefore, more utility for both parties. In addition, the first study showed that even sad feedback upon the rejection of an offer can lead to increased acceptance rates, which can be interpreted as the responder's sympathy with the proposer. At the neuronal level, the results differ distinctively. We were able to show that negative feedback can be a sign of successful altruistic punishment, since the FRN has decreased significantly compared to the pure observation of negative faces. This neural marker may indicate that negative feedback is interpreted as the consequence of intended punishment of the counterpart, a confirmation of the own goal of action. Furthermore, it could be shown that basal emojis can have a framing effect on social interaction partners. It was possible to classify certain opponents according to their feedback behavior, even if no specific influence of individual feedback reactions on a behavioral level was identified. The direct comparison of more realistic emojis and human faces could not show any differences in the acceptance behavior of the subjects - in both cases the rewarding positive identity achieved higher acceptance rates compared to the neutral control identity. However, there were significant differences in the neural processing of human faces and emojis. Both the face-specific component N170 and the FRN showed significantly greater negativities for the emojis. One possible explanation for this result was that emojis do not match the neural template of a neutral human face and thus deviate from the expected social characteristics of a human face. In the last study the influence of socially unexpected positive feedback was investigated. It could be shown that positive feedback after a rejected offer at the behavioral level led to significantly lower acceptance rates compared to the neutral control identity. Furthermore, this unexpected positive feedback showed a distinct activation in the FRN and P3 components. This neural activity reflects the special function of the rewarding face as a negative feedback stimulus and underlines its unexpected and therefore salient character.

These results provide an important insight into the study of social feedback and its influence on human behavior. In the following, these findings will be embedded in the existing literature and future research possibilities will be presented.

3.2. IMPLICATIONS

Although according to *rational choice theory* (Von Neumann & Morgenstern, 1944) individuals should accept all offers to maximize their own profit, they reject a considerable portion of the (unfair) offers across all our studies. The rejection rates act as a function of fairness, i.e., the more unfair an offer appears, the more likely it is to be rejected (Mussel et al., 2013; Sanfey, 2007). Although emotional factors should have no influence on monetary decisions according to *rational choice theory* and were indeed irrelevant to the monetary outcome in our studies, we were able to show that people deviate from rational choice as acceptance rates were higher for identities who reward acceptance with a smile. Several studies have already shown that affective processes have a significant influence on decisions in the ultimatum game, although they might lead to monetary loss (e.g., Harlé & Sanfey, 2007; Mussel et al., 2014; Pillutla & Murnighan, 1996). The increased acceptance rate found in study 1 for an identity that may indicate sorrow in response to the rejection of an offer could not be replicated in study 2 and 3. Hence, there could be interindividual differences involved that favor this mechanism (see chapter "individual differences"). In the literature, the findings regarding the influence of valence also seem to be inconsistent. On the one hand, several studies (e.g., Andrade & Ariely, 2009; Harlé & Sanfey, 2010; Riepl et al., 2016) showed that positive emotions such as amusement or happiness increase acceptance rates, whereas negative emotions such as disgust (Moretti & Di Pellegrino, 2010) and sadness (Harlé & Sanfey, 2007) decrease them. On the other hand, further studies could also find an increased acceptance rate after the induction of disgust (Bonini et al., 2011) or anger (Harlé & Sanfey, 2010). In the latter study, it is argued that the motivational component of these negative emotions could be decisive. In the case of anger, an approach-related motivation, such as amusement, would determine behavior. However, it should be noted that the latter mostly refers to the influence of task irrelevant emotions (i.e., incidental emotions), which are for this reason not optimally comparable with our task related emotional influence.

In general, there is a significant difference between the findings of tasks on *reinforcement learning* as researched in many studies and our presented paradigm. Most of the time the subjects were explicitly informed about the meaning of a certain cue (e.g., Baker & Holroyd, 2008; Liao, Gramann, Feng, DeáK, & Li, 2011). This would imply for our paradigm that we would have had to introduce the different identities and their reaction patterns beforehand. However, we wanted to explicitly focus on independent learning of the social interactions with the counterpart in order to avoid that participants interact with the identities with reservations. In addition, other studies often used elementary forms such as depictions of lemons or gold bars as cues (e.g., Martin & Potts, 2011; Potts et al., 2006) and therefore not as complex stimuli as faces of human beings (Osinsky et al., 2013). Whereas in study 2 and 3 the decision-feedback contingencies were easier to learn since the same stimuli were presented several times in succession, in study 1 and 4 the interleaved design hampered the learning of these contingencies. Although we have shown in study 4 that the acceptance rate patterns for the four identities remain relatively stable after 2-3 blocks (about 100 trials), it is possible that a full learning process was not completed during all experiments.

3.2.1. ULTIMATUM GAME OFFERS

With respect to the offer-locked FRN in the ultimatum game, two possible patterns have been established in the literature. On the one hand, a linear trend of the FRN could often be identified as a function of the offer size (e.g., Luo et al., 2014; Peterburs et al., 2017). This is based on the assumption that the FRN is more negative in unfair offers, which becomes more and more positive as the fairness of the offer increases. On the cortical level, Sanfey et al. (2003) identified the insula, the dorso-lateral prefrontal cortex and the anterior cingulate cortex as strongly active brain regions in the decision-making process. In particular, the activation in the insula was consistently higher in processing unfair compared to fair ultimatum game offers, which is an indication of the emotion-driven rejection of such unfair offers. This assumption was supported by Hewig et al. (2011), who found an increased skin conductance for extremely unfair compared to very fair offers, and by Van't Wout et al. (2006), who showed an increased skin conductance after the rejection of unfair offers. The FRN as part of the outcome evaluation is increased in the case of unwanted or unexpected outcomes, similar to the ERN, in order to subsequently adapt the behavior via reinforcement learning to obtain less bad outcomes in such situations in the future. Accordingly, the FRN detects negative reinforcement.

In contrast, some studies have reported a parabolic function of the a later occurring negativity in relation to the offer size (e.g., Zhong et al., 2019). The greatest negativity of FRN is thereby expected for medium sized offers, where the highest decision uncertainty prevails (often offers with approx. 50% acceptance rate, i.e., 20-30% of the stack) and cognitive conflict is elicited. Conversely, very fair offers are virtually always accepted, and very unfair offers are largely rejected, which means that there is no conflict of decision. The conflict in medium sized offers is accompanied by a higher activation of the ACC and could also be associated with a shift of the unconscious system, especially in fair and unfair offers, to the conscious system, which is needed to respond to the conflict-laden mid-value offers. These two systems are based on Kahneman (2003) and his idea of distinguishing between fast, automatic thinking and slow, deliberate thinking. Polezzi et al. (2008) could also show that the response times to answer mid-value offers were significantly higher than those for fair and unfair offers, indicating slow, deliberate thinking, although their study found a linear relationship between FRN and offer size. This seems to support the thesis of greater uncertainty for mid-value offers, as a clear strategy prevails for fair and unfair offers. In summary, the results that found a parabolic FRN effect suggest characterizing the FRN as a conflict function (as an alternative to the negative reinforcement described above). However, only a few studies have explicitly focused on mid-value offers and, in addition, the taxonomies for the offer categories fair, mid-value and unfair diverge widely and are not uniformly defined in the literature.

In our first study we found a differentiated pattern for the offer-locked FRN: For the analysis of the N2 amplitude we were able to show a conflict-oriented pattern for medium to rather unfair offers, which evoked a greater negativity than completely unfair and very fair offers. In the difference analysis of the P2 and N2 components, on the other hand, we were able to demonstrate the linear effect with a greater positivity for fairer offers. This increased positivity for fairer offers could also be found in studies 2, 3, and 4. Hence, we were able to show that the RewP stemming from fair offers seems to overlay the increased negativity of the conflict elicited by medium size offers, especially when the P2 brain potential is included in the ERP analysis (see discussions concerning the neural processing of the offer presentation in study 2 and study 3). Therefore, our results are consistent with the *reinforcement learning theory* of feedback potentials (Holroyd et al., 2008; Proudfit, 2015).

In summary, we were able to report findings for both theoretical approaches to explaining the FRN in our paradigm, on the one hand a linear relation with fairness via P2, which speaks for

RL, and a relation with conflict decisions via N2. At this point, it is important to note that when comparing neural findings on ultimatum game offers across studies, there are researchers who focus exclusively on the N2 component and those who explicitly include both P2 and N2. Nevertheless, we will not make a final judgement, as this requires a precise differentiation and a very close examination with possibly more structural procedures such as functional magnetic resonance imaging.

3.2.2. EMOTIONAL FACES

Apart from study 2, in all studies we performed a baseline measurement of the different valences of emotional faces in a pure presentation task before playing the ultimatum game. In the literature to date, the findings regarding the valence specificity of the N170 arousal effect for emotional faces are mixed. A meta-analysis by Hinojosa et al. (2015) showed that both negative emotional expressions (i.e., fear and anxiety) and happy facial expressions lead to a greater N170 effect than neutral faces. However, there are also studies that have found this effect exclusively for negative faces (e.g., Blau et al., 2007). With regard to the functional significance of the N170, the meta-analysis by Hinojosa et al. (2015) concludes from the heterogeneous findings that the N170 represents a correlate of multiple sources of information, which can represent both simple facial expressions and facial characteristics of a higher order. Accordingly, the amplitude of the N170 is composed of both the affect-related processing of faces and the context in which they occur.

Also, within the studies presented here, we could find both patterns. While in study 1 a global valence effect of N170 for negative and positive emotions could be detected, in study 3 an effect exclusively related to negative emotional expressions was found. Due to the absence of negative emotions, the N170 effect in study 4 could only be in favor of the positive emotions. Consequently, our analyses could not provide a clear indication of whether there is a processing that is specifically enhanced for negative or positive valence by the early N170 component, since both patterns debated in the literature were found in our experiments. For more details on the study-related interpretations of the N170 components, see in particular the discussion section of study 3 and 4.

In the first study, the FRN was significantly more positive for smiling compared to neutral, angry and sad faces, indicating that a smiling face is inherently rewarding. Unfortunately, we could not demonstrate this effect in study 3, which had an identical stimulus set in terms of valence as study 1. In the discussion part of study 3 we have already argued that the deviation of emojis from faces at the neural level may have blurred possible effects in the sense that emojis may lack essential facial details that are required for the specific processing of information. In the fourth study, however, we could also find a rewarding function of the smiling face compared to the neutral one, which was additionally supported by an increased P3 amplitude of the smiling face. This increased P3 amplitude was attributed to a higher relevance of smiling in comparison to the neutral faces and thus increased attention. However, this was the only P3 effect that could be revealed across all studies in terms of viewing emotional faces outside of bargaining interactions.

In summary, smiling faces had a rewarding effect just by looking at them, especially if the smiling face had already led to an increased arousal in the N170 component. In study 3, both this specific arousal and the positivity were absent, which could possibly be due to the relative deviation of the neural processing of emojis compared to human faces.

3.2.3. EMOTIONAL FEEDBACK

In this dissertation, the influence of emotional feedback on social decision-making behavior and its neural correlates was the focus of the individual experiments. In the integration of the results, we will first refer to the overall influence and then examine the findings on emojis separately in the following section.

In the first study on altruistic punishment it could be shown that, in the context of the ultimatum game, the feedback processing within the FRN reversed the pattern of the pure observation of faces. As a neural signature of altruistic punishment, positive and negative feedback faces had a greater positivity, which can be understood as an indication of a reward positivity (Holroyd et al., 2008) in the sense of a successful intended action (i.e., reward after acceptance and effectiveness of punishment via rejection). Furthermore, the increased P3 amplitudes regarding the angry and sad identity indicated that this punishment was perceived as subjectively particularly important by the participants. Although the smiling face also signals the desired outcome of a monetary transaction, it is conceptually not related to altruistic punishment since there was no punishing behavior by the participants in this interaction. Unfortunately, in study 3 we were unable to demonstrate any identity-specific effects of the various proposers. Here, too, we refer to the superposition of emojis in comparison to human faces. Their deviation in neural processing could have ensured that, apart from the global differences between emojis and human faces, no more specific differences in the brain can be processed in such early components. A classification of the results from study 3 in the literature regarding emotional feedback is given in the following section "Emojis."

Consequently, there are two conceivable possibilities that determine the neural processing of emotional feedback in our studies. Firstly, the perception of feedback depends on whether it is congruent feedback on an intended action (positive emotions as reward for acceptance or negative emotions as sorrow following rejection). On the other hand, the absence of feedback seems to cause neural disturbances, since no profitable information can be extracted from the counterpart's feedback. It should therefore be noted that any feedback provides more information than no feedback and that important information can be extracted, especially from feedback that informs about action goals. Due to the different results of the two emoji studies, this neural pattern seems to depend on human faces. With regard to the absence of useful information from the neutral control identities, the goal relevance debated in emotion research

(Frijda, 1986) could play an important role. The goal relevance could indicate how much a stimulus reflects revealing information about the status of an intended goal (e.g., Moors, 2007; Roseman & Smith, 2001). In relation to our paradigm, this is a crucial factor, since the neutral face in both conditions (acceptance versus rejection) is unlikely to have a direct impact on an individual's goals.

In the fourth study, on the other hand, the neutral control identity had the greatest negativity in the FRN time-window. In comparison to different combinations with positive feedback, the absence of emotions according to the FRN function as an evaluative component is classified worse than expected. A possible explanation for this would be that beyond altruistic punishment, the lack of relevant information could cause the more pronounced FRN of neutral faces. In general, the results of the fourth study differ conceptually from the other studies, as the focus here was on the unexpectedness of a feedback stimulus. As can be read in detail in the discussion section in study 4, we were able to show that a rewarding feedback stimulus in response to a loss-associated event (i.e., rejection of an offer and thus 0 cent reward) evokes a very specific neural pattern. Regarding the FRN, we were able to show that the unexpected smile led to a reduced negativity compared to the neutral feedback on acceptance. Accordingly, the positive emotion is processed similarly to positive feedback, although it leads to a negative consequence. Similar to the results of the first study, this lower FRN amplitude would again mark the intended outcome of a social interaction. Furthermore, the smiling face showed an increased P3 amplitude after rejection, which speaks for the special salience of this unexpected stimulus. Analogous to studies on liked persons (Calvo & Beltrán, 2013), this unexpected identity could still be sympathetic and therefore more subjectively meaningful than a completely unemotional control identity.

3.2.4. EMOJIS

In addition to investigating general principles of emotional influence, two of the studies presented here have provided a closer look at the social influence of emojis. Based on various studies (e.g., Hantula, Kock, D'Arcy, & DeRosa, 2011; Kock, 2004), it is assumed that people are not particularly good at interpreting written text correctly, especially in relation to affect and emotional valence, as our communication originally developed by deciphering and transmitting information in face-to-face interactions. A few studies have already dealt with various experimentally controlled influences by emojis. For example, Ganster, Eimler, and Krämer (2012) used chat conversations to show that the responder's mood can be manipulated by emojis in both positive and negative directions. Recently, Gesselman, Ta, and Garcia (2019) focused on the basic needs of partnership and investigated the extent to which the use of emojis influences sexual and romantic interpersonal encounters. The authors were able to show that increased use of emojis leads to more meetings beyond the first date and is also associated with more romantic and sexual interactions in the past year.

In the strictly controlled environment of the ultimatum game, our first study on the social influence of emojis on decision-making failed to show any behavioral effects that could be attributed to emotional influence. In contrast, the third study indicated the influence of rewarding feedback on the acceptance behavior in the ultimatum game with both human faces and emojis. This is an important finding for the classification of current digital communication, because we could show that feedback by emojis has a comparable social value as a real human face. Although the rewarding nature of a smiling face has universally led to higher acceptance rates in the third study, this effect was absent in the second study. Therefore, we cannot speak of a global reward effect, but rather of a stimulus-dependent reward. The stimuli of both studies differed mainly in the degree of realism of the depiction. The distinct differences between the emojis in the two studies reveal how important a certain degree of credibility of the feedback quality and the familiarity of the stimulus itself are. A conceptually related comparison was made by Ganster et al. (2012) with two different artificial emoticon types. The authors investigated the difference between more realistic smileys, which resemble the emojis used in study 3, and more artificial emoticons, which consist of ordinary topographic symbols rotated at a 90-degree angle. As a result, no differences could be found between smileys and emoticons regarding the interpretation of a message, but the smileys had a significantly greater influence on the mood of the subjects than the emoticons. The latter result could therefore give an indication of the absence of effects in study 2, as the simplicity of the emojis may not have had any meaningful effect on the mood. An alternative explanation for this could be that the influence of the emojis in study 3 was enhanced due to the other stimuli in the paradigm, as they were used alongside real faces. The mixing of real faces as proposer identities and the emoji identities could have led to the faces having an after-effect and therefore to an assimilation of the corresponding emoji identity to the human identity in behavior.

At the neural level, the results of the second study revealed that smiling and frowning emojis as feedback stimuli distinctively characterize a proposer identity. Specifically, the P3 component was not influenced by the offer itself, but rather by the identity of the proposer. In contrast, the emojis in study 3 showed a parallel course to human faces. Moreover, especially the N170 and P3 components were significantly more prominent for the emojis than those of the human faces. If we reconcile these results, it becomes apparent that for a more specific processing a certain familiarity seems to be necessary. Caharel, Courtay, Bernard, Lalonde, and Rebaï (2005) were able to show that personally more important faces are identified faster and lead to a greater activation of N170 compared to less important faces. This would explain the mental comparison of the two emoji types, but not the deviation of emojis from human faces in study 3. Therefore, the missing effects in study 2 might be better explained by findings on the sociality of feedback stimuli. Sakaki et al. (2012) reported that socially emotional stimuli (e.g., images of people or faces) require a deep elaborative neural processing. Hence, the emojis in the second study might have been hardly perceived as socially emotional stimuli themselves. It is therefore possible that only the context, meaning that the participants received block-wise feedback from an interaction partner in a social decision-making task, led to a transfer effect of the emotion represented by emojis on the neural processing of the offers. In the third study, however, the emojis might have been perceived and processed as socio-emotional feedback, but due to their deviation from human faces they needed additional cognitive resources and processing to be decoded correctly.

3.3. INDIVIDUAL DIFFERENCES

When it comes to human decision-making, personality traits sometimes play a very central role. Although the general psychological processes behind feedback evaluation were examined in the course of this dissertation, an understanding of possible influences of personality is now to be created.

The question arises whether demographic characteristics such as age or gender can have an influence on social decision-making behavior. With regard to age, Bailey, Ruffman, and Rendell (2012) have shown that younger participants in particular reject unfair offers from younger proposers, but not from older ones. Both age groups have reported a higher level of anger if younger proposers made these unfair offers. Moreover, there are studies showing that one's own age group is given preferential treatment (e.g., Holm & Nystedt, 2005) and that there is a generally greater compassion with older people (e.g., Cuddy, Norton, & Fiske, 2005). Therefore, the question arises for the present and future studies to what extent the stimulus material itself in combination with the age distribution of the sample could bias results. Although these characteristics were not considered in the studies of this dissertation, age effects might well be present in our samples, since most of the participants were relatively young (mean across all studies = 26.18 years, *SD* = 8.08). With regard to the ultimatum game, there are specific findings indicating that developmental changes take place in the age range of undergraduates. In the course of their studies, ultimatum game offers change to the effect that first-year students make even more unfair offers than more advanced students (Carter & Irons, 1991). In addition, Henrich (2008) was able to show that in economic games the behavior regarding offer levels reaches its plateau at around 24 years of age, after which hardly any changes take place into older age.

Considering that in many psychological studies predominantly female volunteers are recruited (i.e., on average 66% in the experiments of this work), possible gender differences should be discussed. However, the findings are heterogeneous. Eckel and Grossman (2001) have already shown in a repeated ultimatum game that women on average make more generous offers than men. In addition, women accept certain offers more frequently in the role of the responder. In general, offers are accepted more frequently if the proposer is a female opponent. Saad and Gill (2001) have also reported that men make more generous offers to women. In contrast, Solnick (2001) found that women are offered less money than men, regardless of the proposer gender. In this study, both men and women chose a higher minimum acceptable monetary offer when interacting with a woman. Thus, women are expected to be more generous and even fairer than men.

Concerning the studies of this dissertation, we had an average proportion of women of about 66%, which could result in a general shift towards a specific effect for women. In summary, for an optimal design a future study should aim at an age distribution matched to the real life population and a balanced gender distribution in order to be able to infer specific gender and age-related differences in the processing of emotional feedback, which goes beyond the existing findings.

In their review, Zhao and Smillie (2015) attempted to integrate literature on basic personality traits and their significance in the context of economic games. The most consistent and stable results could be shown with the personality traits agreeableness from the Big Five (McCrae &

Costa, 2008) and honesty-humility from the HEXACO personality model (Ashton et al., 2004). In terms of the responder role in the ultimatum game, persons with higher agreeableness rejected fewer offers. This fits well with the underlying descriptions of an agreeable person who is strongly concerned with the well-being of their fellow human beings. However, the extent to which agreeableness explains variance in the behavior of the participants is highly variable. According to Mischel (1977), this could hold on to the so-called strength of a situation. Thus, in a very strong situation the influence of the personality would appear to be rather small, whereas in a weak situation the personality has a strong impact (Cooper & Withey, 2009). In the ultimatum game, this would mean that fair (5:5) and unfair (1:9) splits are strong situations (Gong et al., 2017), since almost all people have a clear preference for decisions based on social norms (Boksem & De Cremer, 2010). Accordingly, the reactions (acceptance versus rejection) of the responders are very consistent. The division of 3:7 could represent a prototypical weak situation, since it could produce a conflictual decision whether to accept such an offer for one's own benefit or rather punish the respondent by rejecting the offer (Gu et al., 2016). In this case, certain personality traits could have a decisive influence on the direction of the decision. On the proposer side, on the other hand, significantly more variance was explained by honesty-humility than by agreeableness. According to Ashton and Lee (2008), on the side of honesty the traits of honesty, sincerity or fairness concerns are characterizing this domain of personality and on the other side the traits of humility like greed or deceit. An examination of the findings presented in this dissertation aimed at agreeableness might also show whether this trait leads to generally increased acceptance rates or whether it is also specifically increased by a rewarding identity.

This brief insight into possible individual differences that can affect behavior in economic games is only intended as a possible outlook. Many other personality concepts such as altruism (Simon, 1993), empathy (Elliott, Bohart, Watson, & Greenberg, 2011) or the pursuit of dominance (Sidanius, 1993) are further characteristics that could provide valuable insights into behavior in social interactions. In the following section on possible clinical applications of our paradigm, individual differences in feedback processing, which have not been further discussed in this section, will also be addressed.

3.4. CLINICAL SIGNIFICANCE

In the theoretical introduction of this thesis it has already been noted that the relationship between depression and behavior in the ultimatum game has been investigated by Harlé et al. (2010). The increased discrepancy between people with depressive symptoms and healthy controls with regard to the emotional response to unfair offers indicates a clinically relevant use of such social decision games. The use of emotional feedback could further increase this benefit and specifically evaluate the processing of certain emotions in connection with different psychological disorders that are related to affect such as depression and anxiety disorder. In the context of depression, for example, the decreased behavioral response to reward (Pizzagalli, Jahn, & O'Shea, 2005) and the blunted neural positivity of rewarding stimuli (e.g., McCabe, Woffindale, Harmer, & Cowen, 2012; Nelson, Perlman, Klein, Kotov, & Hajcak, 2016) as a function of reduced approach goals (Dickson & MacLeod, 2004a; Dickson, 2006) could be further investigated using the presented paradigm in this thesis. In contrast to depression, anxiety disorders have been shown to lead to an increased formation of avoidance goals (Dickson & MacLeod, 2004a; Dickson & MacLeod, 2004b). To speak in the language of our paradigm, negative feedback (i.e., above all anger, but also sadness) could thus firstly be more strongly avoided by higher acceptance rates even for unfair offers and, in addition, the feedback itself could lead to a more pronounced FRN in anxious individuals. One construct that encloses this particular facet of social anxiety even more is the so-called fear of negative evaluation (FNE). In a study on the cognitive mechanisms of attention bias in social anxiety, Rossignol, Campanella, Bissot, and Philippot (2013) examined the connection between FNE and emotional faces in a dot probe paradigm. The results suggest early neuronal hypervigilance of facial stimuli in socially anxious individuals. In the clinical context, feedback processes in social decision-making situations could therefore be disentangled. Especially with regard to the distinction between (sub)clinical depressive or anxiety-related tendencies, the identities used in study 1 and 3 could reflect both types and the mixed type, since both the reduced reward response (happy identity) and the increased avoidance tendency due to threat (anger identity) are taken into account in the task. Since we have considered the presented studies from a general psychological point of view, it could also be interesting to know to what extent previous findings may be based on precisely these threat and reward-related aspects of the affective integration of emotional social feedback.

3.5. LIMITATIONS

Before we move on to the outlook for possible follow-up studies, we would like to briefly examine some limitations of the four experiments. First, we have assumed medium effects across all studies and adjusted sample recruitment accordingly. In order to make smaller population effects measurable, larger samples would have been necessary. Secondly, in all conditions the feedback stimuli were deterministically linked to the response behavior of the participants. This inevitably leads to an unequal frequency of occurrence of the different stimuli with an overrepresentation of neutral feedback. Although in study 4 we corrected for this overrepresentation of neutral feedback in studies 1-3, the effects of the decision and the effects of pure feedback are always confounded. To disentangle this is not trivial and may require a new paradigm. Thirdly, transfer effects of the individual identities may have occurred in all studies. In both the interleaved and the block-wise representation of the individual identities, the response pattern of the preceding identity could influence the acceptance behavior of the subject for the subsequent identity, despite the built-in randomization. With a considerable enlargement of the sample, it would be possible to test in a between-subjects design whether the unique influences of the feedback correspond to those of a within-subjects design. Finally, we took the facial images from previously rated databases. Across all studies the tendency can be detected that the neutral facial expression was evaluated rather negatively in the manipulation check. This corresponds to the findings of Lee, Kang, Park, Kim, and An (2008), who concluded that prototypical "neutral" faces are, under certain circumstances, more likely to be negatively evaluated and could therefore lead to a conceptual confound as reference category. For future studies researches may try to define a more neutral facial expression in advance and validate it accordingly by pre-ratings. Moreover, in most of the studies presented here, a sparse post-interrogation of the test persons was carried out. In order to be able to fathom the decisions of the participants more deeply, more in-depth subjective information about their own acceptance behavior as well as the perception of the individual identities would be necessary. Especially in study 4, a subjective assessment of the positive feedback following the rejection of an offer would have given further insight on the motivation of the subjects.

3.6. OUTLOOK

In order to further specify the influence of emotional feedback on behavior and physiology, it could be interesting to measure pupil dilations when looking at feedback from the different proposer identities. Bradley, Miccoli, Escrig, and Lang (2008) were able to show that changes in the pupil were related to the emotional arousal of an image showing people and not to its valence. Since the subjective arousal ratings in our studies often reflect an effect of emotionality (i.e., positive and negative emotions with higher arousal than neural), an additional differentiation of the arousal could occur through this physiological extension. Furthermore, Sanchez and Vazquez (2014) found that the attention-related components initial orientation, fixation frequency, and fixation time were significantly more pronounced in positive faces compared to angry and sad faces. In combination with the previously mentioned clinical relevance, which could be explored more closely with our paradigms, the addition of eye-tracking could provide further insight for specific psychological disorders. In a meta-analysis, Armstrong and Olatunji (2012) reported that people with anxiety disorders show hypervigilance for threatening stimuli even in pupillometric data. Depressed persons, on the other hand, were not sensitive to threatening stimuli, but showed a reduced fixation of positive stimuli and a maintaining gaze function of dysphoric stimuli.

Another meaningful extension of the findings presented here would be the embedding of probabilistic feedback. The acceptance patterns in our studies were rigid and thus divergent from everyday life. Therefore, two probabilistic adjustments would be conceivable: for example, the rewarding happy identity could only smile after acceptance with a certain probability (e.g., 75%) and provide neutral feedback for the remaining part. Furthermore, the distribution of offer sizes could be designed probabilistically. In previous studies, we have presented all offers equally often in order to guarantee a uniform number of trials in the EEG analyses. In a behavioral experiment, however, it could be investigated how overly fair proposers with distinct feedback patterns could differ in their acceptance rates from very unfair proposers with specific feedback patterns. Finally, a combination of both probabilistic offer behavior and probabilistic feedback behavior, in an admittedly quite complex task to be tested with fewer than more identities, could be used to investigate which social character would benefit most and which the least.

Additionally, based on the limitations in study 4, subjective ratings of the trustworthiness or likeability of the individual identities could help to find out which concepts are responsible from the respondent's point of view for the preferential bargaining with certain identities. A detailed post-evaluation of subjective behavior could provide specific indications of which non-clinical personality traits are associated with the perception of social feedback and its inclusion in future economic decisions.

3.7. CONCLUSION

Integrating the emotional facial expression of a social interaction partner into one's own actions is a common, yet utmost relevant process. From this feedback we derive intentions, feelings and possible personality traits that we incorporate into our own behavior. In the digital age in which we currently live, it is also very important to understand the extent to which non-verbal communication at the media level influences social structures. For this reason, emojis have become important representatives for transporting emotions via messenger services. This dissertation has therefore highlighted different facets of emotional influence on our behavior and thinking. We have shown that rewarding feedback from both human faces and common emojis leads to more cooperative action. We not only examined congruent feedback, but also reported that unexpected social feedback can specifically influence our actions. In addition, we worked out that neural patterns reflect emotional feedback for specific action expectations. On the other hand, we found that emojis differ significantly in their neural processing from human faces. Finally, we have argued that in the modified ultimatum game there are still many possibilities how open research questions regarding personality, but also clinically relevant topics can be linked to the scientific contribution of this dissertation.

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09/2019	59th Annual Meeting of the Society for Psychophysiological Research, Washington, D.C., USA.
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Study Design	PM	MW	JH		
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Study Design Methods Development	MW	JG	PM	JH	JR
Data Collection	MW	JG			
Data Analysis and Interpretation	MW	JG	JR	PM	JH
Manuscript Writing					
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Writing of Materials & Methods	MW	JG	JR	PM	JH
Writing of Discussion	MW	JG	JH	PM	JR
Writing of First Draft	MW	JG	JH	PM	JR

M. Weiß: data collection and curation, conceptualization, formal analysis, visualization, writing original draft as well as writing review and editing.

J. Gutzeit: data collection, conceptualization, writing review

J. Rodrigues: formal analysis, review

P. Mussel: conceptualization, writing review and editing

J. Hewig: supervision, funding acquisition, conceptualization, writing review and editing

Publication (complete reference): Weiß, M., Mussel, P., & Hewig, J. (2019). The value of a real face: Differences between affective faces and emojis in neural processing and their social influence on decision-making. *Social Neuroscience*.					
Participated in	**Author Initials,** Responsibility decreasing from left to right				
Study Design Methods Development	MW	PM	JH		
Data Collection	MW				
Data Analysis and Interpretation	MW	JH	PM		
Manuscript Writing Writing of Introduction Writing of Materials & Methods Writing of Discussion Writing of First Draft	 MW MW MW MW	 JH JH JH JH	 PM PM PM PM		

M. Weiß: data curation, conceptualization, formal analysis, visualization, writing original draft as well as writing review and editing.

P. Mussel: conceptualization, writing review and editing

J. Hewig: supervision, funding acquisition, conceptualization, writing review and editing

Publication (complete reference): Weiß, M., Mussel, P., & Hewig, J. (2020). Smiling as negative feedback affects social decision-making and its neural underpinnings. *Cognitive, Affective, & Behavioral Neuroscience, 20*(1), 160-171.					
Participated in	**Author Initials,** Responsibility decreasing from left to right				
Study Design Methods Development	MW	PM	JH		
Data Collection	MW				
Data Analysis and Interpretation	MW	PM	JH		
Manuscript Writing Writing of Introduction Writing of Materials & Methods Writing of Discussion Writing of First Draft	 MW MW MW MW	 PM PM PM PM	 JH JH JH JH		

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J. Hewig: supervision, funding acquisition, conceptualization, writing review and editing

The doctoral researcher confirms that she/he has obtained permission from both the publishers and the co-authors for legal second publication.

The doctoral researcher and the primary supervisor confirm the correctness of the above mentioned assessment.

Martin Weiß		Würzburg	
Doctoral Researcher's Name	Date	Place	Signature

Prof. Dr. Johannes Hewig		Würzburg	
Primary Supervisor's Name	Date	Place	Signature

“Dissertation Based on Several Published Manuscripts“

Statement of individual author contributions to figures/tables/chapters included in the manuscripts

Publication (complete reference):

Mussel, P., Hewig, J., & Weiß, M. (2018). The reward-like nature of social cues that indicate successful altruistic punishment. *Psychophysiology*, *55*(9), e13093.

Figure	**Author Initials,** Responsibility decreasing from left to right				
1	PM & MW				
2	PM & MW				
3	PM	MW			
4	PM	MW			

P. Mussel: conceptualization, writing of original draft, writing review and editing

J. Hewig: supervision, conceptualization, writing review and editing

M. Weiß: conceptualization, data collection, visualization, review, and editing

Publication (complete reference):

Weiß, M., Gutzeit, J., Rodrigues, J., Mussel, P., & Hewig, J. (2019). Do emojis influence social interactions? Neural and behavioral responses to affective emojis in bargaining situations. *Psychophysiology*, *56*(4), e13321.

Figure	**Author Initials,** Responsibility decreasing from left to right				
1	MW & JG	JR	PM	JH	
2	MW	JG	JR	PM	JH
3	MW	JG	JR	PM	JH
4	MW	JG	JR	PM	JH
5	MW	JG	JR	PM	JH
6	MW	JG	JR	PM	JH

M. Weiß: data collection and curation, conceptualization, formal analysis, visualization, writing original draft as well as writing review and editing.

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J. Hewig: supervision, funding acquisition, conceptualization, writing review and editing

I also confirm my primary supervisor's acceptance.

Martin Weiß		Würzburg	
Doctoral Researcher's Name	Date	Place	Signature

AFFIDAVIT

I hereby confirm that my thesis entitled “The neural principles of behavior modification using socioemotional facial feedback cues in economic decision-making” is the result of my own work. I did not receive any help or support from commercial consultants. All sources and / or materials applied are listed and specified in the thesis.

Furthermore, I confirm that this thesis has not yet been submitted as part of another examination process neither in identical nor in similar form.

Place, Date

Signature

EIDESSTATTLICHE ERKLÄRUNG

Hiermit erkläre ich an Eides statt, die Dissertation „Die neuronalen Mechanismen der Verhaltensmodifikation durch sozio-emotionale faziale Feedbackreize bei ökonomischen Entscheidungen“ eigenständig, d.h. insbesondere selbstständig und ohne Hilfe eines kommerziellen Promotionsberaters, angefertigt und keine anderen als die von mir angegebenen Quellen und Hilfsmittel verwendet zu haben.

Ich erkläre außerdem, dass die Dissertation weder in gleicher noch in ähnlicher Form bereits in einem anderen Prüfungsverfahren vorgelegen hat.

Ort, Datum

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